BUILDING INFRASTRUCTURE - BUILDING THE NATION

राष्ट्रीय राजमार्ग एवं अवसंरचना विकास निगम लिमिटेड

NATIONAL HIGHWAYS & INFRASTRUCTURE DEVELOPMENT CORPORATION LTD.

FINAL DETAILED PROJECT REPORT
SUDHMAHADEV - DRANGA TUNNEL

CONSULTANCY SERVICES FOR PREPERATION OF DETAILED PROJECT REPORT AND PROVIDING PRE-CONSTRUCTION ACTIVITIES IN RESPECT OF THE FOLLOWING STRETCH ON NH-244 (OLD NH-1B) IN THE STATE OF JAMMU AND KASHMIR.

(1) SUDHMAHADEV- DRANGA TUNNEL OF APPROX. LENGTH 4.5 KM AND ITS APPROACH ROAD ON CHENANI - SUDHMAHADEV- GOHA ROAD PORTION.

(2) VAILOO TUNNEL OF APPROX. LENGTH 10.0 KM UNDER SINTHAN PASS AND ITS APPROACH ROAD ON GOHA-KHELLANI- KHANABAL ROAD PORTION.

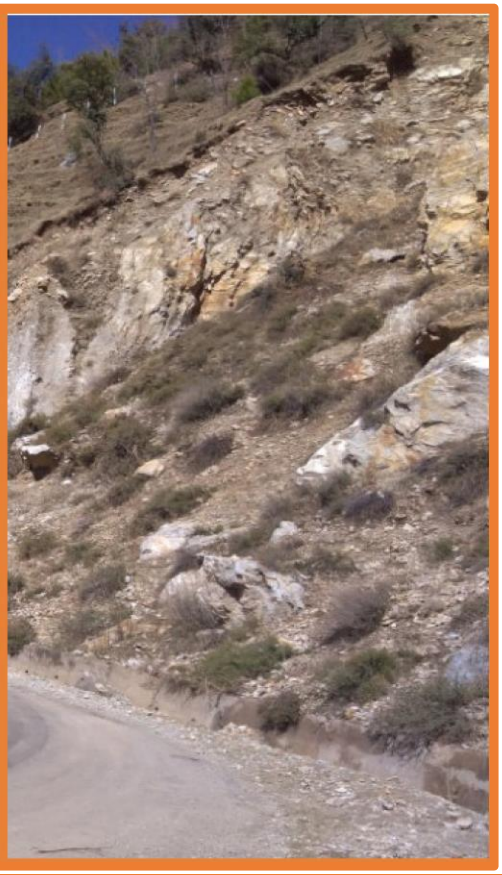
(3) ROAD PORTION FROM 82.675 TO 82.925 AT KM 83 ON BATOTE-KISHTWAR ROAD SECTION OF NH-244.

(4) EXTENDED ROAD SECTION FROM GOHA TO KHELLANI OF 30 KM LENGTH









PACKAGE-1 – KM 0+000 TO KM 6+405
PACKAGE-2 – KM 6+405 TO KM 12+850
VOLUME - V-TECHMICAL SPECIFICATION

FEBRUARY 2020

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IN ASSOCIATION WITH

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TECHNICAL SPECIFICATION

Tunnel

TABLE OF CONTENTS

1 SCOPE OF WORK 11
2 GENERAL 11
2.1 Definition 11
2.2 Work during Bad Weather Condition 13
2.3 Submittals 13
2.4 Standards and Units 13
2.5 Listing of Standards 14
2.5.1 Indian Standards 14
2.5.2 European Standards 17
2.5.3 British Standards 19
2.5.4 International Standards 20
2.6 Materials 21
2.7 Quality Management and Records 22
3 SITE INSTALLATION 23
3.1 General 23
3.2 Contractor's Camp 23
3.3 Site Office, Stores 24
3.4 Lighting & Ventilation during Construction 24
3.5 Electrical Power Supply 24
3.5.1 General 24
3.5.2 Earthing 25
3.5.3 Cables 25
3.6 Site Communication 26
3.7 Water Supply 26
3.8 Concrete and Material Processing Plant 26
3.9 Testing Laboratory 26
3.10 Removal 27
4 WORKING ENVIRONMENTS 28
4.1 Health, Safety and Welfare 28
4.2 Noise & Vibration 29
4.2.1 General 29
4.2.2 Temporary Fencing and Barriers 29
4.2.3 Plant & Equipment 30
4.2.4 Noise & Vibration Monitoring 30
4.3 Access & Egress 30

4.3.1 Maintenance of Routes 31
4.3.2 Access for Others 31
4.3.3 Traffic Safety and Management 31
4.3.4 Signing, Signalling & Lighting 32
4.3.5 Survey & Reinstatement 33
4.3.6 Access within Works 33
4.4 Disposal of Spoil & Water 33
4.4.1 Solid Waste Disposal 34
4.4.2 Liquid Waste Disposal 34
5 DEWATERING ARRANGEMENT 35
5.1 General 35
5.2 Construction Site 35
5.3 Tunnel 36
5.4 Measurement and Monitoring 38
5.5 Final Tunnel Dewatering Arrangement 39
5.5.1 Ground Water 39
5.5.2 Carriageway Water 39
6 OPEN EXCAVATION 40
6.1 General 40
6.2 Standards 41
6.3 Cut 41
6.4 Excavation Classification 43
6. Excavation Material Disposal 44
6.6 Fill and Embankment 44
6.7 Back Fill 45
6.8 Gabions 46
6.9 Rip-Rap Layers 46
6.10 Water Proofing Membrane 47
7 UNDERGROUND EXCAVATION 48
7.1 General 48
7.2 Overbreak 50
7.3 Tunnel Excavation 51
7.3.1 General 51
7.3.2 Geotechnical Design 51
7.3.2.1 General 52
7.3.2.2 Determination of Actual Ground Type 53

7.3.2.3 Assessment of System Behaviour in the Excavation Area 54
7.3.2.4 Determination of Excavation and Support and Prediction of System Behaviour 54
7.3.3.5 Check of System Behaviour 55
7.3.3.6 Updating of Design 56
7.3.3 Blasting 56
7.3.3.1 General 56
7.3.3.2 Controlled Perimeter Blasting 57
7.3.3.3 Explosives 58
7.3.3.4 Blasting Vibrations 59
7.3.4 Geological Mapping 59
7.3.5 Exploratory Drillings 60
7.4 Shaft Excavation 60
7.4.1 General 60
7.4.2 Safety 61
7.4.3 Temporary Shafts 61
7.4.4 Construction 61
7.5 Control Survey 62
7.6 Excavation Cross Section Check 63
7.6.1 General 63
7.6.2 Definitions 63
7.7 Temporary Ventilation System 64
7.7.1 General 64
7.7.2 Ventilation 65
7.7.3 Monitoring 66
7.7.4 Checking & Inspection 68
7.7.5 Control of Dust Silica and Noxious Gases 68
7.8 Lighting 69
8 GEOTECHNICAL INSTRUMENTATION MONITORING 70
8.1 General 70
8.2 Ground Movement Monitoring 71
8.3 Tunnel Excavation Monitoring 72
8.4 Daily Review Meeting 73
8.5 Key Performance Indicators 74
8.6 Required Excavation and Support Sheet (RESS) 76
8.7 Contingency Measures and Emergency Procedures 77
8.8 Instrumentation 78

8.8.1 General 78
8.8.2 Installation Comments 80
8.8.3 Quality Assurance 82
8.8.4 Installation and Reading Frequency 83
8.8.5 Trigger limits for deformations 86
8.8.6 Reading Information and Presentation 86
8.9 Requirements of Instruments 87
8.9.1 Bolts and Pins 87
8.9.2 Theodolites and Reflectors for Convergence Measurement 88
8.9.3 Tape Extensometers 88
8.9.4 Borehole Extensometers 88
8.9.5 Strain Gauges 89
8.9.5.1 General 89
8.9.5.2 Concrete Strain Gauges 89
8.9.5.3 Steel Rib Strain Gauges 90
8.9.5.4 Load Cells for Rock Bolts and Rock Anchors 90
8.9.5.5 Pressure Cells 90
8.9.5.6 Temperature Gauges 91
8.9.6 Cables 91
8.9.7 Portable Readout Units 91
8.9.8 Instrument Housing 92
8.10 Probing Ahead 92
9 PRIMARY SUPPORT MEASURES 93
9.1 General 93
9.2 Rock Bolts, Anchors 94
9.2.1 General 94
9.2.2 Bearing Plates 96
9.2.3 Grouted Bolts 96
9.2.3.1 Specifications 96
9.2.3.2 Installation 97
9.2.4 Frictional Bolts 98
9.2.4.1 Specifications 98
9.2.4.2 Installation 98
9.2.5 Self-Drilling Bolts 98
9.2.6 Pre-stressed Anchors 98
9.2.7 Grout 99

9.3 Shotcrete 100
9.3.1 General 100
9.3.2 Mixing 101
9.3.2.1 Aggregates 101
9.3.2.2 Admixtures 102
9.3.2.3 Cement & Additions 104
9.3.2.4 Water 105
9.3.3 Application 106
9.3.3.1 General 106
9.3.3.2 Proficiency of Nozzlemen 106
9.3.3.3 Applying 107
9.4 Reinforcement - Wire Mesh 109
9.4.1 General 109
9.4.2 Specification 109
9.4.3 Installation 109
9.5 Lattice Girder 109
9.5.1 General 109
9.5.2 Specification 110
9.5.3 Installation 112
9.6 Steel Ribs 112
9.6.1 General 112
9.6.2 Specification 113
9.6.3 Installation 113
9.7 Forepoling 114
9.7.1 General 114
9.7.2 Spiles 115
9.7.2.1 Specifications 115
9.7.2.2 Installation 116
9.7.3 Pipe Umbrella 116
9.7.3.1 Specifications 116
9.7.3.2 Installation 117
9.8 Driven steel lagging 117
9.8.1 General 117
9.8.2 Specifications 117
9.8.3 Installation 117
9.9 Yielding Elements 117

9.9.1 Specification ... 117
9.9.2 Installation ... 118
9.10 Grouting ... 118
9.10.1 General ... 118
9.10.2 Drilling ... 119
9.10.3 Mixing ... 119
9.10.4 Materials ... 120
9.10.4.1 Cement ... 120
9.10.4.2 Sand ... 120
9.10.4.3 Additives ... 121
9.10.4.4 Admixtures ... 121
9.10.5 Grouting ... 121
9.10.5.1 Cavity Grouting of In-situ Lining ... 121
9.10.5.2 Consolidation or strata grouting ... 122
9.11 Testing ... 123
9.11.1 Rock Bolts ... 123
9.11.1.1 Suitability Test ... 123
9.11.1.2 Quality Tests During Tunnel Excavation ... 124
9.11.2 Grout Mortar ... 124
9.11.3 Shotcrete ... 125
9.11.3.1 Strength ... 125
9.11.3.2 Field suitability tests - preconstruction tests ... 125
9.11.3.3 Quality Control Tests ... 126
9.11.3.4 Measures on Strength Failures ... 127
9.11.3.5 Thickness of Shotcrete ... 128
9.12 Cross Section Check of Primary Lining ... 128
9.12.1 Tolerances ... 128
9.12.2 Profile Control ... 129
10 CONCRETE WORK ... 131
10.1 Concrete ... 131
10.1.1 General ... 131
10.1.2 Concrete Requirements ... 132
10.1.3 Concrete Composition ... 132
10.1.3.1 Aggregates ... 132
10.1.3.2 Cement ... 133
10.1.3.3 Admixtures ... 134

10.1.3.4 Additions 135
10.1.3.5 Water 135
10.1.3.6 Fibres 136
10.1.4 Temperature 136
10.1.5 Mix Design 137
10.1.6 Mixing and Batching 137
10.1.6.1 General 137
10.1.6.2 Batching 138
10.1.6.3 Mixing 139
10.1.7 Conveying 140
10.1.8 Placing 141
10.1.8.1 General 141
10.1.8.2 Preparation 143
10.1.8.3 Placing 144
10.1.8.4 Consolidation 145
10.1.8.5 Finishing 146
10.1.8.6 Curing 147
10.1.9 Joints 149
10.1.10 Water Stops 150
10.1.11 Quality Check & Tolerances 150
10.1.11.1 Trial Mix Testing 150
10.1.11.2 Conformity Control of Concrete 151
10.1.11.3 Production Control of Concrete 152
10.1.11.4 Tolerances 152
10.1.12 Repair of Damage 154
10.2 Lean Concrete 154
10.3 No-Fines Concrete 156
10.4 Reinforcement 156
10.4.1 General 156
10.4.2 Placing and fastening 157
10.4.3 Splicing 158
10.5 Formwork 159
10.5.1 General 159
10.5.2 Material Requirements 160
10.5.3 Tunnel Formwork 160
10.5.4 Execution 161

10.5.4.1 Preparation 161
10.5.4.2 Installation 161
10.5.4.3 Tolerances 161
10.5.4.4 Concrete Placement 161
10.5.4.5 Quality Control 162
10.5.4.6 Removal 162
10.5.5 Design and Installation Criteria 162
10.6 Design Life and Grade of Concrete Lining in Tunnel 163
11 PAVEMENT 164
11.1 General 164
11.1.1 Tolerances 164
11.1.2 Rectification 166
11.2 Unbound Sub-Base Layer 166
11.2.1 General 166
11.2.2 Laying 167
11.2.3 Compaction 168
11.2.4 Site Traffic 168
11.3 Bituminous Base Layer 169
11.3.1 General 169
11.3.2 Placing 169
11.4 Concrete Pavement 170
11.4.1 General 170
11.4.2 Concrete Composition 171
11.4.2.1 Cement 171
11.4.2.2 Water 172
11.4.2.3 Admixtures 172
11.4.2.4 Aggregates 172
11.4.3 Concrete Requirements 173
11.4.3.1 Consistence (Workability) 173
11.4.3.2 Air content 173
11.4.3.3 Density (Manual of Contract Documents for Highway Works) 174
11.4.3.4 Pavement concrete strength 174
11.4.3.5 Finished Surface Requirements 175
11.4.4 Transverse Joints 176
11.4.4.1 General 176
11.4.4.2 Contraction Joints 177

11.4.4.3 Expansion Joints 177
11.4.4.4 Warping Joints 178
11.4.4.5 Construction Joints 178
11.4.5 Longitudinal Joints 178
11.4.5.1 General 178
11.4.5.2 Longitudinal Construction Joints 179
11.4.6 Dowel Bars 179
11.4.7 Tie Bars 180
11.4.8 Joint Grooves 181
11.4.9 Joint Filler Board 181
11.4.10 Sealing of Joint Groover 182
11.4.11 Inspection of Dowel Bars 182
11.4.12 Curing 182
11.4.12.1 Exposed Aggregate Concrete Surface 183
11.4.13 Trial Tests 185
11.4.14 Texturing of Hardened Concrete 186
11.4.15 Weather Conditions 187
11.4.16 Construction Traffic 188
12 WATER PROOFING SYSTEM 189
12.1 General 189
12.2 Geotextile Fleece 189
12.3 Fixing Element 191
12.4 Layer with higher drainage capacity 191
12.5 Waterproof Membrane 191
12.6 Installation 194
12.7 Checking 196
12.7.1 Field Trials 196
12.7.2 Construction Testing 196
12.7.3 Failure Measures 197
MEP SYSTEM 198

LIST OF TABLES

Table 1: References to sources of Standards, Guidelines and Recommendation 13
Table 2: Indian Standards 14
Table 3: European Standards 17
Table 4: British Standards 19
Table 5: International Standards 20
Table 6: Admissible maximum concentrations of pollution gasses in underground works 67
Table 7: Maximum admissible fine dust concentration with respect of SiO_2 content in the rock 68
Table 8: Distance between measuring sections 83
Table 9: Instrumentation per measuring point with respect to the support category 84
Table 10: Reading frequencies with respect to distance to face, E&S Class and time after installation or period 85
Table 11: Trigger deformation limits for E&S Classes 86
Table 12: Requirements on portable readout units 91
Table 13: Range of the grain size distribution for grain sizes 0/8 and 8/11 102
Table 14: Maximum level of additions (in percentage of binder) 104
Table 15: Mix proportions for cement grout 119
Table 16: Sand gradation used for grout mix 120
Table 17: Sprayed concrete early strength development for a C35/45 mix, ... 125
Table 18: Limits of deleterious material in water for concrete mixing 136
Table 19: Batching tolerances 139
Table 20: Formed concrete finishes 146
Table 21: Unformed concrete finishes 146
Table 22: Types and tolerances for finishing of concrete surfaces 153
Table 23: Tolerances in surface levels of pavement courses 164
Table 24: Maximum permitted number of surface irregularities 166
Table 25: Grading for unbound sub-base layer 167
Table 26: Minimum cement or combination contents with 40 mm maximum aggregates 171
Table 27: Minimum air content with respect to max. aggregate size 173
Table 28: 7 day corrected core compressive strength 175
Table 29: Required macrotexture depth and tolerances 176
Table 30: Requirements of geotextile fleece 190
Table 31: Requirements of drainage elements 191
Table 32: Performance requirements of sheet waterproof membranes 192
Table 33: Construction testing for sheet waterproof membrane 196

1 SCOPE OF WORK

The National Highways & Infrastructure Development Corporation Limited (NHIDCL) has been entrusted with the work of construction of Sudhmahadev-Dranga Tunnel and its approach roads.

2 GENERAL

These Technical Specifications define the technical and quality standards specifically for NATM tunnel construction works in all ground condition.

The construction works shall be executed by the Contractor according to the quality requirements defined in the Specification and to the satisfaction of the Employer's Representative. Any item of work arising from the execution of the works, not covered by the Technical Specification, shall be according to a Standard as agreed with the Employer's Representative and the Contractor.

It is the intent of this Specification to define standards for the tendering process as well as for the planning and execution of the work by the Contractor. This includes the definition of quality standards which must be followed and will be checked during construction by the Employer's Representative. Deviations from the Specification must be submitted in writing in the tender.

This Technical Specification is based on the "Specification for Tunnelling, Third Edition", British Tunnelling Society, Institution of Civil Engineers, 2010 and "MORTH Specification for Road and Bridge Works", Ministry of Road Transport and Highways, 2000.

2.1 Definition

Behaviour Type (BT) means general categories describing similar ground behaviour with respect to failure modes and displacement characteristics.

Contractor means the person(s) named as contractor in the Letter of Tender accepted by the Employer and the legal successors in title to this person(s).

Contractor's Representative means the person named by the Contractor in the Contract or appointed from time to time by the Contractor who acts on behalf of the Contractor.

Cost means all expenditure reasonably incurred (or to be incurred) by the Contractor, whether on or off the Site, including overhead and similar charges, but does not include profit.

Day means a calendar day.

Design drawing, final drawing, construction drawing, fit-for-constriction drawing means drawing of detailed design prepared by the Contractor and approved by Employer's Representative.

Employer means the person named as employer in Contract Data and the legal successor in title to this person.

Employer's Representative and Engineer means the person appointed by the Employer to act as Employer's Representative for the purposes of the Contract and named as such in the Contract Data, or other person appointed from time to time by the Employer and notified as such to the Contractor.

Framework plan means the summary of the Geotechnical Design, including relevant parameters used in the design, and application criteria for the assignment of excavation and support methods.

Ground behaviour means reaction of the ground to the excavation of the full profile without consideration of sequential excavation and support.

Ground Type (GT) means ground, soil or rock, with similar properties.

(Design) Line of excavation means the line of excavation within which no unexcavated ground material shall remain at any time. If due to additional displacements of the ground unexcavated material extend into the line of excavation the Employer's Representative may order to excavate this material at no additional costs.

Materials means things of all kinds (other than Plant) whether on the Site or otherwise allocated to the Contract and intended to form or forming part of the Works, including the supply-only Materials (if any) to be supplied by the Contractor under the Contract.

Overbreak means the excavation beyond the line of excavation.

Overbreak Line means the line to which Overbreak is allowed without any remedial work required.

Plant means the apparatus, machinery and vehicles intended to form or forming part of the Permanent Works.

Site means the places where the Permanent Works are to be executed and to which Plant and Materials are to be delivered, and where the Operation Service is to be provided, and any other places as may be specified in the Contract as forming part of the Site.

System Behaviour (ST) means behaviour resulting from the interaction between ground, excavation profile and support, separated in: system behaviour in the respective excavation section, system behaviour in the supported section and system behaviour in the final state.

Working Day means a day on which working is performed.

Works means the Permanent Works and Temporary Works or either of them as appropriate and the facility to be operated by the Contractor during the Operation Service Period.

2.2 Work during Bad Weather Condition

All works have to be continued during any weather condition. Difficulties due to low temperature or snow falls in winter times or heat, drought or heavy rain falls in summer time are compensated with the unit prices. No extension of construction time is derived.

The Contractor shall investigate the working areas required for the tunnel construction concerning avalanche risk before establishing site infrastructure.

2.3 Submittals

The Contractor shall provide description of all works prior to commencement of any work to the Employer's Representative for approval. The Contractor shall submit the documents in a way that sufficient time is left for approval of the submittals but latest 2 working weeks before start of the relevant works if not specified herein differently or directed by the Employer's Representative.

The description shall include but not limited to procedure, sequence, materials, equipment, laboratory etc. The Employer's Representative may request additional data and supplementation of the submittals at any time.

2.4 Standards and Units

Materials, equipment and methods shall comply with the Standards and Codes of Practice indicated using the versions that are current at the date for submission of tenders. The Contractor may propose the adoption of alternative standards and shall provide explanations with any proposals. The use of such standards shall be subject to the agreement of the Employer's Representative.

Some Indian, European and British Standards and Guidelines are listed in Clause 2.5. The list is provided for information only and does not illustrate all relevant Standards for the Works. All Work shall be in compliance with these Standards and Guidelines. First and foremost the compliance of Indian Standards is required unless defined otherwise in this Specification. International (in the first step European) Standards and Guidelines shall be accessed to when no Indian Standards/Guidelines are available for the specific matter.

References to sources for Standards, Guidelines and Recommendations cited in the contractual documents are provided in Table 1. The list is provided for information only.

Table 1: References to sources of Standards, Guidelines and Recommendation

Abbreviation	Name
ASTM	American Society for Testing and Materials, 100 Bar Harbor Dive West, Conshohocken PA 19429 - 2595, U.S.A.
BSI (BS)	British Standards Institute, 389 Chiswick High Road, London,W4 4AL UK.

Abbreviation	Name
DIN	Deutsches Institut fur Normung e.V. Beuth Verlag GmbH, Burggrafenstrasse6 D-10787, Berlin, Germany.
EFNARC	European Federation of Producers and Applicators of Special BuildingProducts, Association House, 235 Ash Road, Aldershot, Hampshire, GU124DD, United Kingdom.
EN, ENV	European Committee for Standardisation, Central Secretariat,Rue de Stassart 36 B-1050, Brussels.
IRC	The Indian Road Congress, Jamnagar House, Shahjahan Road, New Delhi-110011.
IS	Bureau of Indian Standards, Manak Bhavan, 9 Bahdur Shah Zafar Marg, New Delhi - 110002.
ISO	International Organization for Standardisation 1, rue de Varembe CP 56, CH-1211 Geneve 20, Switzerland.
ONORM:	Austrian Standard Institute, HeinestraBe 38, 1020 Wien, Austria
RVS (Austrian Code for Road Construction)	Austrian Association on Road, Rail and Transport (FSV), Karlsgasse 5, 1040 Wien, Austria
OGG	Austrian Society for Geomechanics, Bayerhamerstrasse 14, 5020 Salzburg, Austria

The units applied are those of Si-System according to ISO 1000. A full stop (.) is used as decimal delimiter. Additionally in the schedule of prices the following abbreviations are applied:

d	calendar day
each	each
ls	lump sum
wd	working day

2.5 Listing of Standards

The list is provided for information only.

2.5.1 Indian Standards

Table 2: Indian Standards

ID of Standard	Description
IS 10262-2009	Guidelines for concrete mix design proportioning
IS 1077-1992	Common Burnt Clay Building Bricks
IS 11171-1985	Dry-Type Power Transformers
IS 1199-1959	Methods of sampling and analysis of concrete
IS 12269-1987	53 grade ordinary Portland cement
IS 12330-1988	Specification for sulphate resisting Portland cement
IS 1248	Direct Acting Indicating Analogue Electrical Measuring Instruments and their Accessories
IS 1278-1972	Filler rods and wires for gas welding
IS 1343-1980	Code of Practice for Prestressed Concrete
IS 1542-1992	Sand for plaster
IS 1554-1988	(Part 1): PVC insulated (heavy duty) electric cables: Part 1 For working voltages

ID of Standard	Description
	upto and including 1 100 V
IS 1566-1982	hard-drawn steel wire fabric for concrete reinforcement
IS 1885-1993	Electro technical Vocabulary: Part 32 Electric cables
IS 1651-1991	Stationary cells and batteries, lead-acid type (with tubular positive plates)
IS 8130-1984	Conductors for insulated electric cables and flexible cords
IS 1786-2008	High strength deformed steel bars and wires for concrete reinforcement
IS 1791-1985	General Requirements for Batch Type Concrete Mixers
IS 1905-1987	Code of practice for structural safety of buildings; masonry walls
IS 2062-2011	Hot Rolled Medium and High Tensile Structural Steel
IS 2116-1980	Sand for masonry mortars
IS/IEC 60947-1-2007	Low-voltage Switchgear and Control gear :Part 1 General Rules
IS 2180-1988	heavy duty burnt clay building bricks
IS 2309-1989	Code of practice for the protection of buildings and allied structures against lightning
IS 2386-1963	(Part 1 & 8): methods of tests for aggregates for concrete
IS 2502-1963	Code of Practice for Bending and Fixing of Bars for Concrete Reinforcement
IS 2505-1992	Concrete vibrators - Immersion type - General requirements
IS 2514-1963	Concrete vibrating tables
IS/IEC 60947-2-2003	Low-Voltage Switchgear and Control gear - Part 2 : Circuit Breakers
IS 13118-1991	High-Voltage Alternating-Current Circuit-Breakers
IS/IEC 60947-3-1999	Low p voltage switchgear and control gear : Part 3 Switches, disconnectors, switch-disconnectors and fuse combination units
IS 269-1989	Ordinary and low heat Portland cement (33 GRADE)
IS 2705-1992	Current transformers
IS 2750-1964	Steel Scaffoldings
IS 2751-1979	Code of Practice for Welding of Mild Steel Plain and Deformed Bars for Reinforced Concrete Construction
IS 280-2006	Mild Steel Wire for General Engineering Purposes
IS13925-1-2012	Shunt capacitors for ac power systems having a rated voltage above 1000 V Part 1:General
IS 2961-1973	Chrome retain finished upper leather
IS 8130-1984	Conductors for insulated electric cables and flexible cords
IS 3043-1987	Code of practices for earthing
IS 3085-1965	Method of Test for Permeability of Cement Mortar and Concrete
IS 3156-1992	Voltage transformers
IS 3231-1986	Electrical relays for power systems protection
IS 3427-1997	A.C. Metal Enclosed Switchgear and Control gear for Rated Voltages Above 1 kV and Up to and Including 52 kV
IS 3443-1980	Crane rail sections
IS 3558-1983	Code of practice for use of immersion vibrators for consolidating concrete
IS 3597-1998	Concrete pipes - Methods of test
IS 5578-1984	Guide for marking of insulated conductors
IS 11353-1985	Guide for Uniform System of Marking and Identification of Conductors and Apparatus Terminals
IS 3764-1992	Code of safety for excavation work
IS 383-1970	Coarse and Fine Aggregates From Natural Sources For Concrete
IS 3954-1991	Hot Rolled Steel Channel Sections for General Engineering Purposes - Dimensions
IS 4031-1989	Methods of physical tests for hydraulic cement

ID of Standard	Description
IS 4032-1985	Method of chemical analysis of hydraulic cement
IS 4081-1986	Safety code for blasting and related drilling operations
IS 4138-1977	Safety code for working in compressed air
IS 432-1982	Mild Steel and Medium Tensile Steel Bars and Hard-Drawn Steel Wire for Concrete Reinforcement
IS 456-1978	Plain and Reinforced Concrete - Code of Practice
IS 457-1957	Code of Practice for General Construction of Plain and Reinforced Concrete for Dams and Other Massive Structures
IS 458-2003	Precast Concrete Pipes (with and without Reinforcement)
IS 4756-1978	Safety code for tunnelling work
IS 4880 (Part 1-7)	Code of practice for design of tunnels conveying water
IS 4925-2004	Concrete Batching and Mixing Plant
IS 4988-1968	(Part 1-5): Glossary of terms and classification of earth moving machinery
IS 5082-1998	Wrought aluminum and aluminum alloy bars, rods, tubes and sections for electrical purposes
IS 516-1959	Method of Tests for Strength of Concrete
IS 5525-1969	Recommendation for detailing of reinforcement in RCC
IS 5640-1970	Method of test for determining aggregate impact value of soft coarse aggregates
IS 5819-1970	Recommended Short-circuit Ratings of High Voltage PVC Cables
IS 5831-1984	PVC insulation and sheath of electric cables
IS 5878-1971	(Part 1-7): Code of Practice for Construction of Tunnels
IS 5892-2004	Concrete transit mixers & agitators
IS 6430-1985	Mobile air compressor for construction purposes
IS 6461-1972	Glossary of terms relating to cement concrete: Part I Concrete aggregates
IS 6461-1972	Glossary of Terms Relating to Cement Concrete - Part III : Concrete Reinforcement
IS 650-1991	Standard Sand for Testing of Cement
IS 694-2010	POLYVINYL CHLORIDE INSULATED UNSHEATHED AND SHEATHED CABLES/CORDS WITH RIGID AND FLEXIBLE CONDUCTOR FOR RATED VOLTAGES UP TO AND INCLUDING 450/750 V
IS 7098-1988	Crosslinked polyethylene insulated PVC sheathed cables: Part 1 For working voltage upto and including 1 100 V
IS 7245-1974	Concrete payers
IS 7251-1974	Concrete finishers
IS 7293-1974	Safety code for working with construction machinery
IS 7319-1974	perforated concrete pipes
IS 783-1985	Code of Practice for Laying of Concrete Pipes
IS 7861-1981	(Part 2): Code of practice for extreme weather concreting: Part II Recommended practice for cold weather concreting
IS 7861-1981	(Part 1): Code of practice for extreme weather concreting Part 1 Recommended practice for hot weather concreting
IS 800-2007	General Construction In Steel - Code of Practice
IS 8041-1990	Specification for rapid hardening Portland cement (2nd revision)
IS 8112-1989	High strength ordinary Portland cement (43 grade)
IS 814-2004	Covered Electrodes for Manual Metal Arc Welding of Carbon and Carbon Manganese Steel
IS 816-1969	Code of practice for use of metal arc welding for general construction in mild steel
IS 817-1992	(Part 1): Training of Welders - Code of Practice: Part 1 Manual metal arc welding
IS 818-1968	Code of Practice for Safety and Health Requirements in Electric and Gas Welding

ID of Standard	Description
	and Cutting Operations
IS 2062-2011	Hot Rolled Medium and High Tensile Structural Steel
IS 8623-1993	Low-Voltage Switchgear and Controlgear Assemblies
IS/IEC 60898 - 2002	Electrical accessories - Circuit-breakers for overcurrent protection for household and similar installations : Part 1 Circuit-breakers for ac operation
IS 9012-1978	Recommended practice for shotcreting
IS 9103-1999	Concrete Admixtures
IS 9284-1979	Method of test for abrasion resistance of concrete
IS 9417-1989	Recommendations for welding cold worked bars for reinforced concrete construction

2.5.2 European Standards

Table 3: European Standards

Codes	Description
Eurocode 1	Basis of design and actions on structures
Eurocode 2	Design of concrete structures
Eurocode 3	Design of steel structures
Eurocode 5	Design of timber structures
Eurocode 7	Geotechnical design
Eurocode 8	Design of structures for earthquake resistance
BS EN ISO 62:2008	Plastics. Determination of water absorption
BS EN 196:2005	Methods of testing cement
BS EN 197-1:2011	Cement. Composition, specifications and conformity criteria for common cements
BS EN 197-1:2004	Cement - Part 1: Composition, specifications and conformity criteria for common cements
BS EN 206-1:2001	Specification, performance, production and conformity
BS EN 295-7:1996	Requirements for vitrified clay pipes and joints for pipe jacking
BS EN 338:2010	Structural timber. Strength classes
BS EN 450-1:2005	Fly ash for concrete - Part 1: Definitions, specifications and conformity criteria A1:2007
BS EN 471:2004	High-visibility warning clothing for professional use - Test methods and requirements
BS EN 480:2006	Admixtures for concrete, mortar and grout. Test methods
BS EN ISO 527-3:1996	Plastics. Determination of tensile properties. Test conditions for films and sheets
BS EN 681-2:2000	Elastomeric seals. Material requirements for pipe joint seals used in water and drainage applications. Thermoplastic elastomers
BS EN 771-3:2011	Specification for masonry units. Aggregate concrete masonry units (dense and light-weight aggregates)
BS EN 772-2:1998	Methods of test for masonry units. Determination of percentage area of voids in masonry units (by paper indentation)
BS EN 791:1996	Drill rigs - safety
BS EN 815:1997	Safety of unshielded tunnelling boring machines and rodless shaft boring machines for rock
BS EN 932-6:1999	Tests for general properties of aggregates. Definitions of repeatability and reproducibility
BS EN 933-1:2012	Tests for geometrical properties of aggregates. Determination of particle size distribution. Sieving method

Codes	Description
BS EN 934-2:2009	Admixtures for concrete, mortar and grout - Part 2: Concrete admixtures - Definitions and requirements, conformity, marking and labelling
BS EN 1008:2002	Mixing water for concrete - Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete
BS EN 1011-1:2009	Welding - Recommendations for welding of metallic materials - General guidance for arc welding
BS EN 1011-2:2001	Welding. Recommendations for welding of metallic materials. Arc welding of ferritic steels
BS EN 1062-7:2004	Paints and varnishes. Coating materials and coating systems for exterior masonry and concrete. Determination of crack bridging properties
BS EN 1090-2:2008	Execution of steel structures and aluminum structures. Technical requirements for steel structures
BS EN 1097	Tests for mechanical and physical properties of aggregates
BS EN 1367	Tests for thermal and weathering properties of aggregates
BS EN ISO1461:2009	Hot dip galvanized coatings on fabricated iron and steel articles. Specifications and test methods
BS EN 1537:2000	Execution of special geotechnical work - rock anchors
BS EN 1542:1999	Products and systems for the protection and repair of concrete structures. Test methods. Measurement of bond strength by pull-off
BS EN 1562:2012	Founding. Malleable cast irons
BS EN 1563:2012	Founding. Spheroidal graphite cast iron
BS EN 1744	Tests for chemical properties of aggregates
BS EN 1849-2:2010	Flexible sheets for waterproofing. Determination of thickness and mass per unit area. Plastic and rubber sheets
BS EN 1928:2000	Flexible sheets for waterproofing. Bitumen, plastic and rubber sheets for roof waterproofing. Determination of water tightness
BS EN ISO 3506-2: 2009	Mechanical properties of corrosion-resistant stainless-steel fasteners - Nuts
BS EN ISO 4624:2003	Paints and varnishes. Pull-off test for adhesion
BS EN ISO 9001:2008	Quality management systems. Requirements
BS EN 10025:2004	Hot rolled products of structural steels
BS EN 10080:2005	Steel for the reinforcement of concrete. Weldable reinforcing steel.
BS EN 10164:2004	General Steel products with improved deformation properties perpendicular to the surface of the product - technical delivery conditions
BS EN 10226-1:2004	Pipe threads where pressure tight joints are made on the threads. Taper external threads and parallel internal threads. Dimensions, tolerances and designation
BS EN ISO 11925-2:2011	Reaction to fire tests. Ignitability of products subjected to direct impingement of flame. Single-flame source test
BS EN 12110:2002	Tunnelling machines - Air locks - Safety requirements
BS EN 12111:2002	Tunnelling machines - Road headers, continuous miners and impact rippers - Safety requirements
BS EN 12310-2:2000	Flexible sheets for waterproofing. Determination of resistance to tearing (nail shank). Plastic and rubber sheets for roof waterproofing
BS EN 12317-2:2010	Flexible sheets for waterproofing. Determination of shear resistance of joints. Plastic and rubber sheets for roof waterproofing
BS EN 12336:2005	Tunnelling machines - Shield machines, thrust boring machines, auger boring machines, lining erection equipment - Safety requirements
BS EN 12350	Testing fresh concrete
BS EN 12390	Testing hardened concrete

Codes	Description
BS EN 12504-1	Testing concrete in structures - Part 1: Cored specimens - Taking, examining and testing in compression
BS EN 12588:2007	Lead and lead alloys. Rolled lead sheet for building purposes
BS EN 12620:2002	Aggregates for concrete
BS EN 12878:2005	Pigments for the colouring of building materials based on cement and/or lime. Specifications and methods of test
BS EN 12889:2000	Trenchless construction and testing of drains and sewers
BS EN 13055-1:2002	Lightweight aggregates. Lightweight aggregates for concrete, mortar and grout
BS EN 13139:2002	Aggregates for mortar
BS EN 13263-1:2005	Silica fume for concrete - Part 1: Definitions, requirements and conformity criteria
BS EN 13492:2004(E)	Geosynthetic barriers - Characteristics required for use in the construction of liquid waste disposal sites, transfer stations or secondary containment
DIN EN 13670-1:2011	Execution of concrete structures
BS EN 13791:2007	Assessment of in-situ compressive strength in structures and pre-cast concrete components
BS EN 14487-1:2006	Sprayed concrete - Part 1: Definitions, specifications and conformity
BS EN 14487-2:2006	Sprayed concrete - Part 2: Execution
BS EN 14488-1:2005	Testing sprayed concrete - Part 1: Sampling fresh and hardened concrete
BS EN 14488-2:2006	Testing sprayed concrete - Part 2: Compressive strength of young sprayed concrete
BS EN 14488-3:2006	Testing sprayed concrete - Part 3: Flexural strengths (first peak, ultimate and residual) of fibre reinforced beam specimens
BS EN 14488-4:2005	Testing sprayed concrete - Part 4: Bond strength of cores by direct tension
BS EN 14488-5:2006	Testing sprayed concrete - Part 5: Determination of energy absorption capacity of fibre reinforced slab specimens
BS EN 14488-7:2006	Testing sprayed concrete - Part 7: Fibre content of fibre reinforced concrete
BS EN 14889-1:2006	Fibres for concrete - Part 1: Steel fibres. Definitions, specifications and conformity
BS EN 14889- 2:2006	Fibres for concrete - Part 2: Polymer fibres. Definitions, specifications and conformity
BS EN 15167-1:2006	Ground granulated blast furnace slag for use in concrete, mortar and grout - definitions, specifications and conformity criteria
BS EN 60204	Safety of machinery. Electrical equipment of machines
BS EN 61672-1:2003	Electroacoustics. Sound level meters. Specifications
DD CEN/TS 14416:2005	Geosynthetic barriers. Test method for determining the resistance to roots
PD CLC/TR 50426:2006	Assessment of inadvertent initiation of bridge wire electro-explosive devices by radio-frequency radiation. Guide

2.5.3 British Standards

Table 4: British Standards

Codes	Description
BS 143 and 1256:2000	Threaded pipe fittings in malleable cast iron and cast copper alloy
BS 1134:2010	Assessment of surface texture. Guidance and general information
BS 4190:2001	ISO metric black hexagon bolts, screws and nuts. Specification
BS 4449:2005	Steel for the reinforcement of concrete - Weldable reinforcing steel - Bar, coil and decoiled product

Codes	Description
BS 4482-2005	Steel wire for the reinforcement, of concrete products. Specification
BS 4483:2005	Steel fabric for the reinforcement of concrete
BS 4921:1988	Specification for sherardized coatings on iron or steel
BS 5228-1:2009	Code of practice for noise and vibration control on construction and open sites. Noise
BS 5228-2:2009	Code of practice for noise and vibration control on construction and open sites. Vibration
BS 5607:1998	Code of practice for the safe use of explosives in the construction industry
BS 5911-1	Concrete pipes and ancillary concrete products. Specification for unreinforced and reinforced concrete pipes (including jacking pipes) and fittings with flexible joints (complementary to BS EN 1916:2002)
BS 5975:2008	Code of practice for temporary works procedures and the permissible stress design of falsework
BS 6100	Building and civil engineering. Vocabulary. (various dates)
BS 6164:2011	Code of practice for health and safety in tunnelling in the construction industry
BS 6319	Testing of resin and polymer cement compositions for use in construction (various dates)
BS 6472:2008	Guide to evaluation of human exposure to vibration in buildings (1-80 Hz)
BS ISO 4866:2010	Mechanical vibration and shock. Vibration of fixed structures. Guidelines for the measurement of vibrations and evaluation of their effects on structures
BS 7385-2:1993	Evaluation and measurement for vibration in buildings. Guide to damage levels from ground borne vibration (Part 2)
BS 7668:2004	Weldable structural steels. Hot finished structural hollow sections in weather resistant steels. Specification
BS 7671:2011	Requirements for electrical installations
BS 7973-1:2001	Spacers and chairs for steel reinforcement and their Specification. Product performance requirements
BS 7973-2:2001	Spacers and chairs for steel reinforcement and their Specification. Fixing and application of spacers and chairs and tying of reinforcement
BS 7979:2001	Specification for limestone fines for use with Portland cement
BS 8102:2009	Code of practice for protection of below ground structures against water from the ground
BS 8500-1:2006	Concrete - Complementary British Standard to BS EN 206-1. Method of specifying and guidance for the specifier
BS 8500-2:2006	Concrete. Complementary British Standard to BS EN 206-1. Specification for constituent materials and concrete
BS 8666:2005	Scheduling, dimensioning, bending and cutting of steel reinforcement for concrete. Specification

2.5.4 International Standards

Table 5: International Standards

Codes	Description
ASTM D 1777	Standard Test Method for Thickness
ASTM D 3776	Standard Test Methods for Mass Per Unit Area (Weight) of Fabric
ASTM D 4491a	Standard Test Method for Water permittivity
ASTM D 4751	Standard Test Method for Apparent opening sizeof a Geotextile
ASTM D 4632	Standard Test Method for Grab Breaking Load and Elongation of Geotextiles
ASTM D 3786	Standard Test Method for Bursting Strength of Textile Fabrics-Diaphragm Bursting Strength Tester Method

Codes	Description
ASTM D 4833	Standard Test Method for Index Puncture Resistance of Geomembranes and Related Products
ASTM D 4533	Standard Test Method for Trapezoid Tearing Strength of Geotextiles
ASTM D 4632	Standard Test Method for Grab Breaking Load and Elongation of Geotextiles
ASTM D 4355	Standard Test Method for Deterioration of Geotextiles by Exposure to Light, Moisture and Heat in a Xenon Arc Type Apparatus
ASTM D 3787	Standard Test Method for Bursting Strength of Textiles-Constant-Rate-of-Traverse (CRT) Ball Burst Test
ASTM D 4157	Standard Test Method for Abrasion Resistance of Textile Fabrics (Oscillatory Cylinder Method)
EFNARC-1996	European Specification for Sprayed Concrete
ASTM C-39	Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
ASTM C-78	Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)
ASTM C-94/C	Standard Specification for Ready-Mixed Concrete
ASTM C-172/C	Standard Practice for Sampling Freshly Mixed Concrete
ASTM C-685/C	Standard Specification for Concrete Made by Volumetric Batching and Continuous Mixing
EFNARC Three Point Bending Test on Square Panel with Notch 2011	Testing Sprayed Concrete - Flexural tensile strength of fibre concrete on sprayed test specimen.
Austrian concrete society publications	Guide line on shotcrete and testing methods
Austrian concrete society publications	Inner lining concrete
JSCE -2004	Recommendation for design and construction of steel fibre reinforced concrete, Publications of Japan society of civil Employer's Representatives
DIN 67524 (Part1/02)	Lighting of street tunnels and underpasses
DIN 67524-2008	Tunnel illumination
DIN 5035	Artificial lighting
RABT (2006)	Guidelines for equipment and operation of road tunnels

2.6 Materials

All materials supplied to the Works shall conform to all of the following:

- This Specification.
- The appropriate Indian Standard, if no Indian Regulation is available the corresponding European or British Standard shall be adopted.
- Where an industry certification scheme is available, material shall be supplied in accordance with that scheme.
- Materials shall be supplied from a quality assured source, operating a Quality Assurance system in compliance with the relevant part of BS EN ISO 9001.

Where required in the particular Specification or where stated on the drawings, samples should

be supplied, and the subsequent material shall conform to the samples.

Materials used on site shall be used in accordance with the manufacturer's recommendations and instructions.

All materials should be handled and stored in a way to maintain their integrity and to avoid damage and degradation.

Details of the level of inspection and testing to be adopted in respect of supplied materials shall be agreed with the Employer's Representative prior to commencement of work. Individual submissions are then restricted to those required by the Quality System.

2.7 Quality Management and Records

The project shall be administered using an accredited Quality Management System conforming to BS EN ISO 9001. The individual requirements for agreement by the Employer's Representative of materials and workmanship throughout this Specification shall be incorporated into agreed self-certification procedures.

The agreed Quality Control arrangements, including hold points and submission of records for the Employer's Representative's acceptance, shall be set out in agreed Inspection and Test Plans.

References to the agreement of materials, workmanship, methods etc. throughout this Specification shall be interpreted as requiring the agreement of the Employer's Representative.

The Contractor shall maintain all records necessary under this Specification, including quality records as appropriate. Electronic records shall be maintained and backed up on a daily basis to prevent loss of data in the event of failure of electronic data storage.

Copies of all site records shall be available to the Employer's Representative.

The Contractor shall supply the Employer's Representative with all information necessary for the Health and Safety File including as-built drawings and records, maintenance schedules, operation and maintenance manuals, within the time specified in the Contract, after substantial completion of the Works. Information shall be provided in the agreed format. The Health and Safety File shall be prepared by the party identified in the Contract.

3 SITE INSTALLATION

3.1 General

The Contractor shall be responsible for providing all necessary provisions for the execution of the construction works under this Contract. This includes plants, equipment, materials and laboratories.

The Contractor shall design, furnish, install, maintain and operate at the project area all temporary works and equipment such as Contractor's camp, offices, stores, workshops, warehouses, assembly areas, machinery, vehicles, material yards, health and safety measures, electric power, telecommunications, illumination, water supply system, concrete and aggregate processing plants, material testing laboratory, temporary construction roads etc.

28 days prior to commencement of any Works the Contractor shall submit layout plans at adequate scale showing the temporary construction facilities of the Contractor to the Employer's Representative and they shall include:

- the Contractor's camp, offices, parking space, workshop, warehouses and storage areas including explosive magazines
- water supply, electric power supply including illumination and communication system
- sewerage, sewage treatment and disposal
- construction roads
- concrete and material processing plant, cement and aggregate storage
- material testing laboratory
- temporary tunnel ventilation system
- survey plan
- security and safety arrangement plan, medical care services.

3.2 Contractor's Camp

The Contractor shall design, furnish, install, maintain and operate the Contractor's camp at the location and within the designated lines defined by the local Authorities or the Employer's Representative. The Contractor's camp shall provide the housing, feeding and recreation of the Contractor's employees and those of his subcontractors. The Contractor's camp shall be designed for the maximum number of employees on the site.

All facilities shall be in compliance with the Indian Construction Workers Act 1996 on permanent

and temporary housing of employees. Prior to any camp construction the Contractor's drawings and Specifications shall be approved by the Employer's Representative.

The Contractor shall provide additional adequate housings for the Employer's Representative staff.

3.3 Site Office, Stores

The Contractor shall design, furnish, install, maintain and operate all required offices, stores, warehouses and testing laboratories at the location and within the designated lines defined by the local Authorities or the Employer's Representative.

The Contractor shall provide and maintain a fully equipped site office for the Employer's Representative staff on each construction site.

3.4 Lighting & Ventilation during Construction

Lighting and ventilation during construction shall be in compliance with Clause 7.7 and 7.8 in this Specification.

3.5 Electrical Power Supply

3.5.1 General

The Contractor shall be responsible for obtaining an adequate electrical supply for all his Site operations during the whole construction period.

Installations shall comply with IEC 60204 Safety of machinery, electrical equipment of machines and IEC 60364 Electrical installations of buildings.

If so required by the Employer's Representative, the Contractor shall make a copy of all certificates prepared upon completion of electrical installations and prepared for all required periodic checks available.

The Contractor shall appoint a competent person to be solely responsible for ensuring the safety of all temporary electrical equipment on site.

The Contractor is to comply at all times with the Electricity at Work Regulations.

The Contractor shall furnish, install and keep operational throughout the duration of the Works standby generating facilities of such capacity as to be able to maintain minimum services such as illumination, ventilation, water supply, dewatering etc. necessary for the Project Area safety and security during a failure of the primary power source.

Oil filled transformers are not permitted in subsurface usage. Transformers shall be air-cooled and dry type.

Electrical heaters or radiators having exposed coils or elements shall not be permitted underground.

The lighting circuits shall be separated from the other sub-circuits.

The Contractor shall furnish, operate and maintain 100% standby diesel-driven generators or alternative source of power supply at each working portal. The generators or alternative supply shall be capable of operating the lighting system and the pumps required to flooding of the underground works besides operating all other systems so to allow the work function smoothly in event of main power system failure. The generators shall be tested by the Contractor weekly to ensure the full working capability.

Drawings showing the design of the electrical power distribution system within each area shall be submitted to the Employer's Representative for approval at least 28 days prior to installation. This shall at least include a single line diagram for the distribution systems within each area, protection schemes for the systems and description of the operation concept. The installation of the electrical distribution systems shall not be started unless the Employer's Representative has approved the submitted documents.

The client or representative of the client shall be allowed to access always all facilities of the construction site.

3.5.2 Earthing

All light fittings, electrical equipment and appliances shall be earthed electrically, and the Contractor's specialized personnel shall periodically check the effectiveness of such earthing. The earthing shall meet the requirements for plant and equipment given by Indian Standard 3043.

3.5.3 Cables

All exposed electrical cables installed within the tunnel shall comply with the following requirements:

- Flame retarding properties to IEEE 383,
- Toxicity level Acid evolution when burned 7%
- Flame propagation Oxygen index value 30% minimum
- Smoke density rating: 35% maximum

Supply cables at 3.3 kV or below shall be 3-core with the armouring used as the earth return in conditions where the cable is not subject to continues movement after installation or where the supply is to be a fixed point.

For supply to mobile or transportable equipment, where operation of the equipment subjects the cable to flexure, cables shall be sheathed in flame retardant LSFH.

3.6 Site Communication

The Contractor shall provide a suitable system for communication between the underground work site and workstations outside the tunnel and maintain such system in working order at all times. An underground station (including telephone socket with bell and indicator) shall always be within 50 m of the point where major work is being carried out and at 200 m intervals along the driven tunnel.

3.7 Water Supply

The Contractor shall provide water that is adequate for year-round use in his camps as well as for general construction use.

The Contractor shall furnish, install, operate and maintain all necessary equipment including pumps, piping, fittings, valves, storage tanks and disinfection for the water supply and distribution systems.

Special measures during low temperature periods shall be taken such as heating or thermal insulation of pipes to avoid freezing of water.

3.8 Concrete and Material Processing Plant

At each construction site, the Contractor shall install and erect all required materials processing plants of sufficient capacity to meet his planned peak requirements during construction. The plants shall be subject to approval by the Employer's Representative. All control and measuring shall be regularly serviced and calibrated.

The following plants shall be installed but not limited to:

- concrete aggregates processing plant (crushing and screening);
- concrete plant (batching and mixing);
- grouting plant

3.9 Testing Laboratory

The Contractor shall install, equip and maintain an adequate field laboratory for the sampling and testing of materials such as concrete, earth or any other materials as specified herein.

The laboratory shall be adequately lit, supplied with sufficient electrical power, water and heating. Adequate space for testing devices and storage areas shall be provided.

The equipment to be supplied and the methods of testing shall be in accordance with the referenced Standards in these Specifications. The proposed type and number of items of laboratory equipment shall be presented to the Employer's Representative and approved prior to purchase.

All facilities and services shall be available to the Employer's Representative as required. All sampling and testing to be undertaken shall be subject to the supervision of the Employer's Representative. The laboratory shall be run by Contractor's personnel experienced in sampling and testing of materials and be subject to quality control.

Specialised testing which may be required, and which cannot be performed in the Contractor's laboratory due to lack of time or equipment shall be assigned by the Contractor to an independent organisation approved by the Employer's Representative. The Contractor shall accept all test results and all instructions or restrictions stipulated by the Employer's Representative based on such tests.

3.10 Removal

The Contractor's Camp shall be dismantled and removed subsequently to completion of the Works by the Contractor, unless otherwise specified or directed by the Employer's Representative.

All temporary installations must be completely removed after finalization of the relevant works. Rubbish, waste, debris and material must be removed.

Any disturbed area that will not be taken over for permanent use shall be restored at the completion of the Works to the original appearance as far as possible.

4 WORKING ENVIRONMENTS

4.1 Health, Safety and Welfare

The Contractor shall adopt safe systems of work which minimise the risk to health and safety. All persons working on the site shall be competent to carry out their tasks and duties safely and in a manner that will endanger neither their own health nor the health of others. Persons, who are employed on the site for the first time, shall be subject to appropriate pre-employment occupational health checks, instructed on the hazards inherent in the site, precautions to be taken, the form of construction, and emergency procedures and fire safety. Such instructions shall be given whenever there is a material change in the working arrangements. The Contractor shall maintain a record of all persons instructed and each person shall be required to sign such record confirming that instruction has been received. No person shall be permitted on site without being inducted as set out above. The Contractor shall prepare a written statement of Safe Systems of Working which shall be issued to all persons at site.

All parties shall comply with the requirements and recommendations of BS 6164, BS EN 815, BS EN 12336, BS EN 12110, BS EN 12111 and BS 7671.

The Contractor shall also comply with the requirements of the Employer's codes of practice for safe working and those of any authority or body where their services or property are affected by the works.

A person responsible for Safety shall be appointed by the Contractor and this person shall be conversant with corporate policy, management operational instructions, regulations, legislation and current best practice and how these relate to health, safety and welfare. Compliance with health and safety requirements is the responsibility of managers and individuals at each and every level.

The Contractor shall establish on site:

- Welfare and first aid facilities with appropriately trained personnel, both on the surface and underground, as required by the scale of the Works. Welfare facilities shall include toilet and washing facilities. Where water washing facilities cannot be provided, appropriate alternative means of hand cleaning shall be provided. Barrier creams etc. for skin protection shall also be provided.
- Occupational health facilities on the surface, staffed by appropriate occupational health professionals as required by the nature and scale of the Works.
- Equipment for the rescue and evacuation of persons underground with persons instructed in its use.

- All necessary equipment, safety barriers, notices and the like for the protection of persons.
- Procedures to ensure that all plant and equipment underground is fitted with on-board fixed fire-extinguishing equipment covering fluid tanks, motors or engine compartments and tyres along with the use of reduced flammability (HFDU) hydraulic fluid.
- Comprehensive fire detection and firefighting facilities.
- Sufficient chemical or compressed oxygen self-rescuer sets for all persons underground in accordance with HSE guidance.
- A competent safety officer shall be appointed by the Contractor who shall be conversant with the hazards associated with the form of construction to be undertaken and who shall be responsible for ensuring compliance with all management directives, rules and regulations concerning occupational health and safety.
- Subject to any legal requirement or requirement of the Employer and the size and nature of the Works, the Contractor may appoint a visiting competent safety officer under item above. He shall visit the site at the start of operations and for changes in methods of working, but in any event his visits shall not be at greater intervals than one month.

4.2 Noise & Vibration

4.2.1 General

The Contractor shall minimise occupational exposure to noise and vibration, the amount of noise emitted to the environment and the environmental vibration levels generated by his work activity.

The Contractor shall select and utilise methods of working and items of plant and control in his Works so as to minimise noise and vibration levels, including occupational noise and vibration exposure of the workforce, and not to exceed maximum permitted noise and vibration levels specified in the Contract or defined by local Authorities.

The adherence to any vibration levels specified in the Contract does not relieve the Contractor of his obligations with respect to structural or other property damage.

4.2.2 Temporary Fencing and Barriers

Where required the Contractor shall erect and maintain throughout the construction period temporary fencing of appropriate height taking account of the need for this fencing to act as a noise barrier around all working areas. The fencing shall be dismantled and re-erected as the progress of the Works requires.

The line of the fencing shall be uniform, and the exterior face of the fencing shall be treated with a

durable finish. Where required, in order to prevent reflection of noise, the Contractor shall line the inside of fencing with sound-absorbent material with accepted acoustic absorption properties. The material shall be fire and water resistant.

Local fencing barriers or shelters shall be erected as necessary to shield particular activities, such as those involving the use of pneumatic or hydraulic techniques, and all stationary plant.

4.2.3 Plant & Equipment

The Contractor shall select and use plant, equipment and working practices which minimise occupational exposure to noise and vibration and minimise emissions of noise and vibration to the environment.

All plant shall be properly maintained, and relevant service records completed. All plant shall be provided with effective silencers and vibration-dampening devices and shall be operated according to the manufacturer's recommendations in such a manner as to avoid causing any excessive noise emission or vibration. The noise emitted by an item of plant shall not exceed the relevant values quoted in the Contract or defined by local Authorities.

4.2.4 Noise & Vibration Monitoring

Where monitoring is required the Contractor shall provide, calibrate, operate according to the manufacturer's recommendations appropriate equipment for monitoring construction noise and vibration throughout the construction period.

The Contractor shall arrange for adequate standby equipment.

The Contractor shall notify the Employer's Representative immediately whenever the specified noise or vibration limit has been exceeded, and agree measures to avoid repetition.

Any items of plant causing excessive noise or vibration levels shall be removed from the site and substituted by alternative compliant equipment.

The Employer's Representative may instruct the Contractor to devise and use an alternative process if a construction method is causing unnecessary disturbance.

4.3 Access & Egress

The Contractor shall make all arrangements and assume full responsibility for transportation to the Site of all construction plant, materials and supplies needed for the proper execution of the Works.

Where designated access routes are indicated in the Contract, the Contractor shall use no other without the agreement of the Employer's Representative.

4.3.1 Maintenance of Routes

All public and private highways and roads which are being used by the Contractor's, Subcontractors' or Suppliers' vehicles for the construction of the Works shall be kept clean and free of dirt and mud arising from the Works. The Contractor, unless otherwise provided for in the Contract, shall provide, maintain and use as necessary suitable equipment including mechanical road sweepers, throughout the course of the Works where and as agreed with the highway authority.

The Contractor shall provide, maintain and use mechanical wheel washers and high-pressure hosing facilities at work sites and at such additional locations as required under the Contract.

The Contractor shall be responsible for all maintenance in all respects of all site roads.

Any area of public highway which is closed because of the Works shall not be reopened until appropriate safety and traffic management measures have been completed and until the Employer's Representative confirms that it is in a suitable condition for use by the public.

The Contractor shall protect the public from the Works by secure fencing and gates and shall control access through the gates as required under the Contract.

4.3.2 Access for Others

The Contractor shall always meet the full requirements for access for fire, ambulance and other emergency services and maintain liaison with them in that respect.

The Contractor shall always maintain access for the authorised representatives of utility providers and allow emergency operations to be carried out on any utility or service facilities within the Site.

The Contractor shall not use public or private rights of way for depositing or storing plant or materials. The Contractor shall maintain those parts of the public or private rights of way not temporarily occupied by the Works in a clean, passable and safe condition always.

The Contractor shall execute the Works in such a manner that safe pedestrian access, including disabled person access, to all properties is always maintained.

Unless otherwise provided in the Contract, methods of construction and programming of the Works shall be such that vehicular access to properties affected by the Works is not restricted.

4.3.3 Traffic Safety and Management

Where work is carried out on or adjacent to a trafficked highway the Contractor shall ensure that personnel shall, always, wear high-visibility fluorescent garments which shall comply with BS EN 471.

All proposals, details, execution, maintenance, removal and necessary reinstatement associated with traffic safety and management and temporary decking and other temporary structures on, or subways beneath, the highway shall be subject to the approval of the appropriate authorities. The Contractor shall supply all information required, for consultation with the appropriate authorities including the local authority, police and other authorities with jurisdiction or interest.

The Contractor shall agree a traffic management plan with the Employer's Representative based on consultation and agreement with highway authorities. This shall show the scheme of traffic safety and management measures including the provision of safety zones and traffic signing. The plan shall include the requirements of emergency services for access into and through the site.

Fenced storage areas, gantries, loading bays, skips and other temporary structures on the public highway shall be provided and maintained to the conditions of a licence issued by the local authority.

All traffic safety and management measures necessitated by the Works shall be fully operational before the Contractor commences any work which affects the public highway.

The Contractor shall devise and put into effect traffic management procedures, including appropriate speed limits, within the site including on haul roads and temporary access roads, which are to an equivalent standard to those for a public highway unless directed otherwise by the Employer's Representative.

4.3.4 Signing, Signalling & Lighting

The Contractor shall provide suitable entry and exit signs, at the points of access to and from the site, for vehicles and plant engaged on the Works. As far as possible, vehicles and plant shall enter and exit the site in a forward direction.

Unless otherwise specified, the Contractor shall make all necessary arrangements including notices to relevant authorities for the provision, erection, maintenance, repositioning, covering and uncovering and final removal of all traffic signs as the progress of the Works requires.

The Contractor shall devise and put into operation traffic management arrangements to separate pedestrian and vehicular traffic. Pedestrian access shall be clearly signed and provided with barriers of adequate strength.

The temporary traffic Contractor shall be responsible for the design, provision and maintenance of all signals and associated equipment unless otherwise given in the Contract.

Where required during the execution of the Works, the Contractor shall provide and maintain temporary lighting for the highways. Temporary lighting shall provide the same level of

illumination as that of the existing street lighting, which it replaces. Temporary lighting shall be provided and approved prior to the removal of any existing street lighting.

4.3.5 Survey & Reinstatement

Prior to commencing the Works, the Contractor shall carry out a condition survey of all roads and footways adjacent to the site. The survey record shall be available to the Contractor.

Unless stated otherwise, the Contractor shall reinstate all roads and footways affected by the Works to the extent, lines and levels that existed prior to the commencement of the Works and to standards that are at least equivalent to those that existed prior to the commencement of the Works.

Unless stated otherwise, the Contractor shall reinstate all surface water drainage systems (including but not restricted to gullies, channels, catch pits, pipe runs, manholes and covers and the like) affected by the Works. The Standard of reinstatement shall be at least equivalent to that existing prior to the Contract commencing.

4.3.6 Access within Works

The Contractor shall provide safe access in and about, the site and underground workings.

All shafts shall have a ladder access in addition to any mechanical means.

The Contractor shall always provide a safe designated pedestrian access in the tunnel and throughout the site area. This shall have a firm, level, slip-resistant and continuous surface and shall be suitable for use in emergencies when lighting may be unavailable.

The Contractor shall segregate pedestrian and vehicular access routes.

The Contractor shall always maintain a clear means of egress from each tunnel face. Such means of egress through or past equipment, trains and similar obstructions shall meet the minimum dimensions in BS EN 12336.

The Contractor shall establish, maintain and operate a system whereby the presence of personnel underground is recorded, together with their location where appropriate.

4.4 Disposal of Spoil & Water

The Contractor shall prepare a Site Waste Management Plan (SWMP), which sets out in detail how spoil and all waste is to be categorised, disposed of and monitored, the programme for disposal and how legislation is to be complied with. This plan will address all waste matters at the site and have specific documented mechanisms for adopting a 'reduce, reuse, recycle' approach to waste minimisation for dealing with all wastes. The SWMP will be reviewed by the Employer's

Representative and accepted or approved as required by the Contract.

4.4.1 Solid Waste Disposal

The Contractor shall remove all excavated material, spoil, surplus materials and rubbish from whatever source on site and shall, except where otherwise specified in the Contract, make his own arrangements for their disposal and provide all the necessary facilities to achieve this. The Contractor shall also comply with any legal or local authority requirements applying to the handling and disposal of any contaminated spoil.

The Contractor shall set up a system to control and monitor the transport of spoil from site to the tip site, in accordance with the current legislation and requirements of the local Authorities. The system shall be agreed with the Employer's Representative and will provide evidence that each load has been deposited at a licensed tip site.

The Contractor shall retain auditable records of waste removed from site. Waste Transfer Notices should be collated and submitted to the Employer's Representative. Transfer and Consignment notes shall be kept in the site file.

The Contractor shall comply with all statutes and statutory instruments relating to spoil disposal.

4.4.2 Liquid Waste Disposal

Before discharging any surplus water, the Contractor shall obtain the prior approval of the owner of the sewer or water-course and of the Environment Agency.

The Contractor shall ensure that the condition of any discharged water complies with permitted limits. The parameters to be monitored include pH values, temperature and suspended solids.

5 DEWATERING ARRANGEMENT

5.1 General

The Contractor shall design, furnish, maintain and remove temporary works for protecting the Works under construction against flood flows in rivers and creeks, and design, furnish, operate, maintain and dismantle the temporary dewatering facilities required to remove water from construction activities and from natural surface flow or groundwater seepage from working areas on the surface as well as in the tunnel.

The Contractor's working methods and systems shall be designed to control ground and surface water to permit the construction of shafts, tunnels, breakouts and portal structures.

Where dewatering operations are used they shall be kept to the minimum necessary for the execution of the Works. If, at any time, during construction, the inflow of water increases more than the installed pumping capacity, the Contractor shall be required to install additional pumping facilities and perform additional sealing as required by the Employer's Representative. The dewatering system shall include a system for identifying ingress of soil material during the dewatering operation.

In planning temporary pumping systems, the Contractor shall take due consideration of water quality, pressure, quantity and variations in water levels.

Settlement ponds and other measures shall be provided so as to ensure that potentially contaminated or polluted matter from the execution of the Works is nowhere released into creeks, rivers or the ground.

The Contractor will be held responsible for all damage caused by his dewatering procedures or the lack of such, and he shall reinstate or repair disturbed ground or structures to their original condition or as otherwise approved.

Plant shall be delivered to site and maintained in good working order. Plant and pipe work shall be fitted with appropriate valves, controls and gauges. Each dewatering well shall be capable of individual adjustment and being shut down and isolated from the rest of the system. Appropriate standby equipment and spares shall be maintained on site at all time.

5.2 Construction Site

The Contractor shall perform all works necessary to drain the surface construction sites of rain, groundwater and service water. The work shall include, but not be limited to the following:

- design and construction of drainage, ditches, pits, pump sumps and settlement ponds with oil separators

- design, furnish, operate and maintain dewatering equipment and conduits
- relocation of dewatering facilities required for the performance of other works
- diversion of creeks where required by construction of any permanent or temporary structure, including spoil and stockpile areas
- all auxiliary work required for the safe and continuous dewatering of the surface construction sites

The Contractor shall perform all work necessary to collect and drain construction water and infiltrating groundwater, convey it to main conduits and convey it out from tunnel work to discharge points. The work shall include, but not be limited to, the following:

- design and construct pits, trenches and drainage measures along the tunnel invert
- design, furnish, operate and maintain dewatering equipment (including pumps and power supply) and conduits
- relocate dewatering facilities as required for the unhindered performance of the tunnel work
- design, construct and operate settlement ponds, with oil separators, at the portals or elsewhere, with discharge into creeks and rivers, as approved
- all auxiliary work required for the safe and continuous dewatering of the underground working areas

The Contractor shall design and install complete facilities for the drainage of the temporary and permanent portal areas and the muck disposal areas.

Drainage ditches shall be excavated along the top of excavated slopes and on the berms. Such ditches shall be kept well back from the excavation edges. In loose materials the ditches shall be lined with concrete or with rock paving set in mortar immediately after completion of excavation. The ditches shall be regularly cleaned out of accumulated silt and other matter so that water may flow freely at all times.

Rivers, creeks and intermittent streams in the vicinity of temporary or permanent works shall be diverted into culverts of lined ditches. Erosion must be prevented. Sediment laden water must be diverted through settling ponds or basins according to the environmental regulations.

5.3 Tunnel

The Contractor shall perform all necessary works to collect and drain construction and ground water in all tunnel drifts at all headings. All required drainage measures including collection and pumping of any ground water in inclined tunnel drifts must be included in the given prices. The

water shall be drained out of the tunnel with minimum impact on ground stability and construction works. This includes, but not limited to:

- pits, trenches and drainage along the tunnel floor
- dewatering equipment including pumps
- pipes along tunnel side wall
- collecting local inflows directly from tunnel perimeter before and after installation of primary support
- collect inflowing water with dimpled sheets along the tunnel perimeter
- settlement ponds or basins with oil separators before discharge into rivers

Mountain water due to tunnel construction shall be collected and drained. Excavation areas shall be drained of all construction water and ground water. Water appearing at the face shall be drained to the longitudinal drainage system as soon as possible.

Dewatering arrangement must be considered for falling and rising gradient of the excavation, a softening and damaging of the bench shall be avoided. The water drainage length shall be kept at a minimum. In case of falling gradient temporary pump sumps must be max 5m behind the excavation face (top heading, bench, temporary and permanent invert).

The Contractor shall provide adequate pumping capacity where required, including a sufficient number of standby pumping units and standby power, to handle all water entering any portion of the tunnel works. These units shall be connected to the power supply and dewatering systems in such a way that proper and uninterrupted drainage will be ensured throughout the construction period.

Heavy mountain water may occur and therefore additional drainage system to the longitudinal drainage system may be required. In such zones systematic drainage drillings ahead of the tunnel face may be required and ordered by the Employer's Representative.

If required, drainage drillings (placement, direction and length according to local conditions) shall be constructed with no delay. Instrumentation, for measuring the pore pressure, may be required by the Employer's Representative.

In tunnel sections with ground material sensitive to water (softening or swelling ground condition) particular care has to be taken concerning water drainage. The inflowing water shall be collected as soon as possible and conveyed in pipes not to allow contact to the tunnel floor. Construction water must be reduced to a minimum and collected and pumped immediately into pipes.

Water entering a working face from another part of the tunnel must be deviated not to affect construction works such as bench/invert excavation or concreting.

Unless otherwise specified, all water emanating from the tunnel excavation shall be discharged into settlement ponds, designed so as to meet the requirements of the prevailing Indian regulations. The outflow from each settlement pond shall be arranged in a way to prevent any oil from leaving the pond irrespective of the volume of water entering the pond.

Dimpled sheet membrane shall be of HDPE with a sheet thickness of 1.0 mm. The drainage capacity shall be 10 l/s/m. The compressive strength shall be 150 kN/m^2.

Strip drains shall consist of dimpled sheet membrane as defined above, wrapped in a nonwoven het bonded geotextile. The geotextile shall comply with Clause 12.2.

5.4 Measurement and Monitoring

The Contractor shall install, operate, maintain and relocate the necessary devices for flow measurements. These measuring devices shall be checked and approved by the Employer's Representative before usage.

Gauging stations shall be installed, and measurement of the total discharge shall be made as follows:

- Heading Zone: Measurement shall be performed during excavation and supporting work at a point not less than 50 m and not more than 100 m behind the heading face. Transfer of the measuring station in drill and blast advances shall be done in 100 m steps or as approved by the Employer's Representative.
- Rear Zone: Flow measurements at the portal or at the outlet of installed pump lines shall be performed during the entire excavation and supporting work.

Measurement of water flow shall be performed once a day jointly by the Employer's Representative and the Contractor or as otherwise agreed upon.

All pumping rates must be recorded and the Contractor shall keep full and detailed records of all monitoring carried out. Copies of such records shall be available to the Employer's Representative.

The Contractor shall monitor all springs and wells which may be influenced by the lowering of the ground and mountain water table due to the tunnel construction. The zero readings must be done prior to any excavation.

5.5 Final Tunnel Dewatering Arrangement

5.5.1 Ground Water

A minimum gradient of 0.5% of the drainage pipes shall be provided in each tunnel cross section.

If not otherwise specified by the detailed design drawings or the Employer's Representative, the following ground water drainage pipes with the given diameters shall be installed at the lines given in the detailed design drawings.

- Side wall drainage: <E> > 250 mm
- Sub-base drainage: O ≥ 150 mm
- Ground water collecting pipe: O ≥ 400 mm

Perforated pipes shall be made of slotted Polypropylene (PP) or polyvinyl chloride (PVC) or any other equivalent material in agreement with the Employer's Representative. The upper section of the pipe shall be longitudinal corrugated and slotted, with the bottom section closed. The width of slots shall not exceed 1.0 mm. The total area of the slots for water intake shall exceed 50 cm2 per metre length of pipe.

The bedding shall consist of dry lean concrete in compliance with Clause 10.2.

The pipe shall be embedded in no-fines concrete in compliance with Clause 10.3.

5.5.2 Carriageway Water

The carriageway water shall be collected and drained in a separate drainage system.

The collection shall be continuous by a slot channel or punctual with a minimum interval of 65 m. Slot channels shall be made of water impermeable concrete with plastic fibre reinforcement.

The slot channel diameter shall be minimum 250 mm. A minimum longitudinal gradient of 0.5% shall be provided.

6 OPEN EXCAVATION

6.1 General

In these specifications, the following works are covered:

- surface excavation in soil or rock (Cut) for the temporary and permanent tunnel
- portals, the tunnel portal structures, control building, muck dump areas, ditches, drains,
- surface fill (Fill) with soil and rock material for the platform of the tunnel portal structures and buildings, muck dump areas or roads,
- erosion protection of embankment slopes with gabions, mattresses, rip-rap, etc.
- sub surface drainage
- backfill of structures
- water proofing of structures before refill

The existing ground surface area below which open excavation is required shall be cleared of trees, brushes, shrubs, embedded logs, fallen timber and surface litter and shall be grubbed of vegetation, roots and stumps. Cleared and grubbed material shall be disposed of in the designated spoil disposal areas.

No unexcavated material is permitted inside the design lines of the excavation.

14 days prior to commencement of any surface excavation the Contractor shall submit all detailed drawings and/or descriptions of his proposed excavation methods, sequences and equipment to the Employer's Representative for approval.

28 days prior to dumping of any spoil, the Contractor shall submit all detailed drawings and/or descriptions of his proposed method for laying, compacting and protection against erosion of the muck dump material including information of dumping sequences and equipment. The muck dump areas shall be within the areas so designated by the Local Authorities or the Employer's Representative and in compliance with Clause 4.4.1.

At least 28 days prior to placing of any fill material, the Contractor shall submit detailed drawing and/or descriptions of the construction procedure, mixing, treatment and compaction procedures, topsoiling, slope stabilisation and surface erosion protection, and other completion works for approval, for construction of embankments. All data of working methods, equipment and provisions for the stability of the construction as well as temporary and permanent drainage of these areas shall be included. Details of volumes, material types, heights and grades shall be provided.

The Contractor shall forward information of the progress of surface excavation including information on excavated volumes, ground type, ground support installed, water inflows and difficulties encountered to the Employer's Representative at an interval in agreement with the Employer's Representative.

6.2 Standards

Open excavation works shall be in compliance with the following Standards and Guidelines unless otherwise defined in these Specifications.

- Specification for Road and Bridge Works (Fifth Revision) printed in April 2013 issued by MoSRT&H and published by IRC.
- IS 2720: Methods of test for soils — applicable parts
- IS 4532: Method of test for stabilized soils
- ASTM D3282: Classification of soils and soil-aggregates mixtures for highway construction purposes
- Eurocode 7: Geotechnical design

6.3 Cut

The excavation requirements and limits shown on the drawings have been established on the basis of the results of subsurface exploration by the Designer. The Employer's Representative will examine the conditions exposed at the actual excavated surfaces and, if the conditions are deemed unacceptable for the intended purpose, will relocate the excavation design lines locally outside of the excavation design lines shown on the Drawings.

If, in the opinion of the Employer's Representative, the necessity for excavation outside of the excavation design lines has been caused by negligence on the part of the Contractor or by ineffective executed excavating or blasting operations by the Contractor, the volume of additional excavation shall be backfilled with concrete or other material as required by the Employer's Representative. Such additional excavation and backfilling shall be done at no additional cost to the Employer.

Unclassified material and rock excavated outside of the excavation design lines for the Contractor's own purposes shall be replaced with concrete or other material as required by the Employer's Representative. Such additional excavation and backfilling shall be done at no additional cost to the Employer.

All initial support measures as given in the detailed design drawings or directed by the Employer's Representative e.g. sprayed concrete, pre-stressed anchors, wire mesh etc. shall be in compliance with Clause 9 of this Specification.

The Contractor shall draw his own conclusions from site inspection, from the logs of rock cores, test pits, test trenches, test tunnels, test chambers and surface exposures and from other site investigation data made available to the Contractor, as to the excavation method that will be best suited for the satisfactory removal of materials to be excavated and as to the behaviour of unclassified material and rock in situ, during and after excavation.

Excavation shall include all items of work, equipment, facilities and material with respect to the proper excavation as specified, including mucking, dumping and transport of excavated materials in stockpile or disposal areas approved by the Local Authorities.

The Contractor shall apply, as approved by the Employer's Representative, excavating, drilling and blasting techniques, which will produce a smooth final profile, i.e. smooth blasting resulting in minimum over break as well as - minimum detrimental effect beyond the design lines for excavation in compliance with Clause 7.3.3. Explosives and detonating systems shall be used by the Contractor to produce a smooth final excavated surface.

The Contractor shall adopt excavation procedures such that the stability of surfaces in open excavations is not impaired. The Contractor shall be responsible for the stability and safety of all excavations until final acceptance of the Works and shall install such instrumentation in the excavations, in addition to the instrumentation required by the Employer's Representative, that the Contractor considers necessary to measure deformation and to establish that unstable conditions do not develop. The Contractor shall execute all remedial work required in excavations to ensure that the excavated surfaces are maintained in a sound and stable condition. The Contractor shall submit to the Employer's Representative all readings taken the instruments he installs not more than 1 working day after taking the readings.

During excavation, and at any time during the Work, all material which is unsafe or appears to endanger persons, the Works or the property of others, shall be immediately scaled and removed from the excavations. The fact that such scaling and removal may enlarge the excavation beyond the excavation pay lines shall not relieve the Contractor from the necessity of doing such scaling and removal of such materials. If it is not possible to remove loose rock by normal barring and wedging, then rock support, shotcrete or chain link mesh or any combinations of each, shall be applied to secure and prevent the loose rock from falling or becoming unstable.

Notwithstanding the provisions specified herein, the Employer's Representative may require the Contractor to take such action as the Employer's Representative deems necessary to assure the

safety of the excavations and the Contractor shall immediately comply with such requirements. Nothing in these Specifications shall be construed to relieve the Contractor from the sole responsibility for safety.

If drilling and blasting operations is required, these shall be carried out in such way that they do not interfere with the work of others nor cause any damage to adjacent structures.

Snow and ice shall be removed when necessary to ensure the safe and effective performance of the Work.

If slides occur in excavated slopes, all materials affected shall be excavated and removed to the designated spoil disposal areas. The slopes shall then be further excavated to a safe, stable and neat condition or to the lines, slopes, dimensions and elevations required by the Employer's Representative. If, in the opinion of the Employer's Representative, any slide was caused by negligence on the part of the Contractor, all remedial work shall be done at no additional cost to the Employer.

The Contractor's excavation operations and schedule shall allow for interruption while the geological conditions exposed at the excavated rock surfaces are mapped and assessed by the Employer's Representative. Local areas shall be cleaned off where required by the Employer's Representative to expose a fresh undisturbed surface. Such interruption and assistance shall be at no additional cost to the Employer.

Construction traffic shall only be routed over suitably protected parts of the excavated surfaces.

6.4 Excavation Classification

Surface excavation shall be classified according to the excavation method as:

- Loose excavation
- Rock excavation

Loose excavation means all excavation which may be performed without continuous and systematic drilling and blasting. Clearing and grabbing of trees, shrubs and plants, stockpiling of topsoil layer, digging, ripping and occasional blasting may be required.

Rock excavation means excavation which requires continuous and systematic drilling and blasting for loosening, including measures for smooth blasting methods. The Contractor shall solely adapt blasting hole diameters, distance, charging and detonating delay of holes to form a smooth, sound surface along the excavation design lines. The distance between blasting holes shall not exceed 10 times of the blasting hole diameter.

6. Excavation Material Disposal

The disposal of excavation material shall be in accordance to Clause 4.4.1 of this Specification.

Excavation material suitable to be utilised in the Works shall be stockpiled separately from materials to be disposed. The use of excavation material in the Works shall be in agreement with the Employer's Representative.

Suitable materials shall, wherever possible, be transported directly from the required excavation to the various designated final locations.

Excavated materials, not suitable for or in excess of the construction requirements, shall be disposed of in spoil areas designated by the Local Authorities or the Employer's Representative. Unless otherwise provided for, spoil areas shall be built up in layers, with a maximum layer thickness of 0.6 m, and evenly compacted by the traffic of the construction equipment, aimed at minimizing future differential settlement. Final sloping and shaping of surfaces shall be as indicated on the Drawings. Other details of the work such as stabilisation and drainage measures are shown on the Drawings.

All activity by the Contractor at spoils areas shall be confined to the limits designated by the Local Authorities or the Employer's Representative. The limits shall be clearly marked and, where directed barricaded to prevent traffic in areas outside the limits.

6.6 Fill and Embankment

The Contractor shall construct all compacted earthfill or rockfill embankment as shown on the Drawings or as otherwise directed by the Employer's Representative.

This work shall include such work as selection of suitable material, transporting, spreading, adjusting moisture content, compacting to specified minimum dry density and completion in all respects, all in accordance with this Specification.

The embankment shall extend to the design lines as given in the drawings.

All permanent and long term temporary slopes shall generally be stabilised and erosion protected by planting of vegetation and greens similar to the typical local vegetation of the area. Additional measures such as bolts, anchors, shotcrete for cut slopes or gabions, rip-rap, geo-textile for embankment slopes must be applied as designed or ordered by the Employer's Representative.

The Contractor shall construct all sub-surface drainage measures in cuts or embankments as shown on the Drawings or as otherwise directed by the Employer's Representative. This work shall include such work as excavation, selection of suitable material, transporting, placing, and completion in all respects, all in accordance with this Specification.

The material beneath the road sub-base shall have CBR values. The testing procedure shall be in accordance to AASHTO T193 and fulfil the requirements shown in the detailed design drawings and Indian Standards.

Trees, shrubs, grass, humus/topsoil shall be removed from the existing ground surface and stockpiled for later reinstatement if required by the Employer's Representative prior to any placing of embankment.

The prepared surface shall be benched in vertical and horizontal cuts to provide a shear key with the embankment material.

The material of the embankment shall be placed and compacted layers with a thickness not exceeding 300 mm loose before compaction.

The moisture content of the material to be compacted shall be as wet or just wetter than optimum moisture content determined by laboratory testing.

All embankment material shall be compacted to a dry density not less than 95 per cent of the maximum laboratory dry density in accordance with IS 2720, Part 8.

6.7 Back Fill

Backfill shall be placed to the specified type of the lines, grades and dimensions in the locations shown on the detailed design drawings by the Contractor or directed by the Employer's Representative.

All material proposed by the Contractor to be used as backfill shall be approved by the Employer's Representative prior to any placing of backfill material. The material to be used as backfill shall be as far as possible obtained from required excavation for Underground Excavation Works.

Backfill material shall be homogeneous without layers, pockets and lenses and may not consist of any organic component. Each load of material shall be distributed well and operation of equipment shall be restricted in the area near permanent structures to avoid any kind of damage. The Employer's Representative may reject full loads of backfill material that contain unacceptable percentage of organic component.

Backfilling may not be done before reaching full load capacity of adjacent structures and only after approval of Employer's Representative. The placing of the backfill shall be done simultaneously and with similar method, procedure and material at the different sides of a structure to avoid differential earth pressure. The work may not be done at low temperatures and frozen backfill material is not permitted.

Back fill material shall consist of well graded granular material containing 35% or less by weight

passing a 0.075 mm sieve, as specified in ASTM D3282 and with a maximum particle size of 300mm.

Back fill material shall be placed and compacted layers with a thickness not exceeding 300 mm loose before compaction and shall be compacted to a dry density not less than 95 per cent of the maximum laboratory dry density in accordance with IS 2720, Part 8.

The moisture content of the material to be compacted shall be as wet or just wetter than optimum moisture content determined by laboratory testing.

Backfill material shall be tested every 300 m^3 or 600 m^2 or 1 test per shift, whichever is less, or as directed by the Employer's Representative. Proctor test procedures shall be done in random backfill and impervious backfill; whereas the relative density testing of IS: 2720 shall be done for free-draining backfill.

6.8 Gabions

The foundation for each gabion and mattress shall be prepared by the Contractor to the satisfaction of the Engineer. Irregularities in the foundation shall be excavated or tightly filled with gravel to produce a surface which has no protrusions or cavities in excess of 100 mm and the surface shall be covered with a geotextile fabric.

Gabions and mattresses shall consist of double twisted woven mesh gabions with coated, polymer sheathed wires or equivalent in agreement with the Employer's Representative.

The construction working procedures of gabions and mattresses shall be in compliance with the manufacturer's recommendations and instructions.

6.9 Rip-Rap Layers

Rip-rap layers shall be furnished and placed by the Contractor on permanent embankments as erosion protection layer as shown on the detailed design drawings of as directed by the Employer's Representative.

Prior to any placing of rip-rap layers the source of the material shall be approved by the Employer's Representative. Rip-rap material shall consist of hard, dense and durable rock. Material from Underground Excavation Works may be used.

The minimum rock size shall not be less than 500 mm and shall not be greater than that which can be encompassed in the specified layer thickness.

Rip-rap layers shall not be placed on earth, gravel or weathered rock foundation when not agreed with the Employer's Representative. When the underground is not suitable for bedding of rip-rap

layers, the rip-rap shall be placed on a 300 mm thick continuous layer of gravel, sand or rock fragments in agreement with the Employer's Representative.

6.10 Water Proofing Membrane

The water proofing membrane shall cover all backfilled structures from water and moister and is similar to the tunnel water proofing membrane as specified in 12.5.

7 UNDERGROUND EXCAVATION

7.1 General

The Contractor shall be responsible for the safety and security of excavations at all times during the execution of the Contract.

The geological/geotechnical information presented in the tender documents represents the state of knowledge of the geological/geotechnical conditions along the tunnel alignment based on available information at this stage.

Tunnel works to be executed are based on the New Austrian Tunnelling Method, hereafter referred to as NATM, with observance of all principles related to the application of this method.

Mechanised techniques for excavation shall be used wherever practicable to eliminate or reduce health and safety risks.

The excavation material shall be classified in compliance with Clause 6.4 of this Specification. Different and adequate excavation methods shall be considered for rock excavation and loose excavation by the Contractor.

A detailed description, defined by the Contractor, of all excavation methods including equipment, location of headings, benches and pilot tunnels, drilling and blasting, controlled perimeter blasting, ripping, mucking, loading, hauling, temporary support systems, scaling, ventilation, lighting, pumping, safety measures, schedules, excavation cycles, simultaneous working of faces and sequence of operations he plans to follow in each excavation area to complete the work shall be included in the offer or submitted to the Employer's Representative prior to commencement for review. Additionally, details concerning installation of pumping, ventilation and lighting systems shall be forwarded to the Employer's Representative for review. The Employer's Representative shall be provided with all submissions in sufficient time ahead of the construction works or at such dates as mutually agreed upon. No excavation shall be started in any excavation area until permission has been received in writing from the Employer's Representative.

The approval given by the Employer's Representative to the Contractor's methods and equipment does not relieve the Contractor of his full responsibility for proper and safe execution of tunnel excavations, or of liability for injuries to persons or fatal accidents, or any obligations under this Contract.

Manufacturer's certificates of compliance shall be submitted certifying that the materials and equipment proposed to be used meet Specification requirements.

During excavation, and at any time during the work, all ground material which is unsafe or appears to endanger persons, the Works or the property of others, shall be immediately scaled and removed from the excavations. The fact that such scaling and removal may enlarge the excavation beyond the line of excavation shall not relieve the Contractor from the necessity of doing such scaling and removal of such materials. If it is not possible to remove loose rock by normal barring and wedging, then rock support, shotcrete or steel mesh or any combinations of each, shall be applied to secure and prevent the loose rock from falling or becoming unstable.

Excavation shall be carried out in a uniform and controlled manner and over-cutting shall be kept to a minimum consistent with the need to maintain the necessary clearance for construction of the Works.

Drilling and blasting operations shall be carried out in such way that they do not interfere with the work of Others nor cause any damage to adjacent structures.

The Contractor's excavation operations and schedule shall allow for interruption while the geological conditions exposed at the excavated rock surfaces are mapped and assessed by the Employer's Representative. Local areas shall be cleaned off where required by the Employer's Representative to expose a fresh undisturbed surface. Such interruption and assistance shall be at no additional cost to the Employer.

The excavation invert shall not be damaged due to construction works. Hence the invert of the tunnel shall be protected against damage and deterioration which may be caused by construction traffic. Any other surfaces which deteriorate or are damaged shall be made good to a standard agreed with the Employer's Representative.

Excavation shall be carried out in sections limited to such lengths, depths and widths as may be safely executed having regard to all the circumstances and as appropriate to the ground conditions and the equipment and method of construction being used.

In water-bearing strata the Contractor shall use such methods and take such steps as are necessary to control flows and maintain the stability of the excavation.

Additional excavation, not shown on the drawings, but the Contractor considers being required for his own purpose such as cross passages, mucking pits, turning cavern or spaces for site installation may only be carried out in agreement with the Employer's Representative. Such excavations are done at no additional cost for the Employer and shall be backfilled to the excavation line.

7.2 Overbreak

The overbreak-line is defined with 30 cm for tunnel sections with drill and blast excavation and 20 cm for tunnel sections with excavation by excavator of road header.

Overbreak shall be secured with determined measures in agreement with the Employer's Representative and according to the local conditions. Loose rock mass shall be removed. Any voids formed during the excavation process by overbreak and temporary works shall be backfilled completely with grout, concrete, sprayed concrete or other approved durable material.

Accepted geological overbreak in tunnel excavation is defined as a local overbreak which occurs while the following four conditions are simultaneously fulfilled:

- overbreak extends beyond the "overbreak"-line;
- the overbreak occurs above the tunnel invert;
- the Employer's Representative is immediately notified and given the opportunity for inspection, while both the cause and the extent of the overbreak are clearly visible; and
- appropriate working methods were used, and adequate rock reinforcement and support was installed in due time, and properly applied by the Contractor.

The Contractor shall survey and plot cross sections at sufficient intervals to allow for a reasonably accurate estimate of the volume of overbreak which he claims to be due to geological conditions.

Voids created by overbreak extending beyond the "overbreak"-line in tunnel excavations shall, as directed, be backfilled up to the "overbreak"-line as required by the Employer's Representative.

In the event of excessive geological overbreak, support shall be installed immediately as required to stabilize the ground. The Employer's Representative shall be informed immediately of such conditions. Remedial works shall be in agreement with the Employer's Representative. The design of the remedial works shall be done by the Contractor and approved by the Employer's Representative. Remedial works shall be executed before further advance of the face unless otherwise directed by the Employer's Representative.

The void formed by the geological overbreak shall be measured in-situ. Individual voids of less than 1 m^3 shall be discarded for measurement purposes. The materials required to complete the repair shall be quantified and approved by the Employer's Representative and certified for payment.

Where forepoling is required no separate remuneration for the additional overbreak will be made, i.e. the additional overbreak shall be included in the excavation costs.

7.3 Tunnel Excavation

7.3.1 General

Tunnel excavation in any kind of ground shall be performed in accordance with modern blasting and excavating practice, using methods and techniques that will reduce overbreak to a minimum outside of the line of excavation (payline), and which will preserve, in the soundest possible condition, the structural integrity of the rock beyond the line of excavation.

Excavations shall not be advanced until the pattern ground support for the previous round has been installed and the profile of the previous round has been checked and all rock remaining inside the line of excavation has been removed. The Employer's Representative may stop the work for removal of undercuts at any time if undercutting is observed.

Tunnel excavation shall not be started until the exposed rock faces in its portal excavation have been stabilized with rock support and shotcrete and drainage measures have been installed as given in the drawings.

The Contractor shall maintain accurate records of all blasting and excavating operations and at the end of each shift he shall provide the Employer's Representative with two copies of the records, together with such additional data as the Employer's Representative may request. The forms shall bear the signatures of the Contractor's and the Employer's Representative certifying that records are accurate and complete and include but not limited to the following:

- length of tunnel excavated, and theoretical volume of solid material excavated
- quantity of any rock support installation
- occurred rock falls, zones of instability and logs of pilot holes
- water inflow at the head and rate of discharge at the tunnel portal
- Unusual occurrences and all delays with reasons for these.

Holes drilled in swelling ground shall be conducted without water.

7.3.2 Geotechnical Design

The procedure of ground characterisation during construction sequence is based on the Austrian "Guideline for the Geotechnical Design of Underground Structures with Conventional Excavation" by the Austrian Society for Geomechanics.

Rock mass classes are determined based on the rock at the excavation face of the tunnel before the commencement of the respective excavation sequence.

7.3.2.1 General

A continuous updating of the geotechnical model and an adjustment of excavation and support to the actual ground conditions during construction is required.

The rock mass characterisation shall be determined according to the following steps, which are summarized and presented in Figure 1.

- Step 1: Determination of the encountered Ground Type (GT) and prediction of ground characteristics
- Step 2: Assessment of system behaviour in excavation area
- Step 3: Determination of excavation and support measures and prediction of System Behaviour in supported section
- Step 4: Verification of system behaviour

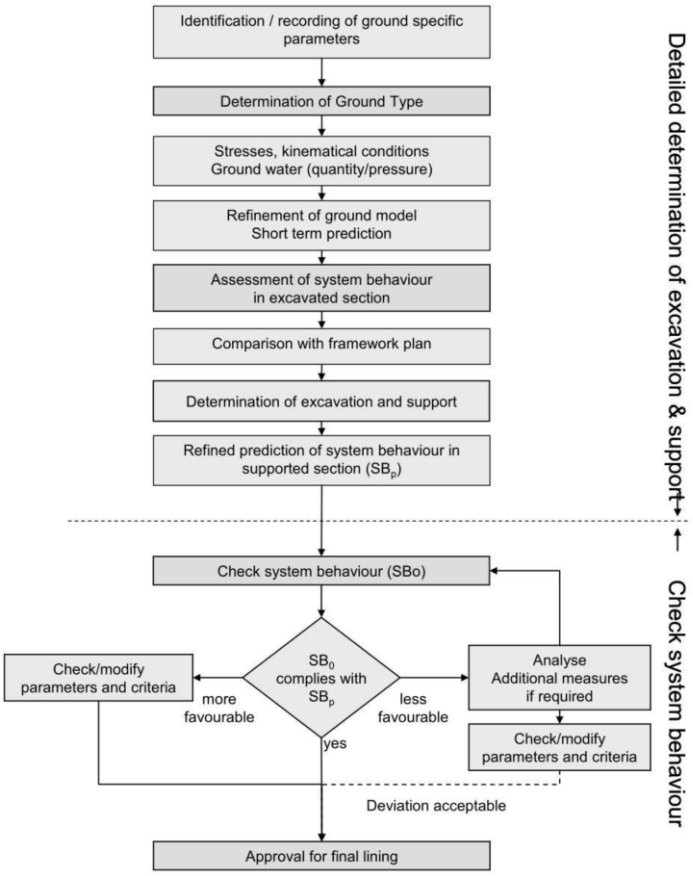


Figure 1: Basic procedure of determination of construction measures and check of system behaviour during construction (SB_p = predicted system behaviour, SB_0 = observed system behaviour) from Austrian "Guideline for the Geotechnical Design of Underground Structures with Conventional Excavation" by the Austrian Society for Geomechanics

Step 1: The geological conditions during construction shall be monitored as defined in Section 7.3.4 to collect and record the relevant parameters specified in the design. Based on the geological conditions the Ground Type (GT) shall be determined. Additional observations, like indications of overstressing, deformation and failure mechanisms as well as results from probing ahead and the evaluation of the geotechnical monitoring shall be used to update the ground model and predict the conditions ahead of the face.

Step 2: Based on the predicted ground conditions, the system behaviour in the section ahead shall be assessed under consideration of the influencing factors and compared to the framework plan. Particular attention must be paid on potential failure modes.

Step 3: To determine the appropriate excavation class and support category, the criteria laid out in the framework plan must be followed. Consequently, it must be checked if the actual ground conditions (Ground Type, system behaviour) comply with the prediction. The additional data obtained during construction form the basis for the determination of the applied excavation and support methods.

The system behaviour must be predicted for the next excavation section, considering ground conditions and the chosen construction measures. This process is to be done during the daily review meeting as per Clause 8.4. Records of this meeting shall be kept and signed of all attended parties in compliance with Clause 8.4.

Step 4: The system behaviour shall be monitored (visually and by measurements) in compliance with Clause 8 of this Specification and the criteria defined in the geotechnical safety management plan. When differences between the observed and predicted behaviour occur, the parameters and criteria used during excavation for the determination of the Ground Type and the excavation and support must be reviewed. When the displacements or support utilization are higher than predicted, a detailed investigation into the reasons for the different system behaviour must be conducted, and if required mitigation measures (like increase of support) ordered. In case the system behaviour is more favourable than expected, the reasons must be analysed as well and the used parameters modified, if appropriate. This allows for a continuous improvement and refinement of the method for assignment of excavation and support methods.

7.3.2.2 Determination of Actual Ground Type

Key parameters shall be defined in agreement with the Employer's Representative for the identification of each Ground Type, considering that those can be recorded during construction. If directed by the Employer's Representative, additional parameters shall be monitored, which

the Employer's Representative deems necessary for determination of the system behaviour.

Each of the key parameters shall be categorized. Whenever feasible, numerical values shall be used preferably than descriptive data, like spacing, joint opening, strength, etc. Due to practical reasons, some of the required parameters can only be described qualitatively.

Using predefined criteria the parameters are weighted and combined, allowing the appropriate Ground Types to be identified. A correlation matrix shall be used.

Data collection on site shall be concentrated on collecting relevant geological and geotechnical data and on observing and recording the ground structure. The collected data are recorded in prepared forms. With the criteria defined during the design the Ground Type is determined. In heterogeneous ground conditions, the ground shall be divided into several sections, and the appropriate key parameters shall be collected for each section separately.

The geological and geotechnical data collected and evaluated on site are the basis for the extrapolation and prediction of the ground conditions. The geological work is not limited to recording the face conditions, but also shall involve prediction of the conditions in the volume of rock that controls the ground response.

7.3.2.3 Assessment of System Behaviour in the Excavation Area

In addition to the parameters required to determine the Ground Type(s), influencing factors, like ground water conditions, ground structure, estimated stress situation and kinematical conditions as well as observations of the system behaviour in the excavation area shall be recorded by the Contractor.

The reaction of the ground to the excavation and support are observed by the Contractor using an appropriate monitoring system in compliance with Clause 8 of this Specification.

The predicted ground structure in combination with the on-site observations and monitoring results shall be used for prediction of the ground behaviour for the sections to be excavated subsequently.

7.3.2.4 Determination of Excavation and Support and Prediction of System Behaviour

For the final determination of the excavation and support method, it must be checked if the ground conditions and system behaviour observed on site conform to the design assumptions. When the observed conditions conform to the predicted ones, stipulations in the framework plan must be followed when determining the construction measures.

In case of a deviation exceeding the specified tolerance in the framework plan, the designer has to be informed to allow for an adaptation of the prediction, based on new findings. The designer

shall agree with the required additional measures in due time and update the framework plan accordingly.

The final decisions on the applied construction measures are based on the design and additional information gained during construction and shall be done during the daily review meeting as per Clause 8.4 of this Specification. The goal is a safe and economical construction. The decisions must be coherently explained and documented, for example in an appendix to the required excavation and support sheet (RESS) in compliance with Clause 8.6 of this Specification.

The prediction of the system behaviour shall contain the following but is not limited to:

- Expected magnitude and orientation of the tunnel displacements, and the surface (if applicable), including the displacements spatial and time dependent development
- Expected utilization factor of the support

7.3.3.5 Check of System Behaviour

The actual system behaviour in the supported area and in the final stage shall be compared to the predicted system behaviour, and checked, whether the behaviour is within the specified limits of the warning criteria. Additional measurements or evaluations may be required on direction by the Employer's Representative to determine for example the utilization of the lining.

Deviations between the expected and the observed behaviours have to be analysed and documented by the Contractor and discussed with the Employer's Representative in the daily review meeting as per Clause 8.4.

The reasons for the deviation in behaviour have to be analysed. In case the assumptions regarding the influencing factors are inappropriate, the parameters have to be modified. The modifications have to be supported by appropriate data and analyses and documented in an updated framework plan.

In case the ground quality is better than predicted, the geotechnical model has to be revised. In case of a significant deviation, the criteria for the determination of excavation and support have to be modified.

In case the ground quality is worse than predicted and warning levels exceeded, contingency measures according to the safety management plan have to be implemented, and excavation and support shall be adjusted accordingly. This can be done for example by additional bolting, installation of a temporary invert, etc. In some cases, the installation of a stronger support in the following rounds may be sufficient to achieve the target. All additional support measures are defined in the daily review meeting and presented in the RESS in agreement with the Employer's

Representative.

In case of significant deviations, the geotechnical model has to be revised and the criteria for the determination of excavation and support have to be modified. This generally requires that the framework plan is updated.

7.3.3.6 Updating of Design

Due to limited information available during design, a number of assumptions and simplified models have to be used to arrive at a design, which is the basis for the framework plan and the tender documents.

A continuously update of the geotechnical design with the increasing level of information shall be done. This applies to the determination of the Ground Types, the assignment and calibration of key parameters and criteria as well as for the determination of the system behaviour. The refinement of parameter categories, the introduction of additional criteria, etc. help in improving the geotechnical model.

The tunnel engineer on site has to report to the designer in case of significant deviations of the actual geological/geotechnical situation or system behaviour from the predicted ones, as outlined in the framework plan. A detailed report, containing all relevant information and coordinated with the site geologist and the Employer's Representative and the Contractor, has to be prepared and submitted. After consideration of the facts the designer has to update the framework plan. This must be documented in a supplement to the geotechnical report.

7.3.3 Blasting

7.3.3.1 General

Not less than 40 days prior to commencement of rock excavation in each area, the Contractor shall submit, for review by the Employer's Representative, details of the drilling and blasting methods which he intends to use in that area. If, at any time in a specific area, a plan which has been previously adopted does not produce conditions at the excavated rock face that conform to the requirements of these Specifications, the Contractor shall submit a revised plan to the Employer's Representative before continuing excavation in adjacent areas.

The Contractor shall develop controlled blasting techniques, which will satisfy the excavation requirements specified herein. In each different type of rock conditions, the Contractor's initial blasts shall be performed as trials, and the burden, drill hole pattern and depth, explosive type and quantity, blasting sequence and drill delay pattern shall be modified to achieve the requirements specified herein.

Blasting means must follow the licensing requirements and orders as well as the manufacturer's

instructions.

Blasting operations shall be carried out only under the direction of an experienced operator. The Contractor shall appoint one competent person to be responsible for the security of explosives.

Blasting shall be carried out carefully so as to avoid loosening or shattering rock beyond the required line of excavation, and loose or shattered rock (where it does not contribute to stability of the excavation) shall be removed by scaling down or other means before personnel will be permitted to restart operations after blasting.

Notices of blasting operations shall be posted on site. Before each firing, the Contractor shall give audible warning, clear the area and shall take positive measures to prevent personnel from entering the danger area.

The Contractor shall monitor the results of blasting closely and, where it is proper to do so, shall propose changes to his blasting operation for the agreement of the Employer's Representative.

Under no circumstances shall any holes be charged until completion of all drilling operations at the face.

After each blasting operation the tunnel drive shall be sufficiently ventilated to remove any nitrous gases and the atmospheric conditions shall be constantly checked prior to personnel accessing the excavated face in compliance with Clause 7.7.

No person shall be allowed to approach the face and no face operation shall commence until the Contractor's authorised person in charge of the operation has given permission after blasting round.

As soon as practicable after blasting and without undue delay, the Contractor shall erect such support as may be necessary to safeguard the excavation and personnel.

The shot-firer must keep a record of the number of shots fired, their time of firing, type and weights of explosives used, and the type and number of detonators used, together with a record of the post-blast situation for each and every location. A copy of the record shall be available to the Employer's Representative at the end of every shift on which shots are fired.

7.3.3.2 Controlled Perimeter Blasting

Controlled perimeter blasting techniques shall be used to produce rock faces conforming to the required excavation lines, slopes, elevations and dimensions shown on the drawings with a minimum of disturbance to the rock at, or outside of, the excavation pay lines.

Drill holes for controlled perimeter blasting shall not be less than 42 millimetres in diameter

and shall be a single row of closely spaced holes drilled to a maximum depth of one round length along the excavation paylines and a spacing of 0.4 to 0.6 m depending on the ground condition. The spacing of the perimeter holes may be modified based on results obtained and in agreement with the Employer's Representative.

All blast holes within a distance of 5 meters normal to the excavation pay lines shall be less than 75 millimetres in diameter and shall be loaded in a manner and detonated in a sequence to ensure that a minimum of damage will result to the face when the main charge is fired.

7.3.3.3 Explosives

The Contractor shall use explosives only in circumstances where it is safe to do so having due regard to the safety of persons, third-party property and the safety of the Works. Explosives shall not be used without the agreement of the Employer's Representative.

The Contractor shall obtain all necessary licences and consents and shall provide secure storage facilities for all explosives and equipment in accordance with Indian or International Standards Code of practice for the safe use of explosives in the construction industry and the requirements of the local Authorities and the Employer's Representative.

Explosives shall be handled and used only by the Contractor's duly authorised personnel. The names and qualifications of such personnel shall be submitted to the Employer's Representative in writing in advance of any possible use of explosives.

At an early stage, in advance of the proposed use of explosives, the Contractor shall notify the Employer's Representative, third parties, statutory authorities and services which have an interest in or are likely to be affected by blasting operations, of the general nature of the operation. The Contractor shall subsequently give a minimum of 14 days' notice to the Employer's Representative and others described above of the proposed use of explosives. With this notification the Contractor shall submit to the Employer's Representative a detailed method statement on all aspects of the proposed use of explosives, including the treatment of misfires.

The Contractor shall comply with the following documents in respect of the use of explosives:

- Indian Explosives Act 1884
- Indian Explosive Rules 1983
- The Manufacture and Storage of Explosives Regulations 2005
- BS 5607:1998 Code of practice for the safe use of explosives in the construction industry
- Control of Explosives Regulations 1991
- Carriage of Explosives by Road. Road Traffic (Carriage of Explosives) Regulations 1996

- PD CLC/TR 50426:2004 Assessment of inadvertent initiation of bridge wire electro-explosive devices by radio- frequency radiation. Guide Quarries (Explosives) Regulations 1988, as far as it is relevant to tunnel works.

7.3.3.4 Blasting Vibrations

For structures in the proximity of blasting, the peak particle velocity shall be measured at the locations immediately adjacent to the structure nearest to the face being blasted or any other location where it is necessary to limit vibration.

Vibration monitoring proposals shall be submitted to the Employer's Representative for his agreement.

The measurement of peak particle velocity shall be obtained from instruments capable of measuring along three orthogonal axes, one of them shall be aligned parallel to the centre line of the excavation and another shall be vertical. The Contractor has to provide supports for the measuring instrument if so required by the manufacturer's instructions.

The measurements of the particle velocities shall be the responsibility of the Contractor. Copies of the readings in an agreed form shall be supplied to the Employer's Representative.

Prior to the commencement of blasting in any location, the Contractor shall demonstrate by the use of test firings, or by other means, that neither the peak particle velocities given in the particular Standards and Specifications will be exceeded.

The maximum allowable blasting vibrations shall be defined by the Contractor for every influenced structure with reference to the applicable Standards and Specifications for the relevant structure. The allowable blasting vibrations shall be approved by the Employer's Representative prior to any blasting operations.

7.3.4 Geological Mapping

Geological mapping shall be performed by the Contractor's qualified geologist to provide a documentation of rock and rock mass condition encountered during excavation. Additionally all exposed rock surfaces of the open and underground excavations shall be washed down by the Contractor for inspection and geological mapping by the Employer's Representative if he deems to do so. Exposed rock surfaces at the required excavation, pay lines shall be mapped after preparation but before shotcrete application. Tunnel and other underground faces shall be mapped just before the start of drilling. The Contractor shall allow in his construction procedure and schedule for the geological mapping of each tunnel face not less than 30 minutes.

The geological mapping shall include but not limited to the following information:

- excavation face
- tunnel meter
- geological unit
- intact rock:
  - rock type and lithology description
  - weathering and alteration degree
  - uniaxial and unconfined compressive strength (from point load tests)
- rock mass:
  - jointing degree
  - geometry, orientation (strike and sip) and properties of discontinuities
  - face condition (homogeneous or heterogeneous)
  - water inflow
  - over breaks (separated in geological and non-geological)
  - ground response
  - suspected pervious zone
- the GSI value and the corresponding excavation class
- groundwater appearance

The Contractor shall provide lights, ladders, platforms and free access and shall assist the Employer's Representative to carry out inspection and geological mapping. Tunnel Face shall properly be cleaned with the help of water/air jet.

In case of sudden and unexpected changes of the geological conditions the Employer's Representative shall be informed immediately by the Contractor.

7.3.5 Exploratory Drillings

Long exploratory drillings with full core recovery shall be carried out when deemed necessary and required by the Employer's Representative. Based on the geological mapping and the exploratory drillings the Employer's Representative may require rock mechanic laboratory tests.

7.4 Shaft Excavation

7.4.1 General

Prior to excavation, the shaft area shall be thoroughly checked for existing pipes, cables or structures and the appropriate measures taken in agreement with the Employer's Representative.

7.4.2 Safety

At all times shafts shall be provided with safe primary and secondary means of access and egress.

Should heavy plant and heavy loads have to be located in close proximity to any shaft, the Contractor shall take into account the effects of these loads as well as any ground loads when designing the shaft.

The Contractor shall guard against distortion of shaft lining during construction and the possibility of shaft settlement or uplift at an intermediate stage of construction.

7.4.3 Temporary Shafts

Full details of temporary shafts required by the Contractor's working methods shall be submitted to the Employer's Representative for his agreement. Such shafts shall be adequately sized for all operations required for the execution of the Works.

Backfill for temporary working shafts shall comprise material agreed by the Employer's Representative.

Where the Contractor wishes to recover temporary shaft linings the structure shall be removed in safe stages as backfilling proceeds, taking care to maintain the safety and structural integrity of the remaining lining. No part of Temporary Works shall be left in the ground within 2 m of the designed final surface level.

7.4.4 Construction

Shaft sinking shall be carried out by a method suitable for all the particular circumstances of the site including ground parameters, groundwater, depth and final purpose.

Where work is done by underpinning, only that ground which may be safely excavated for the installation of one ring or one unit of support shall be carried out. Until that depth is properly secured by permanent or temporary shaft lining, no further excavation shall take place. In the case of pre-formed rings, securing shall include grouting.

Where work is done by a caisson operation, a cutting edge shall be fitted to the leading ring. The Contractor's details for bolting caisson rings shall avoid working at height where practicable.

The cutting edge shall be maintained at an even level all round during shaft sinking. Jacking arrangements or kentledge shall be adequate for the work. The Contractor's arrangements shall

ensure the stability of any kentledge. A lubrication space shall be maintained completely filled with the lubricating material around the full shaft periphery during sinking. On completion of sinking the lubricating material shall be displaced with grout.

Concrete walls installed by slurry trench or secant piling techniques shall comply with best practice. The Contractor's proposals shall be submitted to the Employer's Representative for his agreement.

Where low-pressure compressed air is used to assist shaft construction, air decks and locks shall be designed by the Contractor to give adequate margins of safety against the air pressures to be used in the shaft. The Contractor's proposals shall be submitted to the Employer's Representative for his agreement.

Excavation in rock shall generally be carried out by methods outlined in Section 7. Where explosives are used, full-width shaft covers and blasting mats shall be installed during blasting. Blasting shall be carried out in compliance with Clause 7.3.3.

Full details of Temporary Works required by the Contractor's method of working for the construction of tunnel or pipe jack eyes in the shaft lining shall be submitted to the Employer's Representative for his agreement.

Shaft bases shall be concreted as shown on the drawings. In the case of Temporary Works shafts the Contractor shall submit his proposals for the shaft base structure taking account of ground and groundwater forces and sealing the shaft against water entry. Water pressure shall not be allowed to build up under shaft bases until the shaft has sufficient resistance to prevent flotation. The construction sequence shown on the drawings shall be followed unless agreed with the Employer's Representative.

Shafts shall be sunk to a maximum divergence of 1:300 from the design centre line at any depth.

7.5 Control Survey

The Contractor shall be entirely responsible for the accuracy of the control survey and the plotting and periodic checking thereafter. Location and positioning of all survey control stations, reference pillars, benchmarks etc. must be presented in coordinates and in a map (scale 1:1000) and approved by the Employer's Representative before the start of any works.

The Contractor shall install all necessary above ground survey stations and reference points well in advance of the commencement of excavation works so as to allow the Employer's Representative sufficient time to check the initial control survey and subsequent setting out for the alignment and levels of the respective tunnels.

Survey stations, centre lines, benchmarks and grade lines shall be clearly marked in paint on the

tunnel walls, chainages at 10 metre intervals or as otherwise agreed by the Employer's Representative. The Contractor shall appoint and employ the necessary qualified and experienced staff to carry out the required survey and setting out. The Contractor shall provide all necessary instruments, equipment, record books, level books measuring devices etc. required for survey and setting out. The Employer's Representative shall have use of any of the survey equipment required for the checking of survey work and setting out throughout the period of the Contract. Chainmen and transport shall be provided by the Contractor for checking purposes at the request of the Employer's Representative.

All additional work found to be necessary because of negligence in/or incorrect setting out, shall be carried out immediately by the Contractor as directed by the Employer's Representative at no additional costs.

7.6 Excavation Cross Section Check

7.6.1 General

Tunnels and shafts shall be constructed to the centre lines as defined herein and subsequently agreed on site with the Employer's Representative. Average deviation of the tunnel centreline from the design centreline, along a 100 m length of any tunnel section, shall not exceed 30 mm. If deviations in tunnels excavated exceed the specified tolerance, the Contractor shall be required to adapt his working methods so that the specified tolerances are achieved.

Immediately after excavation and before support installation the cross section of the actual round has to be checked to avoid unexcavated ground reaching into the excavation area as per excavation and support category. The check must be done with proper instrumentation, either with free positioned theodolite or with temporarily installed monitoring device for profile check.

When all ground material inside the excavation area is removed the support installation shall start earliest.

In case of partial excavation, the similar procedure shall be executed for each partial excavation area.

For checking the primary lining cross sections refer to 9.12.

7.6.2 Definitions

The theoretical excavation line means the line of excavation within no unexcavated ground material shall remain at any time. If due to additional displacements of the ground unexcavated material extends into the line of excavation, the Employer's Representative may order to excavate this material at no additional costs.

The practical excavation line shall compensate for radial displacements and construction tolerances according to the actual ground conditions and Support Categories and shall consider allowances for deformation and practical constructability. The values defined in the Bill of Quantities and on related drawings are paying item values. These documents are developed based on the theoretical line of excavation. The displacements must be predicted during detailed design and construction works. Practical excavation line may be adjusted by Contractor to suit actual deformations and excavation techniques used as experience is gained during excavation. Adjustments shall be approved by the Employer's Representative.

All additional quantities due to tolerances and displacements must be included in the item prices which are based on theoretical line of excavation.

In the following the basic geometrical conditions for the definition of line of excavation are given.

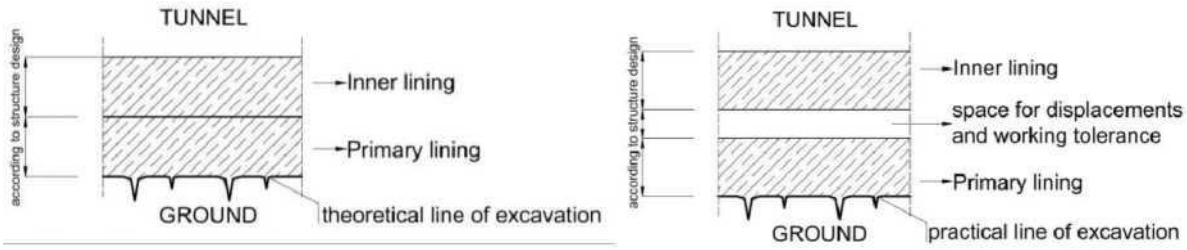


Figure 2 Schematic sketch of the geometrical condition for the definition of the line of excavation

7.7 Temporary Ventilation System

7.7.1 General

Pits, shaft tunnels and headings shall always be kept ventilated to maintain an atmosphere fit for respiration and free from oxygen deficiency, potentially explosive or noxious gases and dust, whether present naturally or otherwise. Ventilation shall also be used to maintain a safe working temperature.

Underground works shall be ventilated in accordance with all applicable regulations. Details of the proposed ventilation system shall be submitted to the Employer's Representative, for review, not less than 40 days prior to the start of commencement.

Where more than one pollutant is present any adverse interaction between them shall be identified and mitigated.

All diesel engines used in the underground works shall be provided with means, which shall be maintained in efficient order, of cooling exhaust gases and reducing the concentration of toxic

gases to acceptable levels, filtering particulates and preventing emission of flames or sparks.

In underground workings and in confined spaces the air breathed by persons shall contain not less than 19% of oxygen by volume, and shall not contain concentration of gases, vapours or dust greater than is safe for the health or workmen, having regard to the effects of time, temperature, humidity and the combined effects contaminants.

Smoking is forbidden in tunnels, headings, pits or shafts and all confined spaces.

In rock excavation all drill holes shall be wet drilled unless otherwise specified in this Specification in compliance with special ground condition.

7.7.2 Ventilation

The Contractor shall agree ventilation proposals with the Employer's Representative. Agreement shall not relieve the Contractor of his obligations under the Contract.

Proposals shall include but not be limited to the types of fan employed, sitting arrangements where appropriate, the power supply and the fan performance data, together with duct characteristics.

In forcing systems, fans shall normally be placed on the surface. The inlet to any surface forcing fan shall have unobstructed access to fresh air. It shall not be in the vicinity of a storage site for oil, chemical or diesel drums. The fan shall also be sited so that it cannot draw in internal combustion engine fumes or gas from charging batteries.

Blasting fumes shall be discharged from the underground works into a filter system or diverted adequately to ensure that concentrations of noxious or other harmful gases or dust are kept to the minimum limit as stated in the applicable laws/ Standards or the limits specified in the contract of lower.

If booster fans are to be employed by in-line staging, they shall be of an approved flameproof (FLP) construction and a monitoring system shall be installed so that the status and condition of such fans can be monitored at all times.

Provision shall be made for the fan to be run continuously whether persons are within the underground works or not. After tunnel break-through the ventilating system shall be kept in operation in order to maintain the fresh air-volume requirements stated hereinafter.

If a ventilation system ceases to function for any reason and for a period exceeding 30 minutes, all work in areas being ventilated by that ventilation system shall immediately cease and all workers shall immediately leave the areas.

Where a fan has been stopped and restarted, the condition of the air shall be tested before

personnel enter the tunnel. If only forcing surface-mounted fans are employed, the ventilation system should be restarted and run continuously ensuring that any plugs of oxygen-deficient, flammable or noxious mixtures of gas are flushed out. Care should be taken that workmen do not encounter any plugs of these gases on re-entry to the tunnel. The Contractor should consider that air residence time in long drivages can be several hours and that layered gases of different densities are difficult to disperse, especially where the gradient of the tunnel changes.

All equipment and ventilation duct shall always be maintained in sound working order. Any damage to ventilation duct shall be repaired within 12 hours of the damage.

The outlet of the duct shall be kept as close to the face as is practicable, designed to avoid turbulence and creation of dust and not more than 10 m away.

Where dust is being produced by the tunnelling system, exhaust ventilation shall be used to extract such dust from the working area.

Tunnelling shall not continue more than 10 m from the shaft or pit unless positive ventilation has been established.

The fresh air supply for underground works shall not be less than two cubic meters per minute at the face for each man underground and four cubic meters per minute per kW power for all diesel units operating underground. These fresh air volumes shall be cumulative, and the Contractor shall allow, in his design calculations, for the maximum number of persons and diesel-powered equipment deployed in the Works at any one time. Any estimated losses, e.g. due to the leaks in the ducts, shall be considered. The fresh air supply shall also be adequate to produce a linear velocity of 0.3 meters per second throughout the underground works.

Testing devices shall be provided for measuring carbon monoxide, methane, oxides of nitrogen and aldehydes in underground works during the operation of internal combustion engines. Readings of carbon monoxide content shall be taken by the Contractor at least once during each shift. Readings of oxides of nitrogen content and of aldehydes content shall be taken frequently to ensure safety of the workers. A record of all taken readings shall be kept by the Contractor and submitted to the Employer's Representative daily.

Ventilation ducts shall be firmly fixed to the vaults in such position that a minimum clearance of 20 cm remains between the duct and the extremities of vehicular traffic employed in the Underground Works.

7.7.3 Monitoring

Atmospheric monitoring equipment shall be positioned at each working face and also within 20 m of the tunnel entrance when the tunnel has advanced 250 m or more. Monitors shall also be

provided every 500 m along the tunnel. Monitoring equipment shall be capable of continuously monitoring the levels of potentially explosive gases, toxic gases and radioactive gases as appropriate and the oxygen content. The equipment shall give both visual and audible warning of the presence of potentially explosive, radioactive or toxic gases and where the oxygen content falls below safe working levels defined in Table 2. An immediate and effective means of communicating warnings to the surface shall be installed. The atmospheric monitoring system shall be a fixed system supplemented by portable monitoring equipment as necessary, except in small tunnels where the use of portable equipment only shall be permitted at the discretion of the Employer's Representative.

Table 6: Admissible maximum concentrations of pollution gasses in underground works

Pollution gas	Max. concentration
H2S	10 ppm
SO2	2 ppm
CO	50 ppm
NO2	5 ppm
CO2	5000 ppm
CH4	1000 ppm
Silica dust	8 mg/m^3

Each working shaft and the full length of all tunnels shall be monitored continuously for the presence of explosive or noxious gases or lack of oxygen. Records shall be kept of monitoring results. If concentrations of noxious gases or other inflammable gases exceed the permissible limits stated in Table 2, BS 6164 or HSE guidance document EH40, or oxygen content below the level set out in BS 6164, all operations shall be interrupted immediately and personnel shall be removed to a safe area. All sources of ignition shall be extinguished or removed. All equipment with the exception of ventilation equipment shall be shut down.

When any explosive gas concentration of 1.25% is present, all persons other than those essential for safety shall be withdrawn from all parts of the tunnel. The use of explosives and locomotives shall be prohibited and all electrical equipment not intrinsically safe shall be disconnected. All persons shall be withdrawn when the explosive gas concentration exceeds 2.0%.

The required measures will be mutually determined and agreed to by the Employer's Representative and the Contractor. If required by the Employer's Representative, the Contractor shall consult the services of an independent consultant experienced in gaseous tunnelling. Re-entry and resuming of the Work shall be prohibited until the Employer's Representative has authorised re-entry.

If the ventilation system is for any reason not in operation for a period greater than 2 hours, a start-up procedure shall be invoked. This requires that the shaft and tunnel shall not be re-

entered until one complete air change in the tunnel has taken place and the tunnel atmosphere is shown, by monitoring, to be safe.

Persons re-entering after shutdown must carry instruments to detect the presence of dangerous gases and the sufficiency of oxygen, and these must be used continuously during re-entry.

7.7.4 Checking & Inspection

During each shift, the following checks shall be made:

- The fan or fans shall be checked for heat, unusual noise and vibration. The results shall be reported, and remedial action shall be taken if required.
- The ventilation ducting shall be checked for damage and the joints checked for integrity. The results shall be reported, and remedial action shall be taken if required.
- The atmospheric monitoring system shall be checked at both local and remote stations and the results shall be recorded.

The air flow quantities shall be checked at both the face and 20 m from the shaft bottom on a weekly basis. These figures shall be recorded and compared with the calculated flows. Any shortfall shall be made good.

The ventilation records shall be maintained and be made available for inspection by the Employer's Representative.

7.7.5 Control of Dust Silica and Noxious Gases

To reduce the amount of dust, only wet drilling will be allowed and during mucking, muck piles shall be kept constantly damp by sprinkling with water. The use of high-pressure water jets for this purpose is not permitted.

Air Samples for this purpose shall be taken within 10 days of commencing underground excavation, at 30 days intervals thereafter and within 20 days following major changes in tunnel excavation operation or whenever required by the Employer's Representative. Samples shall be taken from actual working areas. The sampling and testing shall be performed by a qualified person or laboratory to be proposed by the Contractor and approved by the Employer's Representative. A copy of the test results shall be submitted to the Employer's Representative within 2 weeks of the sampling date.

In general, the concentration of fine dust (diameter less than 0.005 mm) may not exceed the value of 8.0 mg/cum of air and in relation to the silicon dioxide SiO2 content in the rock this value is lowered in compliance with Table.

Table 7: Maximum admissible fine dust concentration with respect of SiO_2 content in the rock

per cent per weight	mg/m³ air
1-15%	8.0
15-20%	6.0
20-30%	4.0
30-60%	2.0
60-80%	1.5
80-100%	1.3

The Contractor shall take necessary measures and install appropriate equipment in agreement with the Employer's Representative if the concentration of fine dust exceeds the limits stated in Table 3.

Use of internal combustion engines, other than approved mobile diesel-powered equipment will not be permitted in underground construction Sites.

7.8 Lighting

Floodlighting on the site surface shall be adequate for the safe operation of the site. It shall be shrouded where necessary to ensure the light is directed to areas within the site, and to avoid nuisance.

Lighting in the tunnel shall extend the full length and not be less than that required for safe working and access. Lamps shall be located with an interval of 25 m.

An alternative source of power and emergency lighting system shall be provided to allow emergency securing operations and evacuation safely in the event of a primary power failure as specified in Clause 3.5.1. An adequate number of hand lamps shall be located at key points underground.

The Contractor shall also provide suitable movable lamps to illuminate any area in Underground Works including areas for instrumentation and where the Engineer may wish to carry out inspection and rock mechanics tests or instrumentation.

Lighting illumination by flame is strictly not permitted in the underground Works.

8 GEOTECHNICAL INSTRUMENTATION MONITORING

8.1 General

The Contractor shall submit to the Employer's Representative for agreement a detailed method statement for instrumentation and monitoring, including instrumentation layout, trigger, design and allowable values and the procedures for evaluating the monitored data.

The Contractor shall appoint within his site team an experienced Monitoring Employer's Representative who shall lead the Contractor's monitoring team. The Monitoring Employer's Representative shall present the results of the previous day's monitoring in the daily monitoring meeting as per 8.4 with the Employer's Representative where they shall be presented to the Employer's Representative by the Monitoring Employer's Representative.

The frequency of such review meeting may be increased if requested by the Employer's Representative. In any case it shall be adapted to the frequency marked by the monitoring program from a holistic point of views, so it may be decreased also under the approval of Employer's Representative.

The Contractor's Site Manager shall attend monitoring review meetings if requested by the Employer's Representative.

The accuracy and precision of the required measurement will depend on the purpose of the monitoring.

Assessments shall be carried out to establish the zone of influence due to tunnelling works, i.e. ground perturbation ring around the cavity, and to determine if there is a likely damage that will occur to existing above-ground and subsurface infrastructure.

The outcome of the assessments shall determine the type and amount of monitoring that will be required.

Instrumentation and monitoring for the tunnel and appurtenant structures shall be carried out with the following instruments but not limited to:

- theodolites and reflectors/optical targets
- tape extensometer and convergence pins
- borehole extensometers (multiple-point, in rock mass ring periphery)
- strain gauges (in final lining)
- load cells (anchors)
- radial pressure cells (interface ground/primary lining, optional on representativeness)

- sliding micrometre (optional in face extrusion control)

All instrumentation operating on electrical, mechanical or hydraulic systems shall be accompanied by individual test certificates, and shall be tested in the presence of the Employer's Representative prior to installation, unless specifically stated otherwise.

The installation of instruments may interfere with the overall construction progress. The Contractor shall make provision for such interferences in his construction schedule. He will not be entitled to any compensation or extension of the Time for Completion by reason of any such delays, including repair and replacement of damaged instruments if the damage is due to construction procedure of Contractor.

No material shall be installed prior to the Employer's Representative's approval. However, approval by the Employer's Representative of the Contractor's proposals and drawings or data shall not relieve the Contractor from his sole responsibility to meet all the requirements.

8.2 Ground Movement Monitoring

In this particular Project, initially it is not expected an influence from tunnel excavation to the ground surface movements and settlements, even in portal areas, due to presence of competent rock formations in the excavation slopes which will be stabilised, if required. The natural slope gradients are high and tunnels will gain quickly ground rock cover, and values of overburden will be huge.

Consequently, in this Contract it might not be mandatory for the Contractor to monitor the effects of tunnel construction at the surface, including all ground movements and the effects on all structures..

Nevertheless, Employer's Representative may decide the installation of control points to monitor movements in civil constructions, buildings and other structures located in stretches above tunnel alignment near the portals, if there are chances of portal instability or poorer ground conditions than forecasted.

In this case, monitoring shall be referenced to stable survey stations located outside the zone of influence of the Works. Such benchmarks and coordinated stations shall be established and agreed with the Employer's Representative before any ground is excavated and before any ground support or treatment. They shall be checked at intervals during the duration of the Works.

The Contractor shall observe, record and analyse the readings to establish trends in movement and reconcile movements measured with those predicted. He shall provide a copy of all recorded results to the Employer's Representative. He shall make available results to the

Employer's Representative in accordance with an agreed programme. However, movements greater than predicted shall be reported to the Employer's Representative immediately.

Prior to construction Works commencing, in case of monitoring requirement, a defect survey shall be carried out of all structures within the zone of influence and a schedule of defects shall be prepared.

This schedule shall be agreed by the Contractor and the owner of the structure, or his representative, prior to the start of construction. Existing pipelines, tunnels and services shall be regarded as structures

During the execution of the Works, defects which have been scheduled shall be inspected and monitored as necessary. Defects which arise during the course of the Works shall be recorded. The Contractor shall keep records of such inspections and a copy shall be available to the Employer's Representative.

Monitoring of settlement, scheduled defects and defects arising during the course of the Works shall continue at agreed intervals for a period of at least 6 months after completion.

8.3 Tunnel Excavation Monitoring

The Contractor shall survey, monitor and record tunnel construction as it proceeds to form a registry of the Work, available to the Employer's Representative at any time. Monitoring shall generally be per unit of advance and include line, level, cross-sectional accuracy, shift advance and total advance. Spatial relationship between excavation volumes/paces and cavity deformation is crucial to understand ground/support behaviour.

Monitoring of construction work's units parameters like lining concrete temperature, pressure & volume of contact/treatment grouting, and all other concerned, as well as environment parameters like water ingress flow quantities, noxious gases concentration, are not included in this kind of monitoring, unless they will interfere in the instrumentation monitoring results. This kind of Works monitoring shall be considered in another separate chapter.

All information recorded by the Contractor shall be provided to the Employer's Representative on a daily basis unless another interval has been agreed.

3D deformations of the tunnel lining shall be monitored by means of optical methods, and complemented by tape extensometer measurements when and where required. The points to be observed are marked by targets or reflectors mounted on standard convergence bolts.

Where the Contractor considers that any corrective action he may take will exceed the tolerances in the Contract, he shall so inform the Employer's Representative and obtains his agreement. Measurements shall be carried out with a free-stationed high precision electronic

theodolite as laid down in Clause 8.9.2 with integrated coaxial EDM device. The flow of data shall be fully automatic. The software shall allow determination of displacements in an absolute coordinate system with an accuracy of min ± 1.0 mm.

The Contractor shall determine the elevation of tunnel crown, and/or invert points as directed by the Employer's Representative, during tunnel excavation to monitor vertical settlements and bottom heaves, being able to interpret and figure the absolute amount of displacements together with convergence readings out. Pins or bolts shall comply with Clause 8.9.1. The method of performing the level measurements shall be such as to ensure an accuracy of ±1 mm.

Necessary conclusions shall be drawn from the geotechnical measurements, from their magnitude, alterations and tendencies about stability of the primary lining and surrounding rock, performance of the initial support applied and ground response to the supporting elements, either defined by the Project or countermeasures put on ground as adaptation to unpredicted conditions.

The locations and spacing between geotechnical measurement sections depends on geological conditions, frequency of geological alterations, rock mechanical behaviour, tunnels length, primary stress conditions, and size of tunnels. The location and spacing between designed measurement sections shall be modified during tunnelling according to the local geological conditions, and the experience gained during tunnel driving, as required and approved by the Employer's Representative.

In this sense, geological mapping of tunnel face, its record and geotechnical interpretation will be in full swing with the implementation, and modifications if required, of the instrumentation monitoring program at such sections location. The Contractor shall keep copies of all recent face records at the workface for the information of supervisory personnel.

8.4 Daily Review Meeting

The monitoring instrumentation shall be read on a regular basis - as per drawings and monitoring plan - and the results shall be made available for a daily review meeting (DRM) attended by the senior members of the Contractor's and the Employer's Representative's staff. Input into the meeting shall also include current geotechnical investigations, face logs and any recent non-conformance reports relating to the tunnel construction.

This DRM shall be held daily during the excavation of the tunnels at the site unless otherwise agreed by the Contractor and the Employer's Representative. Periodicity of such meeting would be most suitable adapted to the monitoring plan.

The minimum team attending the meeting shall include the following persons:

- Monitoring Contractor's Representative
- Monitoring Employer's Representative
- Contractor's Representative
- Employer's Representative

At the meeting the Contractor shall present the current results of all monitoring equipment of the tunnels together with its evolution trend and comparison with the values of variables predicted by the calculations. Additionally, the Contractor shall present the installed support measures and most recent geological mapping records, along with sequential excavation round lengths and cycle time for excavation/support.

The purpose of the daily review meeting is to assess the behaviour of the set primary lining/ground in order to:

- confirm the design input parameters and assumptions
- confirm that the construction methods are appropriate for the ground conditions
- provide early warning of potentially unpredicted behaviour
- determine the likely cause of adverse behaviour
- confirm the safety of the applied construction method

The outcome of the meeting shall be a report, the Required Excavation and Support Sheet (RESS) as per Clause 8.6, agreed by the Contractor and the Employer'sRepresentative, who states that tunnelling may continue as proposed, or gives the requirements for modifications to the tunnelling (e.g. support measures, shorter advances, smaller headings etc.).

The Contractor shall keep minutes records of the geotechnical instrumentation monitoring meetings, which shall be signed by the attendees. Monitoring results shall be attached to the minutes and recorded on site. All records from these meetings including face logging and monitoring results shall be kept and be available for inspection until the termination of the Contract.

8.5 Key Performance Indicators

A key performance indicator (KPI) system shall be developed for monitoring variables so that actions can be taken in a timely manner, thereby ensuring that damage to existing buildings and subsurface infrastructure is within calculated predictions.

The KPIs to be used to guide construction shall relate to specific monitoring activities as follows:

- surface ground and concerned structures displacement monitoring (not required under

expected conditions)

- in-tunnel convergence (SCL) and face displacement monitoring
- ground movement monitoring in the tunnel periphery
- deformations/strains observed on the primary lining, (and final lining if required)
- geological mapping

The KPI values specified in the design documentation shall be used to indicate whether there is cause for concern during tunnel construction or no. To ensure that the response is appropriate for any specific concern, certain procedures shall be implemented when a KPI is exceeded. These are summarised below.

- A full review of the lining performance shall be conducted for the relevant tunnel sections and checked against the KPI values. This includes checks on the ground/soil conditions, the quality of construction and the monitoring results provided by the Contractor.
- A comprehensive review of the trends for monitoring data specific to the area of concern shall be carried out by the Contractor and the Employer's Representative, including asymmetrical behaviour.
- The Contractor shall assess the extent to which the deformations comply with the SCL serviceability and extreme limit conditions.
- Together with the Employer's Representative, the Contractor shall decide whether changes in the SCL, other support elements and excavation sequence are required. This is an interactive process that will determine whether it is safe to proceed with construction or if there is reasonable cause for concern, the extent to which it is necessary to implement additional measures or emergency procedures. These measures will be included in a new RESS.
- The Contractor and Employer's Representative shall implement the Action Plan, the emergency response to develop contingency measures. If there is founded cause for concern, it is emphasised that the response must be rapid. Please refer to point 8.7.
- The performance of the tunnel is kept under continuous review until the monitoring data indicate that KPI trends show a stable condition.

At least three trigger values shall be established: a green, amber and red limit. The green limit marks the boundary of normal behaviour. The amber marks the boundary of serviceability while the red trigger should be set below the ultimate capacity of the lining. The Contractor's Action Plan should include pre-planned contingency measures that can be taken if a trigger

value is exceeded.

All monitoring results which indicate that amber and red trigger levels are reached in a specific tunnel section, shall be cross-checked through an on-site inspection to the concerned section/stretch, in order to detect lining structural defects, signs or symptoms which may confirm the instrumentation monitoring interpretation.

If a trigger value is reached, first the site team should check that the reading is correct, reliable and consistent with the readings from other instruments. If the trigger has really been breached, then contingency measures will be instigated, in accordance with a predefined Action Plan and as directed in the DRM. The contingency measures are designed to correct any anomalous behaviour.

8.6 Required Excavation and Support Sheet (RESS)

Based on the design and the evaluation of the results of monitoring, a RESS will be issued as the outcome of the Daily Review Meeting (DRM) as per Clause 8.4. In the absence of any approved changes, the RESS will reflect exactly what is shown on the relevant design drawings.

The RESS shall be prepared and endorsed by the Contractor's Site Manager, who is responsible for the tunnelling works, the Designer and the Employer's Representative on site. Unless all the three signatures are obtained, the proposals indicated on the RESS shall not be implemented. It shall be applied a communication procedure to ensure agility in the decisions and actions derived from.

The RESS shall address, but not necessary be limited to, the following matters:

- the tunnel section (chainage) to which the RESS is applicable
- the support to be installed
- the excavation sequence
- the method of working related to ground support including staging of application of sprayed-concrete layers and lapping of reinforcement
- monitoring to be installed in the tunnel section in question, and spacing between sections
- measures to be taken during stoppage of works
- other instructions relevant to the tunnel section in question
- reference to relevant design drawings
- ground conditioning

A copy of the RESS will be given to the foreman in charge of the work in the tunnel and shall be

kept at the working face.

A RESS is required for every advance per round of the tunnel excavation.

If, for any reason, the approved design method of working is changed, then this will be reviewed prior to the DRM and, subject to acceptance by the Employer's Representative, a new RESS will be issued.

8.7 Contingency Measures and Emergency Procedures

The Contractor shall determine contingency measures to deal with potential hazards that may affect the Works. The Contractor shall submit for approval to theEmployer's Representative an Action Plan which shall detail the actions, procedures and contingency measures to be followed, in the event that the monitoring system shows unacceptable levels of deformation/displacement, or other variables defined in the warning & alarm criteria, if potential hazards occur.

Hazards to be addressed include:

- changing ground conditions
- excessive strain of the linings
- excessive ground (and surface/structures if it is the case) deformations
- unplanned stoppages
- insufficient labour resources
- failure of services to underground works (air, light, power, etc.)
- incidents within underground works
- delay in supply of sprayed concrete (SCL)

Among the first measures designed in the Action Plan are:

- Verification of the reliability of instrument readings, and level of confidence w.r.t. real ground/lining system behaviour. It must be cross checked with an additional set of measurements.
- Site inspection to evaluate the effects of unacceptable values, or critical trends in variables/parameters controlled, on the tunnel lining or structures concerned. If the visual inspection shows signs of excessive deformation, new structural defects (cracks), or overstress symptoms (bending of steel reinforcement, LSC limit deformation, etc.), it is required to activate the support countermeasures protocol.

- Increase of density of monitoring sections along the concerned stretch to evaluate the extension of the phenomenon or potential hazard. This shall be executed according to specified subsidiary monitoring sections.
- Increase of frequency in monitoring readings for concerned sections or stretch
- Activation of support countermeasures protocol, with quick action based on coordination of all involved parties. It is important to establish the trigger limits which allow applying on time support countermeasures compatible with the response time available, in order to avoid further lining degradation, and protect the structural integrity of tunnel.

In underground construction works, changes tend to be progressive with evidence of structure or ground behaviour becoming apparent before failure occurs. For this situation a system of hierarchical trigger levels will be appropriate. This allows proportionate response to adverse indications from monitoring.

Trigger levels will be based on the results of assessments of at-risk infrastructure. If the assessment indicates that the at-risk infrastructure is unlikely to be able to tolerate the change due to the Works, then triggers will be set based on the levels of change that will be tolerable.

There may be some situations where change is less progressive and monitoring may simply be required to give a yes/no response. In these cases, reporting is simple and systems of triggers are not appropriate.

8.8 Instrumentation

8.8.1 General

The supply of all labour, supervisors, plant, Contractor's Equipment and materials and the execution of all work necessary to supply, assemble, check, calibrate, drill, install, backfill, embed, test and protect instrumentation in the tunnel and appurtenant structures or elsewhere as specified on the drawings and as specified herein, shall be provided by the Contractor.

During the period of the Contract, the Contractor shall ensure that his construction operations do not interfere with, or damage any of the existing instrumentation, shown on the drawings, or the instrumentation to be installed by the Contractor and by others. The Contractor will be penalized, as specified herein if any of the existing instruments or instruments that have been installed by others or by the Contractor, are damaged by his construction equipment. In addition to the penalty, theContractor, within the days required by the Employer's Representative, shall supply and install a replacement instrument adjacent to each instrument that was damaged by his construction equipment, at no additional cost to the Employer.

Not less than 120 days prior to the required installation date of each instrument, which is shown on the Contractor's work schedule, the Employer's Representative will either confirm that the instrument to be supplied is to conform to the requirements of the Specifications or he will issue information on the number, type, model number, manufacturer, supplier, location and other details of the instrument or instruments that are to be supplied and installed.

The Contractor's request for approval to supply and install alternative instruments shall provide sufficient information on each alternative instrument for the Employer's Representative to compare it with the specified instrument. The information shall be submitted to the Employer's Representative not less than 90 days prior to the first installation of that instrument.

Not less than 60 days prior to the start of instrument installation, the Contractor shall submit to the Employer's Representative a detailed description of all instrumentation, cabling and accessories including any ancillary measuring equipment, details of his checking, testing, calibrating, installing and monitoring procedures for each of the instruments.

Not less than 30 days prior to installation, each instrument shall be checked, tested and calibrated according to the instrument manufacturer's instructions and as specified herein to ensure that the instruments are in good working order and properly calibrated. A report on each such checking, testing and calibration of each instrument shall be submitted to the Employer's Representative not more than seven days after the checking, testing and calibration of that instrument.

Each instrument shall have a certificate from the manufacturer stating that the instrument was assembled in its factory, inspected before leaving such factory and presenting details of the instrument tests and calibration. A copy of the certificate for each instrument shall be submitted to the Employer's Representative not more than three days after the delivery of the instrument to the site.

A manual shall be provided with each type of instrument.

The Contractor shall supply all components, accessories and electrical leads for the instruments from the sensor to the observation house or station including materials, equipment and tools required to install, calibrate and protect the instruments as specified herein and as shown on the drawings.

All instruments and their accessories shall be new and have been successfully performed in similar projects.

The instruments and accessories shall be stored at the site by the Contractor under the condition

conforming to the manufacturer's requirements.

Instruments shall be handled, stored and installed with care so as to avoid damage. If during handling, storing and installation instruments are damaged, the Contractor shall replace and reinstall the instruments within 30 days as specified herein, as shown on the drawings or as required by the Employer's Representative and at no additional cost to the Employer.

All instruments and equipment used and required for the geotechnical measurements shall be made available to the Employer's Representative throughout the construction period.

8.8.2 Installation Comments

Instruments shall be installed as specified herein and in accordance with manufacturer's instructions at the locations and to the lines, slopes, dimensions and elevations shown on the drawings or directed by the Employer's Representative. No instrument shall be installed until the Employer's Representative has approved the testing and calibration. Instruments and instrument leads shall not be backfilled or embedded in concrete until the Employer's Representative has inspected the installation and has given his approval.

All work in connection with the calibration and installation of instrumentation shall only be done in the presence of the Employer's Representative. Calibrating, adjusting, assembling, installing and maintenance work in connection with the installation of instrumentation shall be undertaken by personnel who have been employed full time during the last five years installing geotechnical and other instruments on major civil works projects.

Instrument installation shall be supervised by a graduated geotechnical Employer's Representative who has specialized in the installation and monitoring of instruments in soil, rock, fill, concrete and metals.

The instrumentation supervisor and all other Contractor's personnel working on instrument installation shall be subject to the approval of the Employer's Representative and shall be replaced for cause if required by the Employer's Representative. Unless otherwise required by the Employer's Representative, the calibration of each instrument shall be checked and, if necessary, adjusted at the site and the instrument shall be installed by the Contractor, all in the presence of a representative of the manufacturer.

During construction of the Works, the Employer's Representative will survey the installed locations of instruments. The Employer's Representative will take an initial set of readings of all instruments immediately after the Contractor has completed their installation. The placement of concrete and backfill material over the instruments or instrument leads shall not be started until these readings have been taken.

To ensure that the instruments are being installed as specified and to make a permanent record of the soil and rock properties, the Employer's Representative will take samples of soil and rock from drill holes and will perform in situ tests whenever he considers them necessary. The Contractor shall allow time in his construction schedule to enable such samples to be taken and such tests to be made.

All instruments and connections shall be protected from damage and displacement during the progress of the work.

At all times, the Contractor shall ensure that adequate lighting is available, whether by natural or artificial means, to ensure proper execution of the work.

Instruments embedded in concrete shall be visibly and clearly marked. No traffic or equipment other than placing and compacting equipment, or shotcrete machine required for concrete placement shall be allowed to pass close to any instrument or connection installed in the concrete or rock until they are conveniently embedded. Protection cages, markers and barricades shall be provided by the Contractor where required by the Employer's Representative.

Cables and tubes shall be installed in the maximum lengths practicable. Splicing and coupling shall be performed in accordance with the manufacturer's recommendations. Calibration readings shall be taken prior to and immediately alter splicing. Open ends of all incomplete lines of tubing and casing shall be kept plugged or sealed and the Contractor shall at all times during installation keep the insides of casings and tubes free from foreign matter. Cables and tubes shall be protected from mechanical damage.

The instrumentation shall be put in operation at the earliest practicable period during construction in order to obtain relevant information pertaining to the support design performance of the tunnel.

The Contractor shall protect all instruments and connections from damage and displacement during the progress of the Works. If damage or displacement of the instruments or connections occurs during the progress of the Works, they shall be repaired or replaced immediately by the Contractor and new baseline readings shall be taken before any further construction work proceeds.

The Contractor shall be fully responsible for the maintenance and repair of all instrumentation for the duration of the Contract period.

The geotechnical instrumentation and monitoring program may always be subject to alterations and modifications if required by the actual geological or geotechnical conditions or the

Employer's Representative.

8.8.3 Quality Assurance

The Contractor shall prove that the system of monitoring instruments and measurement devices are suited to the particular purpose and fulfil the requirements and specifications. All instruments shall be factory calibrated and shall have multiple zero reading features. The Contractor shall carry out an agreed program of functional tests.

Comments on instrument calibrations and certificates are included in paragraph 8.8.1.

Not more than 15 days after the installation of each instrument, the Contractor shall submit type and model of instrument, location coordinates and elevation, date and time of installation, weather, temperature, rainfall and wind conditions, construction activities in the vicinity during installation, drilling records, core log, groundwater observations, a description of any unusual observations during drilling, installation records, method, materials, any unusual observations during installation, a plan and sections to scale showing the structure in which the instrument has been installed, instrument location, the exact location of the leads, location of all connections in the leads, the materials used in its installation, colour photographs of the installation including close-ups of the instrument before embedment and adjustments made and testing data taken during installation.

The Contractor shall cooperate with the Employer's Representative to permit continuous observations and recording of the data to be obtained by the Employer's

Representative from existing instruments previously installed and those installed by the Contractor and by others.

The Contractor shall allow in his construction planning for the instrument readings to be completed by the Employer's Representative within a reasonable time.

During the time that the instruments are being read no construction equipment shall be operated within 50 meters of the instrument.

The Contractor, after consultation with the Employer's Representative, shall program his work and make all necessary arrangements to allow the reading of instruments as soon as possible after their installation. Such arrangements shall include, where necessary, the provision of temporary read out points.

During construction, the Contractor shall read the instruments according to the data requirement of the ground behaviour as specified in this section or as directed by the Employer's Representative. The data collected from instrumentation should be immediately provided to the Employer's Representative for his use and he should have access to all the data

records through the construction period.

During the service life of equipment, calibrations of readout units are required.

Calibrations of any embedded components provided with in-place calibration check features shall also be required. Instrument calibrations shall be performed by qualified personnel responsible for data collection. The intervals for calibration shall follow the manufacturer's recommendations or be carried out as requested by the Employer's Representative.

Parts of the instrumentation which are not embedded in the rock, fill or other protective material, shall be adequately protected against mechanical (e.g. site vehicles) and environmental damage. Protective covers or housings shall be used to prevent damage of the instruments.

The installed measuring instrumentation as well as the required space for measuring must be kept free and accessible for the entire duration of construction works. Defective or damaged measuring devices shall be replaced at the earliest opportunity to enable the continuity in monitoring readings and trend-lines.

The Contractor shall arrange and maintain all the equipment throughout the construction period which is required for the installation and the monitoring of the measuring sections.

8.8.4 Installation and Reading Frequency

In case of absolute 3D displacement monitoring through optical methods, two measuring cross sections, main measuring sections and subsidiary measuring sections, are defined. The distance between measuring sections with respect to the Excavation & Support Class shall be in accordance to following Table:

Table 8: Distance between measuring sections

Support Category (E&S Class)	Main measuring section	Subsidiary measuring section
10	150 m	75 m
11	150 m	50 m
1	100 m	50 m
2	75 m	37.5 m
3a	50 m	25 m
3b	50 m	25 m
4	30 m	15 m
5b-5v	30 m	10 m
5a	20 m	10 m
5w	20 m	6.5 m

The locations of convergence sections with convergence pin installation will be same as above, allowing cross-check measurement verification for both the methods. The number of

convergence pins per section will be the same than optical reflectors, and locations as closest as possible.

The purpose of subsidiary measuring section is to be installed and control activated in the stretches where the main measuring sections are showing displacement exceeding the allowable limits or trigger values.

It might be noted as well that the spacing between optical instrument sections are integer divisions of the distance between cross passages (around 300 m), because in the cross passages intersections it is required minimum a monitoring section, plus two subsidiary sections (at both sides of CP axis, one per side) for the E&S Classes 3 to 5.

The number of instruments as specified in 8.9 installed in each measuring section shall be in compliance with below Table, with respect to the support category existent in the main measuring section. It is reflected also the recommended spacing between sections, quantified as a multiple of spacing of optical/convergence pins sections

It is assumed that in E&S Classes 10, 11, 1 and 2 there is no requirement of instrument installation and monitoring control other than optical reflector or convergence pins sections. In case of unfavourable evolution or trend in displacements, it could be required the installation of instruments in that section, under the consideration and approval of Employer's representative, but the habitual lack of agility in this process may invalidate this contingency measure.

Table 9: Instrumentation per measuring point with respect to the support category

Instrument	No. per Main measuring section			Spacing b/sections w.r.t. optical spacing		
	E&S Class 3	E&S Class 4	E&S Class 5	E&S Class 3	E&S Class 4	E&S Class 5
Reflectors/ targets/pins	5	5 - (+1 invert)	5 section 5 in face (+1 invert)	x 1 - -	x 1 - x 3	x 1 x 3 x 1
MPBE Extensometers	-	3: crown & 2 shoulders Rods: 3, 6, 9 & 12 m long	3: crown & 2 shoulders Rods: 6, 9, 12 & 15 m long	-	-x 10	x 8
Anchor load cell	-	4, 2 per TH sidewall	6, preferably 3 per sidewall	-	x 5	x 3
Strain gauges	-	4, 2 per side symmetrical.	6, 3 per side symmetrical		x 10	x 8
Radial pressure cells	-	4, 2 per side symmetrical.	6, 3 per side symmetrical		x 15	x 12
Sliding micrometre	-	-	1 at face centre (full section)	-	-	x 3

Note: Values enclosed in parenthesis are optional, depending on monitoring results and

interference

The Employer's Representative will take the initial readings on each instrument which will consist of not less than five separate readings at intervals of 15 minutes. The further reading frequency of each instrument shall be in accordance to following Table unless otherwise specified herein or directed by the Employer's Representative.

Table 10: Reading frequencies with respect to distance to face, E&S Class and time after installation or period

Distance to face (TH, BN or IN)	**Time period in days (only for relevant E&S Classes)** ***Max. expected velocity of deformation***			**Reading frequency**
	E&S Class 3	E&S Class 4	E&S Class 5	
0 (-30 at BN & IN)-+50 m	(-10 at BN & IN)-20 *2.5-1.5 mm/day*	(-15 at BN & IN)-30 *6.5-8.6 mm/day*	(-25 at BN & IN)-50 *14.0-17.5 mm/day*	every 24 hours
50-120 m	20-50	30-75	50-100	every 48 hours
120-300 m	50-100	75-180	100-240	once per week
More than 300 m	>100	>180	>240	once per month

Note: TH refers to Top heading stage, BN to benching stage, and IN to invert

Reading intervals shall be agreed with the Employer's Representative and shall be dependent on the position of the excavation face, activities in the vicinity and actual deformation behavior. However, the Contractor shall increase the reading frequency whenever directed by the Employer's Representative.

In the event of any change of trend or where other circumstances may be anticipated, for example influence due to the construction of other structures or nearby junctions, openings or intersections, the frequency of readings shall be increased.

Readings shall continue to be taken until the rate of change in the reading has diminished sufficiently to allow a lower frequency to be adopted with the confidence that the safety of the works is not in doubt and such that the amount of data retrieved allows trends with time to be clearly identified and evaluated. Decrease of any reading frequency shall be in agreement with the Employer's Representative. At any time the Employer's Representative may require an increase of reading frequency. The readings of instruments shall not be ended without the approval of the Employer's Representative.

When the bench is approaching the instrumentation section, which was installed during top heading, the reading frequencies shall be increased again. When the parallel tunnel tube approaches the station of an instrumentation section installed in the first tunnel tube, readings shall be activated again and reading frequencies increased respectively.

At sections where increasing rates of deformation occur, readings shall be taken frequently (at

least once per day) until the rate of deformation decreases with time.

Readings shall be taken by the same personnel. If the person needs to be replaced, a series of duplicate readings shall be carried out by the out-going person and the replacement.

The Contractor shall ensure that all activities carried out during the execution of the monitoring programme comply with his Health and Safety Management Plan.

8.8.5 Trigger limits for deformations

The trigger limits for tunnel periphery deformations are green zone to amber zone limit, corresponding to 75% of expected deformation by calculation (deformation tolerance) specified in DPR Design Report, and amber zone to red zone limit, corresponding to 125% of deformation tolerance.

The absolute limit before which the contingency measures and support countermeasures must have been executed or put on ground is the *Alarm Limit* indicated in the DPR Design Report.

Table 11: Trigger deformation limits for E&S Classes

Excavation & Support Class	Trigger deformation limits (mm)		
	Green limits	Amber limits	Red limits
E&S Class 10	12 (UP) 9 (LO)	19 (UP) 12 (LO)	30 (UP) 19 (LO
E&S Class 11	13 (UP) 8 (LO)	22 (UP) 13(LO)	35 (UP) 22 (LO
E&S Class 1	19 (UP) 12 (LO)	32 (UP) 19 (LO)	40 (UP) 32 (LO
E&S Class 2	15 (UP) 10 (LO)	25 (UP) 15 (LO)	35 (UP) 25 (LO
E&S Class 3	22 (UP) 15 (LO)	38 (UP) 22 (LO)	60 (UP) 38 (LO
E&S Class 4	44 (UP) 30 (LO)	76 (UP) 44 (LO)	120 (UP) 76 (LO
E&S Class 5a (SM)	135 (UP) 90 (LO)	225 (UP) 135 (LO)	360 (UP) 225 (LO
E&S Class 5v	165 (UP) 110 (LO)	275 (UP) 165 (LO)	440 (UP) 275 (LO

Note: UP refers to upper limit and LO refers to lower limit

8.8.6 Reading Information and Presentation

Measurement results shall be both tabulated and presented to the Employer's

Representative in graphical form. The graphical data submission shall be presented as follows:

- development of measuring results versus time related to the progress of the excavation headings

- development of measuring results versus distance of the measuring sections from the excavation face

The Contractor shall use a software package to allow a direct data flow from the optical displacement measurements and to be in compliance with the following Specifications:

- free stationing of the theodolite and calculation of standard deviation in all three coordinate directions
- automatic target identification and recognition of new zero readings
- calculation of 3D-coordinates and displacements of any desired point and its radial distance to the theoretical profile
- correction of errors based on physical effects
- transformation of coordinates after control measurements
- measurement results shall be tabulated and presented in graphs

When recording instrumentation readings, all site conditions that may affect the results shall be recorded including but not limited to the following:

- progress of excavation and other works
- time elapsed between particular construction activities
- taking of first readings
- temperature and humidity
- date and time of reading
- measuring instrument and / or read out unit reference

8.9 Requirements of Instruments

8.9.1 Bolts and Pins

Bolts or pins shall consist of ribbed bars protected against corrosion with a minimum length of 250 mm. Prior to installation of bolts and pins the type shall be approved by the Employer's Representative. The pins shall be securely attached to the exposed rock or shotcrete surface. After installation the convergency pins shall be protected by a protective cap.

In case of opto-electronical measurements the bolts shall be provided with a plastic cap with a predetermined breaking point serving as an adapter for the mounting of a reflector with marked centre point.

8.9.2 Theodolites and Reflectors for Convergence Measurement

Convergence measurement shall be performed in underground excavation works to determine the absolute horizontal and vertical displacements of measuring points placed around the excavation perimeter.

The measuring points shall consist of plastic reflectors of an approved manufacturer by the Employer's Representative and mounted on a treaded bar grouted into predrilled holes.

The absolute position of the reflectors shall be measured in 3-dimensional space by opto-electronical theodolite equipped with coaxial electronic distance measuring facility and data logging. The equipment shall be such as to ensure an accuracy of 3 seconds for directions and an accuracy of ± 0.1 mm for distances.

The reflectors shall be installed directly behind the face within the heading and bench zones, as appropriate, immediately after the installation of supports. Installation frequencies and numbers of reflectors per measuring cross section shall be in compliance with Table 4, Table 5 and Table 6 or as directed by the Employer's Representative.

The reflectors shall be designed for high precision measurements with two axes of rotation and to be observable from both sides.

The reflectors may be replaced by a positive centred prism, if required, with the same standard as the reflector above and in agreement with the Employer's Representative.

The recorded data shall be available and submitted to the Employer's Representative on a daily basis and discussed as per Clause 8.4.

8.9.3 Tape Extensometers

Convergence measurements shall be supplemented by direct measurement of convergence using tape extensometer units. Arrays consisting of three bolts or pins shall be installed at a spacing of 100 m or as directed by the Employer's

Representative. At each cross section a pin or bolt shall be installed in the crown of the tunnel with the two remaining pins or bolts to be installed in the side walls to enable convergence in three directions.

The tape extensometer unit shall comprise of a steel tape, fixed to the reference pins and tensioned with a constant force. An integrated dial gauge shall allow a sufficient accurate measurement.

8.9.4 Borehole Extensometers

Rod extensometers shall be installed in boreholes drilled in tunnel in upward, horizontal and

downward directions.

The rods shall consist of fibre glass or stainless steel fitted with groutable anchors with grout tubes, packers, protective tubes and caps and shall be of the multipoint point type with not less than four down hole anchors installed at different elevations in the bore hole, a rod connected to each anchor and a reference head, where measurements are made. The furthest anchor may be 25 m from the excavation perimeter. So the Contractor shall allow and provide drilling equipment for such a length and for the borehole diameter required for four anchors in one hole in compliance with the manufacturer's recommendations and requirements.

Reference heads shall be of the electric version fitted with displacement transducers to allow remote read out or the use of data loggers. Displacement transducers shall be of the vibrating wire or potentiometer type.

Multipoint extensometers may have a cumulated rod length of up to 50 m and shall comply with the following Specifications:

- Measuring range: 150 mm
- Accuracy: ±0.01 mm
- Resolution: 0.1 %

8.9.5 Strain Gauges

8.9.5.1 General

Strain gauges shall be required to record the tensile and/or compressive strain in concrete and shotcrete linings and in steel ribs and shall be of the vibrating wire type.

Strain gauges shall be used to measure strain in the tunnel lining which will be used to monitor the performance of the lining in the long term.

Strain gauges to measure strain in steel ribs are used to monitor the performance of the steel rib support.

Strain gauges shall be supplied by an approved manufacturer by the Employer's

Representative and shall permit a remote readout and data storage using an appropriate data recorder.

8.9.5.2 Concrete Strain Gauges

Concrete strain gauges shall be of the embedment type and shall be orientated in the tangential and radial direction before the placing of the concrete for the final tunnel lining or the application of sprayed concrete for the primary lining.

Concrete strain gauges shall be installed in the final tunnel lining as directed by the Employer's Representative.

Concrete strain gauges shall comply with the following Specifications:

- Measuring range: 3000 micro strain, set mid-range
- Operating temperature: -50°C to 100°C

8.9.5.3 Steel Rib Strain Gauges

Strain gauges for steel ribs shall be of the surface mount type and shall be installed parallel to the axis of the steel set and located on the centre line of the web of the steel set.

Strain gauges shall be installed on steel ribs as directed by the Employer's Representative.

Steel rib gauges shall comply with the following Specifications:

- Measuring range: 3000 micro strain, set mid-range
- Operating temperature: -50°C to 100°C
- Resolution: 1 micro strain
- Accuracy: ±0.1 % F S

8.9.5.4 Load Cells for Rock Bolts and Rock Anchors

Load cells are required to measure and monitor loads within rock bolts and rock anchors. The capacities of the load cells shall be 300 and 600 kN and they shall be suitable for the specified rock bolts and rock anchors.

The cells shall be installed as directed by the Employer's Representative.

Load Cells shall comply with the following Specifications:

- Load capacity: 150% of FS
- Accuracy: ±0.5% FS
- Resolution: 0.1% of FS

8.9.5.5 Pressure Cells

Hydraulic pressure cells shall be used for measurement of stress distribution in tunnel lining and sprayed concrete. Hydraulic pressure cells shall consist of a flat jack, which is placed at the rock surface or in the sprayed concrete, so that increasing stress can act on the flat jack. The pressure cells shall be installed as directed by the Employer's Representative. The change of pressure shall be measured and the radial and tangential loads determined.

8.9.5.6 Temperature Gauges

Temperature gauges are required to monitor the temperatures in concrete structures as directed by the Employer's Representative. These gauges are in addition to those the Contractor may need to control the placement temperature of the concrete in compliance with Clause 10.1.4.

The temperature gauges shall comply with the following Specifications:

- Minimum range: -10°C to +80°C
- Accuracy: ±0.2°C
- Resolution: 0.1 °C

8.9.6 Cables

Special cables suitable for use in concrete shall be used and shall be subject to the approval of the Employer's Representative.

All cabled instruments shall be supplied complete with the required length of cable. Splicing of cables on site shall be avoided wherever possible. No splicing of cables on site may be performed without the approval of the Employer's Representative.

Switchboxes shall be mounted in recesses in concrete structures, in instrument housings or at temporary read out points. Switchboxes shall be weather- and dustproof and all metal parts shall be of stainless material.

8.9.7 Portable Readout Units

The Contractor shall supply sets of portable readout units suitable for readout of all sensors used in the work.

The readout unit shall be capable of storing of up to 2000 readings with sensor identification number, date and time of record.

The portable readout units shall comply with the Specifications defined in Table

Table 12: Requirements on portable readout units

Parameter	Specification
Range	450 - 600 Hz
Resolution	0.01% FS
Accuracy	± 0.02% of Hz reading
Temperature measurement	-20° - 120°C
Temperature accuracy	± 1°C
Memory capacity	min 2000 readings

8.9.8 Instrument Housing

The Contractor shall construct instrument housings as required. Instrument housings shall be of steel cabinet construction with a painted mild steel lockable security door.

8.10 Probing Ahead

Where required the Contractor shall be responsible for probing ahead of the tunnel face in order to prove or investigate the ground.

The selection of plant for probing shall be agreed with the Employer's

Representative and shall take the probable nature of the ground ahead and its water-bearing capacity into account.

Probing shall be carried out in such way to allow modification of the excavation and support according to the encountered ground conditions. The number of probes, the diameter of drilling, their positions in the face and angles with respect to the tunnel drive shall be governed by the actual ground conditions and the machinery in use. The maximum probed distance ahead of the face shall be governed by the ground conditions and the degree of uncertainty with distance.

The diameter of probe holes shall be not less than 38 mm.

The used flush shall be suitable for the type of ground conditions anticipated and the machinery in use.

An accurate and systematic record of probe hole positions (positions in the face and angles with respect to tunnel drives), drill penetration rate, drill parameters

(percussion, torque, thrust), flush (colour, percentage return), drilling sounds (loud, quiet, intermittent), water strikes and interpretation of the nature of the ground ahead shall be noted at the time the holes are bored and a copy provided to the Employer's Representative. Full facilities shall be provided for the Employer's Representative to inspect probing work in progress.

9 PRIMARY SUPPORT MEASURES

9.1 General

Generally, the primary support measures are installed immediately after the performed blasting round and a break of work prior to support construction is not permitted. The type and amount of tunnel support is directly related to the Rock Classification as established. The initial support associated with the established rock classification system is shown on the Employer's design drawings. The Contractor may design his own tunnel support. However, as a consequence of variations from the anticipated rock conditions the support systems as shown on the Contractor's design drawings for each Excavation Class may require modifications and adjustment during construction as directed by the Employer's Representative.

The Contractor shall ensure that support elements will be installed or applied in such a manner and sequence as to prevent disintegration and loosening of the rock mass surrounding the excavated tunnel.

Comprehensive records, containing all particulars of the tunnel support actually installed and its performance in the course of the works, shall be prepared and maintained by the Contractor and made available to the Employer's Representative on a daily basis. These records shall include type, quantity and location of installed support elements, the clearance profile after installation of support, deviations from the designed support systems, observations of excessive deformations, shotcrete cracking, etc. Observations of excessive deformations, shotcrete cracking, etc. shall be reported immediately to the Employer's Representative.

The Contractor shall keep a record of the chainage of each face position and shall keep this record updated as the face progresses. This record shall be available for consultation at any time at a convenient location close to the relevant face.

The Contractor shall record the results of all tests performed on the rock bolts prior to, during and after their installation, and submit these documents to the Employer's Representative.

The records as defined above in this Technical Specification will be submitted daily to the Employer's Representative for review and approval.

The Contractor has to check the rock mass support measures by on-going visual inspection.

Surfaces of water sensitive rock mass shall be sealed immediately with adequate measures.

The Contractor shall apply shotcrete on rock masses which tend to local overbreak immediately.

Structural support consisting of wood is only permitted temporarily. It is not permitted to leave wooden support in the shotcrete or concrete layer.

Damaged rock mass support system due to re-profiling shall be reconstructed subsequently (see also 9.12).

The Contractor has to provide an adequate amount of rock mass support systems and required equipment on the site; hence no delays of excavation shall occur. Prior to the beginning of excavation, the required rock supports shall be provided by the Contractor on the site.

Blasting round lengths, time schedules, construction sequences, quantity and location of installed support elements shall be constructed as per drawings. Deviations from the designed support systems shall be reported immediately to the Employer's Representative and shall be approved.

The Contractor shall in case of emergency be obliged to undertake independently such support measures as he deems necessary without the prior consent of the Employer's Representative. In such cases the Contractor shall inform the Employer's Representative immediately.

Rock mass support is defined as follows:

- Primary support: is defined as the support which is installed systematically within the heading, bench and invert zone in order to ensure the short-term integrity of the underground excavation and safety of personnel during excavation. The installation of primary support is an essential element of the excavation cycle.
- Final lining: is defined as support which is installed subsequent to the primary and supplementary support and which does not form part of the normal excavation cycle. It serves as the permanent lining of the tunnel and shall be a cast in situ concrete lining, plain or reinforced according to structural requirements.
- The final lining may be installed in any section of the tunnel, with the Employer's Representative's approval, at any time after convergence measurements show that movement in the rock in the immediate vicinity has stabilised.

9.2 Rock Bolts, Anchors

9.2.1 General

Unless otherwise defined herein, rock bolts shall comply with the following Indian Standards or their equivalent International Standards:

- IS: 1786 Specifications for high strength deformed-steel bars and wires for concrete reinforcement
- IS: 2062 Steel for general structural purposes

Rock bolts are untensioned steel bars threaded at one end and provided with a face plate, shim

plates and a conical seated washer and nut or split or deformed steel tubes. Steel bars shall be grade 500 N/mm^2, deformed type 2 bars complying with BS 4449. Threaded parts of bars, nuts and seatings shall comply with the requirements of BS 4190. Face plates shall be of a dish shape in steel to the appropriate standard and shall have a hemispherical seating with centralised slot to suit dimensions of the rock dowels.

Where required, the bar and components shall have corrosion protection and the threaded end shall be sealed by an end cap.

Rock bolts shall be installed according to the length, direction, placement and number as per approved design drawings for each relevant Excavation Class unless otherwise determined by the Employer's Representative. Rock bolt length, direction, placement and number shall be adjusted to the Ground Type.

Comprehensive records about details of the installation of rock bolts during drivage, such as reference number, grout consistency, drilling depth, length, inclination and type of rock bolts, deviations from the theoretical position, type and time of grouting, time of tightening, special observations, details of tests carried out, geological ground condition, etc. shall be kept for each rock bolt and round by the Contractor and countersigned by the Employer's supervisory personnel. Copies of these records should be submitted to the Employer's Representative.

The trademark of rock bolts and anchors to be installed shall be approved by the Employer's Representative. A quality assessment is required, unless common anchor steel and anchor plates were used. The Contractor's construction execution shall comply with the manufacturer's specifications and recommendations regarding drilling, installing, testing and maintenance of rock bolts.

The characteristic bearing capacity of the anchor plate and the connection between the anchor and anchor plate shall be equal to the characteristic bearing capacity (Ptk according to BS EN 1537) of the anchor steel.

The diameter of the drillings and the drilling technique shall be adjusted to the anchor type and Ground Type. Holes for the installation of bolts shall be drilled straight and with an accuracy of ±10°.

The drilling hole shall be flushed and cleaned with compressed air or water immediately prior to the installation of the bolt. The used technique shall be adjusted on the Ground Type (e.g. bore holes drilled in swelling ground no water flushing is permitted).

The water pressure during drilling may have an inadequate impact on the surrounding ground (e.g. decrease of mechanical strength properties) due to this the water pressure may be reduced

or dry drilling may be conducted as directed by the Employer's Representative.

Unless instructed otherwise, rock bolts shall be installed and tensioned prior to the excavation of the next bench or round excavation. The tension force shall be determined by the Employer's Representative after completion of the initial testing program.

The Contractor shall provide torque wrenches of a type acceptable to Employer's Representative. All impact and torque wrenches shall be calibrated once every month.

The grouted hole shall be completely filled with grout. This shall be done by filling the drilled hole from the bottom of the hole and withdrawing the grout slowly, always maintaining the hose embedded in the grout. A regular surface shall be provided to seat the face plate by trimming rock surfaces or forming pads of quick-setting mortar. Where mortar pads are required, they shall be of adequate thickness and extend beyond the face plate by 25 mm all round at that thickness before being chamfered at 45°. Care shall be taken to ensure that the mortar does not interfere with the installed bolt.

9.2.2 Bearing Plates

Rock bolts shall have face plates which shall be of a dish shape in steel to the appropriate standard and shall have a hemispherical seating with centralised slot to suit the dimensions of the rock bolts.

Bearing plates shall be flat or dished steel plate of minimum dimensions of 150 x 150 x 10 mm conforming to IS: 2062, or as otherwise recommended by the manufacturer and approved by the Employer's Representative. Bevelled or hemispherical washers shall be used and nuts shall be heavy hexagonal type. For rock bolts that are permanently exposed, the bearing plates shall be coated before installation with an anti-corrosion protective coating compound. Any defects in the coating shall be adequately recoated after installation. The outer ends of the rock bolts, nuts and washers shall also be coated with anti-corrosion compound after installation and tensioning. The remaining portions of all rock bolts shall be clean and free of all deleterious materials.

Anchor plates, directed by the Employer's Representative to be checked, shall be held free until the check for the section is completed.

9.2.3 Grouted Bolts

9.2.3.1 Specifications

Grouted rock bolts (SN-bolts) shall consist of deformed reinforcing steel bars with a corrugated surface and one end shall be fitted with a suitable thread which is to receive an anchor plate and a fixing nut.

High quality cement shall be used for the grouting. The anchor shall reach 40 % of the

characteristic bearing capacity (Ptk according to BS EN 1537) after 6 hours and 100 % of the characteristic bearing capacity after 12 hours.

Bolts shall have a minimum load capacity as defined in the design drawings. The load capacity shall also apply to the thread, nut, anchor plate and coupling, if any.

Washers and nuts shall allow the secure transfer from the anchor force to the anchor plate.

Where required, the bar and components shall have corrosion protection and the threaded end shall be sealed by an end cap.

9.2.3.2 Installation

Boreholes for all rock bolts shall be drilled to the depths as required by the lengths of rock bolts specified for the respective Excavation Class and at diameters which ensure best workability for grouting, coupling and installation. The minimum diameter of the boreholes shall be 10 mm larger than the diameter of the installed rock bolts/couplings. Holes shall be drilled to produce straight holes of the required length and with an accuracy of ±10°.

The boreholes shall be cleaned out by flushing with compressed air or with clean water to remove all drill cuttings, sludge and debris prior to fixing the rock bolt. The amount of water-flushing shall be kept to an absolute minimum. The installation of rock bolts shall follow the drilling and preparation of the borehole within 3 hours.

Prior to the installation of the rock bolt, the entire borehole shall be filled with cement mortar by inserting the grout hose to the full depth of the hole and withdrawing as the grout is pumped in. The nozzle shall be kept buried in the grout as the pipe is withdrawn so that air is displaced as the hole is filled. The grouting shall start at the bottom of the hole. For grouting of vertical anchors, the consistence of the mortar shall be chosen that no mortar leakage from the hole is appearing.

The bolts are inserted in the drilling hole after filling with cement grout and therefore fully bonded with the surrounding rock. The outer end shall be fitted with a suitable thread to receive an anchor plate, a washer and a fixing nut to allow the secure transfer of the anchor force to the anchor plate. The anchor plate is fixed on the bearing surface within 2 rounds behind the face or at least 6 hours with the anchor nut to achieve an approximate force of 20 kN. This force shall be applied by a calibrated torque wrench.

In case of confined working space and/or great length of rock bolts, coupling shall be permitted. The number of coupled parts shall be kept to a minimum. However, the load capacity of such coupled rock bolts shall not be less than that of a standard integral rock bolt. Special attention shall be paid to the grouting procedure in order to ensure full embedment of the bolt by grout.

9.2.4 Frictional Bolts

9.2.4.1 Specifications

Frictional bolts (e.g. Swellex or similar) are mechanically folded steel tubes with immediate bearing capacity after installation in the pre-drilled borehole as high water pressure (~300 bar) inflate the tube and adapt its shape to the irregularities of the borehole (split set bolt, expandable bolt or similar).

Steel anchor plates with a minimum size of 150x150 mm (thickness as required) allow the transfer of the anchor force at the anchor head to the shotcrete or rock surface. The frictional bolts shall have a minimum breaking load of 200 kN or higher as defined in the design drawings.

9.2.4.2 Installation

Boreholes for the rock bolts shall be drilled to the depths as required. The boreholes shall be cleaned of all drill cuttings, sludge and debris.

The installation of rock bolts shall be done not later than two hours after drilling of the borehole.

For inflation of bolts, equipment as recommended by the manufacturer of the bolts shall be used. After applying the water pressure, the water shall be drained into the excavation.

9.2.5 Self-Drilling Bolts

Self-drilling bolts are a combined system of a rock bolt with typical diameters larger than 32 mm outer diameter and a drill rod.

The system enables the installation of rock bolts in case of collapsing boreholes. Grouting of the bolt is conducted through the internal grouting canal.

The installation of self-drilling bolts shall be in accordance to the manufacturer's instructions and requirements.

9.2.6 Pre-stressed Anchors

Borehole drilling, grouting, installation, tensioning and testing procedures of pre-stressed ground anchors shall be in accordance with BS EN 1537.

Pre-stressed anchors shall be transported, stored and installed in compliance with the manufacturer's recommendations.

The boreholes shall be drilled in such way that the borehole is in the defined location given in the drawings within a tolerance of 75 mm and the bore hole axis is inclined within a tolerance of 2°. The maximum tolerance of the bore hole is 1/30 of the anchor length unless otherwise accepted by the Employer's Representative.

Aberration from the defined tolerances shall be submitted immediately to the Employer's Representative.

The drilling method shall be in agreement with the Employer's Representative.

The installation of buckled tendons due to transportation, storage etc. is not permitted. Boreholes shall be of sound condition prior to installation of tendons. Borehole drilling, installation of tendon and grouting shall generally be done in one working day.

Grouting pressure and volumes shall be recorded and made available to the Employer's Representative at any time for review.

The tensioning of the tendons shall commence minimal 7 days after grouting of the fixed anchor length unless otherwise specified by the Employer's Representative.

Pre-stressed anchors shall be tensioned to the specified level as per detailed design or as directed by the Employer's Representative. Pre-stressing equipment shall be calibrated not longer than 6 month prior to any pre-stressing of anchors. The protocol of calibration shall be available at the site.

Records of tensioning sequences of each anchor with information of identification of anchor, time, personal, achieved pre-stressing force and distance shall be kept at site and submitted to the Employer's Representative for review.

Testing of pre-stressed anchors shall be in compliance with Clause 9.11.1 and the requirements of the Employer's Representative. Number of anchors to be tested shall be in compliance with BS EN 1537 or as directed by the Employer's Representative.

9.2.7 Grout

Grout constituents shall comply with Clause 9.10.4 and Clause 10.1.3 of this Specification.

Cementitious grouting material shall be injected starting from the furthest point of the drilled hole so that the dowel is completely encased in grout. Grout shall not be used after a period equivalent to its initial setting time. Where cement grout is used, a set of six cubes of cement grout shall be taken when each series of rock dowels is in progress. Sampling, preparation, curing and testing shall be in accordance with BS EN 196. Half the cubes shall be tested at 1 day and the remainder at 28 days. The average compressive strength determined from any group of cubes shall exceed the specified characteristic strength by:

- 1 N/mm^2 for cement grout tested at 1 day
- 3 N/mm^2 for cement grout tested at 28 days.

9.3 Shotcrete

Shotcrete shall be mixed, charged, applied, cured and tested according to given Specifications which are based on "Specification for tunnelling" by British Tunnelling Society. Additionally, to these Specifications and where these specifications do not cover any aspect the "Guideline for Sprayed Concrete", Austrian Society for Concrete- and Construction Technology, 2005, Austria. enclosed in Addendum 2 shall be applied.

9.3.1 General

70 days prior to any shotcrete application the Contractor shall submit detailed description of shotcrete to the Employer's Representative for review and approval such as:

- number and type of equipment used for mixing, batching and applying shotcrete
- Manufacturer's certificates detailing any proposed admixture, inter alia, accelerator admixture and the Contractor's proposals for the use of such admixtures
- mix design

The Contractor shall, 42 days prior to commencement of the actual work of spraying concrete or as otherwise approved, submit results of preconstruction tests of sprayed concrete with the actual materials, inclusive of admixtures, mixed in the proportions proposed for the Works for approval.

The Contractor shall make available testing, production and application records daily to the Employer's Representative when concrete is applied. The application records shall contain information on when, where and how much sprayed concrete was applied in each operation.

The sprayed concrete shall comply with the BS EN 14487-1 Sprayed concrete, except as noted otherwise below.

The requirements listed below generally refer to high-quality temporary or permanent sprayed concrete.

This Specification is primarily for the use of wet-mix sprayed concrete but in certain circumstances dry-mix sprayed concrete may be suitable.

Sprayed concrete shall be applied by either the wet or dry process as appropriate to the circumstances. All aspects of the application of sprayed concrete shall be subject to the agreement of the Employer's Representative. Particular emphasis shall be placed on the provision of adequate ventilation.

The compressive strength of shotcrete in-situ (taken from the tunnel lining or from panels sprayed in the tunnel) shall develop progressively to a final strength according to the minimum

requirements specified below. Uniaxial compressive strength tests shall be done in accordance with the provisions stipulated in Clause 9.11.3. The strength development due to suitability tests must exceed the specified in-situ strength by a factor of 1/0.85 (=1.18)

The sprayed concrete mix design shall, unless otherwise stated, comply with the characteristic strengths specified by the detailed design for early-age and long-term loading.

The 28-day-strength (cube) of shotcrete shall be minimum 45 N/mm^2. The strength development of shotcrete shall be such to meet 5 N/mm^2 after 12 hours, 10 N/mm^2 after 24 hrs.

9.3.2 Mixing

The Contractor shall develop a sprayed concrete mix and a plan for its production and application. Constituent materials shall comply with those listed within this Section.

The mix for shotcrete shall be designed by laboratory tests and field trials as indicated in Clause 9.11.3 of this Specification to meet the requirements for strength development and final strength.

Batching and mixing shall be carried out by equipment capable of properly mixing materials in sufficient quantity to maintain the continuous application of sprayed concrete and to the accuracy defined in BS EN 14487-2.

All measuring equipment shall be maintained in a clean serviceable condition and shall be zeroed daily and calibrated once in a month.

If required according to the support category, additional fibres shall be at a stage in the mixing suitable for the sprayed concreting equipment. Fibres shall be added and mixed in a manner to avoid clumping and bending of fibres. Any fibre clumps in the mix shall be diverted and removed by means of a screen placed over the sprayed concrete hopper. Fibres shall be uniformly distributed throughout the mortar matrix without isolated concentrations.

9.3.2.1 Aggregates

Aggregates for sprayed concrete shall comply with BS EN 12620 and the Section 10.1.3.1 of this Specification.

The aggregates shall be clean, strong, durable, suitably graded and shall not contain detrimental amounts of dust, mud, clay or organic impurities.

The aggregate shall be checked for chemical reactions, such as alkali-aggregate reaction, with latent hydraulic binders and admixtures, especially accelerators.

The grading and moisture content of the individual fractions of the aggregate shall be checked and recorded daily.

The total chloride content shall not exceed 0.35 %.

The coarse aggregates shall not contain a large quantity of long stone pieces

The maximum size of the aggregates shall not exceed 16 mm for the dry-mix process and 12 mm for the wet-mix process unless otherwise agreed with the Employer's Representative. The grading shall lie within the grading range in compliance with the Austrian Guideline on Sprayed Concrete given in Table below.

Table 13: Range of the grain size distribution for grain sizes 0/8 and 8/11

Maximum grain size [mm]	passing the screen in [m%]
11	95-100
8	85-95
4	65-75
2	45-55
1	30-40
0,5	18-25
0,25	8-12
0,063	2-6

Frozen aggregates shall not be used. Minimum temperature of the aggregates shall be 5° Celsius.

During rainy and cold weather periods the aggregates shall be stored under cover for at least 48 hours before being used, in order to reduce the water content.

9.3.2.2 Admixtures

Admixtures may be used in sprayed concrete. Admixtures shall be compatible with each other and the mix. Details of the mix design and technical data demonstrating compliance with BS EN 206-1 and BS 8500 shall be submitted to the Employer's Representative for approval.

Accelerating admixtures shall be compatible with the cement used. The compatibility shall be tested in the laboratory and in field trials to achieve the required properties for setting and strength development as specified in Clause 9.11.3 of this Specification.

Admixtures shall be free of chlorides such that the percentage of chlorides shall not exceed 0.1% by weight.

The required characteristic values and consistency of delivery to the site shall be agreed in writing with the manufacturer of each admixture before commencement of concrete spraying. Storage conditions and usage of admixtures shall comply with the manufacturer's recommendations.

Written confirmation of the stability of admixtures with the mix water shall be provided prior to commencement of site trials.

The content of SO_3 shall not exceed 4.8% by weight of total binder content.

Only liquid alkali-free accelerators (pH value between 3.0 and 8.0 and having alkali content less than 1% by weight Na_2O equivalent) shall be used unless pre-bagged dry mix is used where powdered accelerator has already been mixed in. Only the minimum quantity of accelerator necessary shall be permitted in normal concrete spraying operations. At no stage in the strength development should the strength of the accelerated mix drop below 0.7 times the strength of the unaccelerated concrete mix. The dosage rate to be used is evaluated following the suitability tests carried out in compliance with the characteristic compressive strength requirements of Clause 9.11.3 of this Specification. Compliance with this Clause shall be demonstrated by site trials. Any addition to this dosage rate shall not exceed 1% of the cement content of the mix design by weight. The dosage rate may be reduced if required for down hand and vertical spraying positions. Automatically device shall be used to add the accelerating admixture. Actual dosage shall be decided by laboratory tests. At least one set of tests shall be performed each month.

Testing of accelerators and the base mix with respect to acceleration of setting, early strength and decrease of strength at a later age (28 days), shall take place in due time before commencement of concrete spraying.

Setting time of the Portland cement and accelerator shall be determined in accordance with BS EN 196-1 and 196-3. The results should be:

- initial set <3 min
- final set <10 min

Additives for the improvement of performance, workability etc. may be added with the approval of the Employer's Representative.

Additives intended to be used shall be included in the tests as described in Clause 9.11.3 of this Specification.

Accelerating admixtures shall be used to meet the requirements for setting and strength development of shotcrete applied in-situ.

Laboratory testing of the selected type(s) of accelerator shall be carried out at dosages as recommended by the manufacturer, to establish the variability of the above properties with dosage. Accelerators showing excessive variability with dosage will not be permitted.

Accelerators delivered to site shall be tested at least once every two months for their reaction with the Portland cement used, with particular reference to the setting behaviour and strength decrease after 28 days. The stability of accelerators during storage shall be visually inspected at similar intervals. Storage times and working temperature ranges shall be in accordance with the manufacturer's recommendations. The manufacturer's safety instructions shall be observed.

Plasticisers and retarders complying with BS EN 934-2 may be used to reduce the quantity of the mixing water and to improve the pumpability of the concrete. The effects and optimum dosages of plasticisers and retarders shall be determined by site trials.

The influence of the plasticisers and retarders within the concrete mix shall be checked regularly for setting time, water reduction and development of strength. These values shall be compared with the results from the pre-commencement trials.

Compatibility of plasticisers and retarders with Portland cements, latent hydraulic binders and accelerators shall be verified by observation and site trials.

Hydration control admixtures may be used to control the hydration of the mix as appropriate to expedite construction of the Works. The effects and optimum dosages of hydration control admixtures shall be determined by site trials.

Compatibility of hydration control admixtures with Portland cements, latent hydraulic binders and accelerators shall be verified by observation and site trials. Hydration control admixtures shall be used in accordance with the manufacturer's instructions.

Dosing of admixtures by hand shall not be permitted.

9.3.2.3 Cement & Additions

Portland cement shall conform to the requirements of BS EN 197-1 or National Standards and must be suitable for sprayed concrete application.

The cement content shall be designed to meet the strength requirements of shotcrete applied in the field.

As a minimum, Portland cement shall be CEM I, strength class 42.5; class N and R are both appropriate.

The Portland cement fineness shall not be less than 350 m^2/kg and C3A content not less than 5%.

The minimum Portland cement content shall be 360 kg/m^3.

The minimum total binder content shall be 400 kg/m^3.

In order to determine a suitable dosage rate of accelerating admixtures, suitability tests shall be carried out

Table 14: Maximum level of additions (in percentage of binder)

Cementitous Material	Maximum Addition
Silica fume (solids)	15% of Portland cement
Pulverised fuel ash	30% of Portland cement
GGBS	30% of Portland cement

Pulverised fuel ash and ground granulated blast furnace slag shall conform to BS EN 450-1 and BS EN 15167 respectively and may also be included in the mix provided.

Silica fume shall be in the form of water slurry and shall comply with BS EN 13263-1.

Silica fume (microsilica) shall comply with the following requirements:

- The content of SiO_2 by weight of dry mass shall be not less than 85%.
- The silica fume shall not contain more than 0.4% elemental silica (by weight of dry mass) or any deleterious materials such as quartz, rust and/or cellulose fibres.
- The specific surface area shall not be less than 15000 m^2/kg.
- The carbon content shall not exceed 2% and the total alkali content as Na_2O equivalent shall not exceed 2%.
- SO_3 content (by weight of dry mass) shall be less than 2%.
- pH value shall be between 5.5 and 1.0.
- The viscosity shall be 20 seconds with a 4 mm viscosity cup in accordance with British Board of Agreement Certificate 85/1568 and the relative density shall be between 1.3 and 1.4.
- The activity index shall be at least 100% after 28 days.

Testing to establish compliance with items above shall be carried out on a monthly basis.

Silica fume shall be regularly agitated by circulation pumps prior to use.

The compatibility of silica fume and liquid admixtures shall be established by carrying out appropriate accelerated testing procedures agreed with the Employer's Representative.

The optimum content of silica fume shall be determined during site trials.

9.3.2.4 Water

Water shall comply with the Clause 10.1.3.5 in this Specification.

For the dry-mix shotcrete, the water content shall be controlled by the nozzle man to suit the conditions of the shotcreting surface and location of application. An indication that the water/cement ratio is in the correct range will be, that the shotcrete will seem to have a slightly shining appearance immediately following application.

For the wet-mix shotcrete, field trials shall be carried out to determine and establish the suitable water/cement ratio.

Due to aggressive mountain water, admixtures shall be defined in agreement with Employer's Representative.

The water/cement ratio range for permanent sprayed concrete shall be not more than 0.50.

9.3.3 Application

9.3.3.1 General

Details of all equipment to be used shall be made available to the Employer's Representative prior to commencement of site trials. The sprayed concrete nozzle and ancillary equipment shall be of an adequate capacity for the volumes to be applied.

The equipment selected and approved by the Employer's Representative will be capable of maintaining the ratio of concrete and accelerator as selected from the trials and approved by the Employer's Representative. The actual ratio of accelerator to selected concrete shall be identified at the nozzle, and take into account the filling efficiency of the equipment and the efficiency of the accelerator dosage equipment to overcome the air and concrete pressure at the nozzle while spraying at typical outputs and air flows.

Equipment shall be thoroughly cleaned at least once per shift. The spray nozzle shall be checked for wear and where necessary replaced. Transport pipes consisting of hoses and pipes shall be designed to convey the concrete efficiently and without leakage or blockage. The transport pipes shall have uniform diameter appropriate to the mix characteristics determined by site trials and be free of any dents or kinks between the sprayed concrete machine and the nozzle.

Working area for sprayed concreting shall be well illuminated and ventilated. Dust pollution shall be minimised by choice of appropriate equipment and by means of additional ventilation, water sprays and by maintaining equipment in good order.

Protective clothing and dust masks shall be provided for and used by all persons present during spraying.

The equipment shall allow for air and water in any combination to be available for preparation of surfaces and/or cleaning of finished work.

The Contractor shall enable the Employer's Representative access to the sprayed concrete Works at all times and shall allow the Employer's Representative access to inspect the excavated ground surface prior to spraying, if requested.

9.3.3.2 Proficiency of Nozzlemen

Nozzlemen shall hold relevant certificates of competence issued by the Contractor or written evidence of previous satisfactory work indicating compliance with EFNARC Nozzleman Certification Scheme, ACI 506R-03 (USA) or similar National Standards to the approval of the Employer's Representative. Each crew shall demonstrate acceptable proficiency in the application

of sprayed concrete to trial areas before being employed on the Works to the agreement of the Employer's Representative.

Subject to the Employer's Representative's agreement, tests for proficiency may be combined with trial mix tests.

Tests for proficiency shall use the equipment selected for use in the Works where practicable.

9.3.3.3 Applying

Rock or previously applied shotcrete surfaces to be shotcreted shall be carefully cleaned of all loose material, scale and other contaminations. It may be necessary to use compressed air and a water jet.

Where groundwater flow could interfere with the application of sprayed concrete or cause reduction in the quality of sprayed concrete. The Contractor shall take all action necessary to control groundwater. Such action shall include the channelling of water by means of pipes and chases.

In order to prevent the build-up of water pressure behind fresh sprayed concrete, apparent water shall be drained through the concrete, either with appropriate drainage holes or by other approved methods, e.g. by installing a perforated drainpipe or drainage channel covered with filter fabric and extending as approved from the leakage area to the drainage system. Such drains must be secured to the rock surface.

Drainage holes shall be drilled in the sprayed concrete lining where the build-up of water pressure may occur, and where drainage was not installed prior to the placement of sprayed concrete. The diameter and spacing of such holes shall be as directed by the Employer's Representative.

The optimum distance between nozzle and surface of application is 1.0 to 1.3 meter. The nozzle shall be positioned at right angles to the surface of application. Two nozzles shall be used at least for regular tunnel heading.

The sprayed concrete shall emerge from the nozzle in a steady uninterrupted flow. Should the flow become intermittent for any cause, the nozzleman shall direct it away from the work until it becomes constant again.

For vertical and near-vertical surfaces application shall commence at the bottom and the leading edge of the work shall be maintained at a slope. Downward spraying shall be avoided where possible. The nozzle may be inclined sufficiently to ensure reinforcement is properly embedded.

The projected shotcrete thickness d_s shall be equal to the summation of thicknesses of each shotcrete layer. The Contractor shall determine the thickness of the shotcrete layers. The

maximum shotcrete layer thickness is 20 cm, thicker layers shall be constructed with sub-sequences. Subsequent layer(s) must not be applied before the previous layer has developed sufficient strength to support the additional layer(s). These additional layers shall be completed within a period not exceeding three days.

Steel ribs, roof ties, wire mesh and other reinforcement shall be embedded in shotcrete as shown on the tunnel design drawings. The minimum cover of wire mesh and re-bars applied at the inner side of a shotcrete lining shall be 4.0 cm. Voids behind reinforcement and steel ribs must be avoided.

The shotcrete lining shall be constructed in a way that all bolts and anchors are fully covered with shotcrete of the primary lining. The surface of the primary lining must be smooth enough for the application of the water proofing system according to the specification of the water proofing system.

If more than one layer of reinforcement is installed, the second layer shall not be positioned before the first one is embedded and covered completely with shotcrete.

No rebound shall be shotcreted to avoid structural weaknesses in the lining. Rebound shall be removed immediately after finishing of each shotcrete application. The rebound shall be removed, in particular at horizontal shotcrete connections due to separate excavation sequences and at all construction joints, if necessary by pneumatic hammers, prior to further application of shotcrete.

All joints in the sprayed concrete lining shall be as specified in the Design.

The surface to receive sprayed concrete shall be damp but shall not exhibit free water.

The temperature of the mix before placing shall not be below 5°C and shall not exceed 35°C unless special provisions are made. Spraying shall not be undertaken when ambient temperature is below 5°C unless special measures can be taken to provide protection against frost until the sprayed concrete has developed a compressive strength of at least 5 MPa.

The surface of the shotcrete lining can follow the rounded surface of the rock mass including corners and edges. The minimum thickness of the shotcrete lining as given in the design drawings must be reached in every point of the lining.

Cracks in the shotcrete induced by shear failure shall be removed and a clean connecting face shall be constructed prior to further shotcreting.

The base mix concrete may be used up to 2 hours after the addition of water to the cement provided that the sprayed concrete can be applied satisfactorily. Any unused material after this time shall be discarded. This period may be extended by the use of hydration control admixtures,

subject to the approval of the Employer's Representative.

9.4 Reinforcement - Wire Mesh

9.4.1 General

The reinforcement for primary support measures shall be in compliance with Clause 10.4 of this Specification.

Cutting of reinforcement for better placing due to edges is permitted; hence additional reinforcement in these sections is required.

Welded wire mesh fabric shall be installed in surface excavations in conjunction with sprayed concrete, as shown on the drawings, or as directed by the Employer's Representative. Chain link fabric may be used for surface applications if previously approved by the Employer's Representative.

9.4.2 Specification

Welded wire mesh fabric shall conform to the requirements of IS: 4948 and shall have a mesh size of 150 x 150 x 6 mm as shown on the drawings, or as required by the Employer's Representative.

The diameter of additional steel bars shall be limited to 14 mm according to Austrian Guideline "Sprayed Concrete". The characteristic yield strength of the welded wire mesh shall be 500 N/mm^2.

9.4.3 Installation

Welded wire fabrics shall be installed in such way so that it follows as close as possible the irregularities of the excavation surface or previous layers of shotcrete. It shall be firmly fixed to prevent vibration and change of position during spraying of shotcrete. The use of wooden pegs or pins for attaching the wire mesh to the rock surface shall not be permitted. Welded wire fabrics shall be installed in the longest practical length. The overlap for welded wire fabrics applied in the shotcrete lining shall be at least twice the pitch distance in circumferential direction. In longitudinal direction, the overlap shall be at least one pitch distance for the first layer of fabric and at least twice the pitch distance for the second layer of fabric.

A minimum concrete cover at the tunnel side of 4.0 cm of all wire mesh layers shall be provided.

9.5 Lattice Girder

9.5.1 General

Steel arches or lattice girders shall be installed to maintain the designed shape of the opening and if necessary, provide an immediate support at the working face over the length of the last

excavation completed. The lattice girder mainly functions as reinforcement. If necessary, the installation of steel arches or lattice girders shall also prevent ground loss and shall improve load distribution.

For the application of support arches and lattice girders the following shall be taken into account:

- axial stress and bending moment in the steel arch ribs induced by the ground loads
- lateral stability and bracing of steel arches or lattice girders
- method of installing the steel arches or lattice girders
- method of blocking and spacing of blocking points
- bearing capacity of the ground at the toe of the arch ribs
- the stand-up time of the unsupported part of the excavation
- the groundwater regime and permeability of the ground

9.5.2 Specification

Lattice girders shall consist of three primary bars, connected by stiffening elements to the manufacturer's design or as shown on the drawings. They shall be designed so as to:

- facilitate sprayed concrete penetration into and behind the girder, thereby minimising the creation of projection shadows and/or voids
- provide good-quality bonding between the steel and sprayed concrete, to form a composite structure acting as a continuous reinforced concrete lining
- make allowance for the specified tolerances including convergence

Stiffening Elements: A minimum of 5% of the total moment of inertia shall be provided by the stiffening elements. This percentage is calculated as an average along the repeatable lengths of the lattice girder. To ensure stability against buckling, the maximum spacing between the stiffening elements shall be less than three times the cross-sectional height of the girder.

Dimensions and tolerances: The lattice girders shall be fabricated to meet minimum clearances and tolerances shown under consideration of accuracy of placement during construction, manufacturing tolerances and of lining deflection following installation. Prior to installation, each girder shall be inspected as specified below and all measurements taken shall be recorded along with any comments. Any changes in the inspection frequency must be authorised by the Employer's Representative following a review of previous inspection results.

Each girder inspection shall check the following criteria:

- That the girder is fully identified with the girder type and the unique traceability
- That the girder links and sinusoidals are in the correct positions and are adequately welded.
- That the reinforcement and plate types and sizes are as specified on the drawings.

When inspecting weld quality, the following criteria shall be used:

- The reinforcement shall be free from undercut in excess of 1 mm.
- The weld metal deposition shall be even and blend smoothly with the bars.
- The weld metal shall be free from cracks and porosity.

The chord length shall be checked by measuring the distance from the outer edge of the connection plate to the corresponding point on the connection plate at the other end of the girder. The measurement shall be taken to the nearest millimetre.

The chord height shall be checked by placing a tight cord across the centreline of the girder between the outer edges of the end plates then measuring the height from the chord to the inside edge of the lower main bar. The measurement shall be taken to the nearest millimetre. Where the girder consists of a double radius the chord lines shall be taken along the outer edge of the connection plates to the point at which the radius changes.

Lattice girders shall also comply with the following tolerances:

- The erected lattice girders shall not deviate from the design shape and position by more than -0 mm and +50 mm.
- Lattice girders shall be fabricated to include an allowance for 10 mm of convergence.

Fabrication: Each of the primary bars of the lattice girder segment shall be composed of only one piece of high-yield steel (minimum grade 500 N/mm^2 characteristic yielding strength). Secondary bars are either plain round profile or deformed high yield steel (minimum grade 500 N/mm^2 characteristic yielding strength).

The connection elements at the end of the girder segments shall be constructed of flat or angle steel to BS EN 10025:2004, grade S275JR. Connections between lattice girder segments shall be bolted as shown on the drawings. Welded connections between segments shall not be permitted. Nuts and bolts supplied are to be grade 8.8 or higher. The connections shall transfer the maximum tension load of the steel bars.

All welding shall be carried out in accordance with BS EN 1011-1:2009.

9.5.3 Installation

The single steel bar is situated at the outer side of the profile. The lattice girder is usually separated in five elements. Three elements form the top heading arch and two elements are placed as bench segments. The arch elements are connected with screwed head plates which are welded onto the main steel bars. The connection has to transfer the (tension) forces in the steel arch bars. The lattice girders have to be embedded entirely in shotcrete.

A minimum 50 mm thick sprayed concrete layer must be in place before the installation of the lattice girders. Under no circumstance lattice girders shall be installed under unsupported ground.

Lattice girder segments shall be secured by use of steel wedges, concrete spacers, mortar sacks and/or other appropriate means to maintain position during application of sprayed concrete. The means of support shall be subject to the approval of the Employer's Representative. No wood blocking shall be used.

Lattice girders shall be firmly fixed in their final position against the excavation prior to application of sprayed concrete. Lattice girders shall be sufficiently clear of the excavation and final internal profile of the structure to accommodate the required sprayed concrete cover.

Lattice girder segments shall have butt plates and the method of installation shall ensure tight connection of all elements.

Immediately prior to concreting, casting or spraying, the lattice girder shall be rendered clean and free from deleterious matter.

9.6 Steel Ribs

9.6.1 General

Steel ribs provide an immediate support of the excavation after installation and shall subsequently act as reinforcement and load distributing members for the shotcrete lining. Steel ribs are required as support for forepoling elements, which are installed in advance of the excavation. During the entire construction period, they will contribute as load bearing members within the shotcrete lining.

The steel ribs shall be manufactured to meet the geometrical requirements for the excavation geometries for each Excavation Class including the relevant tolerances.

Prior to the beginning of the work the complete fabrication details, installation procedures and layout, details of joints, rib connections, rib spacers, geometry etc. and certificates of compliance of the materials shall be submitted to the Employer's Representative for approval.

9.6.2 Specification

The fabrication and installation of structural steel support shall conform to the latest edition of the following Indian Standards or, where not covered by these Standards, to the equivalent International Standards:

- IS: 800 Code of practice for general construction in steel
- IS: 816 Code of practice for use of metal arc welding for general construction in mild steel
- IS: 2062 Steel for general structural purposes

Rib splices shall be welded or connected with bolted plates. Splices shall not reduce the section moment of resistance. Where possible all connections shall be welded and all field connections shall be bolted.

Arches, base plates, ties and connections shall be formed from steel with the characteristic in accordance to reinforced concrete standards. Arches shall be rolled to suit the dimensional requirements of the Contract. Welding shall conform with BS EN 1011-1. Holes for ties, struts and any bolted connections shall be drilled. No burning will be allowed whether for temporary Works items or permanent elements.

Threaded tie rods and struts shall be of adequate length to suit arch centres and allow 25 mm projection each end beyond the nut.

Where arches are to be provided as part of the Contractor's obligation for support the Contractor shall provide dimensional details of the arches, calculations regarding imposed loads and design and such other information that the Employer's Representative may reasonably request.

Galvanised arches, where required, shall be treated in accordance with BS EN ISO 1461. All components, including the rods, fish plates, nuts and bolts, shall be galvanised.

9.6.3 Installation

The length of the single segments of the arch is defined by the contractor. Prior to installation the arches shall be clean and free from oil or other deleterious material.

The number of joints in the arch shall be varied to suit the Contractor's method of working subject to the Employer's Representative's agreement. Steel ribs shall be erected to the lines and levels as indicated on the approved detail design drawings. The exact excavation levels may however be determined by the Contractor to match best his equipment and construction method subject to the approval of the Employer's Representative. Hardwood foot blocks and wedges shall be used to bring the steel ribs to the required line and level. Any timber used in the installation and setting of the steel ribs shall not be permanently remaining in sections where shotcrete or concrete is to be

applied. Tie bars shall be provided to connect the rib to the adjacent steel rib and fix it securely in place.

Steel arch ribs and full circle ribs shall be firmly fixed in their final positions against the excavation. Arch bases shall be provided with integral base plates of size to suit the bearing capacity of the ground and shall bear on rock or concrete of adequate strength. If required, the base plates of the ribs shall be anchored to the rock by rock bolts. Arches and ribs shall be sufficiently clear of the excavation and the final internal profile of the structure to accommodate any required concrete cover.

Placing of the steel ribs shall be perpendicular to the tunnel axis. The bearing capacity of the steel ribs shall not be endangered by the joints of the steel segments.

Immediately after placing of the steel support, the ribs shall be interconnected and braced by means of steel tie rods in order to prevent any displacement and to maintain spacing. Immediately prior to concreting, casting or spraying, the arches, ties and struts shall be rendered clean and free from deleterious matter.

Steel ribs shall be embedded in shotcrete, in order to get contact between rock and steel rib by a solid shotcrete packing which shall have a minimum cover to steel of 40 mm. In the case of overbreak, the bulk of the void space may be filled with cast in place concrete or sprayed concrete, as approved. In the case of TH - profiles, the trough of the steel profiles shall be oriented towards the tunnel in order to enable load transfer and to avoid cavities behind the steel profile.

In sections with a ductile tunnel lining, the steel arches are cut in the area of the gaps in the shotcrete lining. To allow shortening of the steel ribs, they are connected with U-profiles, which allow lateral sliding. In these sections head plates are only used for the connection of the bench arch segments.

The Contractor shall survey and record the chainage of all steel ribs installed in order to facilitate any subsequent drilling operations.

Structural steel supports shall be maintained in position after installation. Any steel support installed improperly or damaged shall be adjusted, repaired or replaced by the Contractor without delay, as directed by the Employer's Representative.

9.7 Forepoling

9.7.1 General

To support the excavation roof (tunnel crown) forepoling elements are installed if required at the upper part of the tunnel excavation face. Forepoling shall be applied in rock and soil conditions

which tend to produce overbreak, collapses or material inflows immediately following excavation. Forepoling shall be applied locally or systematically, as the circumstances require for the safety of the works and for preventing overbreak. The installation of forepoling always requires the erection of steel ribs. They shall be driven from the supporting frame in a slightly upwardly inclined direction at the crown of the heading and should penetrate at least half a set beyond the next excavation cycle.

Forepoling shall be applied as shown on the approved detail design drawings by the Contractor or as instructed by the Tunnel Designer's Representative and/or the Employer's Representative.

Forepoling shall be properly supported by the steel rib and the shotcrete above the steel rib. Therefore, the shotcreting of the gap between steel rib and the shotcreted sealed rock surface along the area of forepoling shall be completed after the installation of forepoling.

Spacing between consecutive forepoling pipes or bars around the crown of the excavation profile shall not exceed the maximum distance specified on the approved design drawings and shall be reduced if the actually prevailing geological conditions at the tunnel face require to do so.

Great care shall be taken to prevent the disturbance of face boards and supports in general during the forepoling cycle.

9.7.2 Spiles

Where spiling is employed to provide support for advancing the excavation, spiles shall be driven into the ground or placed in pre-drilled and grouted holes as specified on the drawings or by the Employer's Representative.

9.7.2.1 Specifications

Spiling is to be done with deformed reinforcing steel bars with a corrugated surface and a nominal diameter of 32 mm or tubes with similar steel cross section according to the design drawings. Deformed reinforcing steel bars shall be of a characteristic yield strength class of at min 500 N/mm^2

The length of the spiles is as given on the drawings based on the support category or directed by the Employer's Representative. The embedded length of the steel pipes shall be minimum 1 m longer than the instructed round length of the subsequently excavation step.

Pre-drilled and self-drilled spiles shall be grouted. If grout is to be used for spile installation, it shall be commensurate with the ground conditions and angle of spile inclination. If grout is used, Specification and methods should comply with those given in Clause 9.10.4 and 10.1.3 respectively.

The accuracy of spile installation shall be better than ±5° away from the alignment specified.

The number, location, overlap and angle of spiles shall be commensurate with the ground conditions and methodology specified on the Contract drawings or by the Employer's Representative.

9.7.2.2 Installation

Spiling with deformed reinforcing steel bars: The spiles are inserted in drill holes with a larger diameter which are filled with grout prior to spile installation. The spiles have a distance of approx. 30 cm. They are installed outside (onto) the steel arch and outside the excavation profile as close as possible to the theoretical line of excavation after the installation of the first layer of shotcrete. After their installation the area of the steel arch and the spiles have to be shotcreted before excavating the next round.

Spiling with steel pipes: Based on the weakness of the ground two methods of installation are commonly used. In rock the pipes are grouted in drill holes with a larger diameter. The grout is pumped into the drill hole through the steel pipe until it flows out from the annulus between rock mass and pipe. In weak ground pipes with a welded tip are pushed into a drill hole of a diameter slightly less than the outer diameter of the pipe. This leads to a tight contact and a fast interconnection of the pipes and the surrounding rock mass. The pipes are not grouted. Both types of spiles have a distance of approx. 30 cm. They are installed outside the excavation profile as described before.

Spiles shall be installed in such manner that a tensile bond is formed between the spile, the ground ahead of the proposed excavation and the sprayed concrete lining. Typically, this may involve grouting the spile into the hole for pre-drilled and self-drilling spiles or hammering the spile in.

Care shall be taken during installation of spiles to ensure minimum disturbance of the ground due to the installation process.

Probing shall be carried out in conjunction with spiling in order that fully embedded spiles are installed prior to the required location.

9.7.3 Pipe Umbrella

9.7.3.1 Specifications

Pipe umbrella shall be of steel pipes with a smooth surface and a diameter of 89 mm and a minimum wall thickness of 8 mm. The pipes shall have a length of 6 m with an overlap of minimum 2 m. The steel pipes shall have a solid steel shell (not punched). The characteristic yield strength of the pipes shall be 310MPa.

9.7.3.2 Installation

The pipes are placed outside the excavation profile as close as possible to the theoretical line of excavation. The inclination of the pipes is approx. 5° and their distance is 30-50 cm according to the ground condition. The pipes are inserted in drill holes with a larger diameter and grouted subsequently to be fully bonded with the surrounding ground.

9.8 Driven steel lagging

9.8.1 General

Steel Lagging (sheet piles) shall be employed mainly in weak ground with low cohesion with the purpose of preventing a collapse of material during and immediately after excavation. The use of lagging will always require the erection of steel ribs.

9.8.2 Specifications

Steel lagging sheets with a thickness of 4 to 6 mm shall be used.

Lengths shall be in accordance with the round length of excavation and the support requirements beyond the face as defined by the drawings or directed by the Employer's Representative.

Voids and gaps behind the lagging sheets shall be either filled with shotcrete or by contact grouting with a suitable cement mortar.

9.8.3 Installation

Lagging sheets shall be driven at distances shown on the approved detail design drawings. They shall be driven in advance of excavation of the respective round to a depth extending a minimum length of 0.5 metres beyond the face of the subsequently round length into the ground.

9.9 Yielding Elements

9.9.1 Specification

Large deformations occurring during tunnel excavation in rock with unfavourable characteristics shall be managed with yielding elements.

The primary tunnel lining shall be divided into segments by means of longitudinal gaps. To make better use of the lining capacity, yielding elements (LSC - Lining Stress Controller or equivalent) consisting of multiple steel pipes in a concentric assembly with a total length of app. 510 mm are installed in the deformation gaps in the circumferential direction.

The yielding elements shall be used to achieve controlled ductility of the tunnel lining in order to prevent overstressing. To allow a smooth initial load development, special provisions have to be foreseen (predetermined breaking points at the ends of the load tube). In order to optimize the

bearing capacity of the shotcrete lining, a multi-stage system may be used in agreement with the Employer's Representative, where the bearing capacity of the element unit is increased stepwise.

It shall be possible to adjust the bearing load of the yielding elements to the actual ground conditions (e.g. variation of steel cylinders of LSC).

9.9.2 Installation

Installation shall be done prior to any shotcreting. The elements shall be fixed to the wire mesh or to steel ribs. The elements shall be protected to ensure functionality after primary lining installation prior to shotcreting.

The elements shall have proper contact to the shotcrete lining to transfer the lining forces.

9.10 Grouting

Grouting operation is defined as follows:

- contact or cavity grouting, at pressures up to 300 kPa, to fill voids between final concrete lining and primary sprayed concrete lining, or between the primary lining and rock
- consolidation grouting or strata grouting, at pressures up to 6 MPa, of the rock surrounding the excavated space, which shall commence after completion of contact grouting, where applied
- consolidation grouting or strata grouting in the heading zone, at pressures up to 6 MPa, in zones of sheared and disturbed material or of high water inflow
- final grouting of temporary drainage holes

9.10.1 General

The Contractor shall prepare a detailed grouting Specification to suit best the actual conditions encountered. This grouting specification shall be submitted to the Employer's Representative for approval unless otherwise agreed or directed by the Employer's Representative. The Tunnel Designer's Representative shall specify the maximum pressures to be used for grout injection at each location. The pressures specified are subject to approval by the Employer's Representative.

Records of all details of grouting works such as location, inclination, diameter of boreholes, drilling time, equipment used, results of water pressure tests, mix, quantity, pressure of grouting, development and special events during grouting operation etc. shall be kept by the Contractor, countersigned on site by the Employer's supervising personnel and submitted to the Employer's Representative.

Where necessary due to the nature of the ground conditions or where adverse water conditions

are anticipated, the requirements for the use of special grouts shall be stated in the Contract.

Special grouts supplied by proprietary manufacturers may be used subject to agreement with the Employer's Representative.

Preconstruction grout trials shall be undertaken to demonstrate that the required setting times and strength gains will achieved. Details of the trials and results shall be submitted to the Employer's Representative.

Quality control of grout mortar shall be in compliance with Clause 9.11.2 of this Specification.

As directed by the Employer's Representative, water pressure tests shall be carried out.

9.10.2 Drilling

Grout holes shall be drilled either with percussion type or rotary type drilling equipment, depending on Ground Type.

The diameter at the bottom of the grout holes shall not be less than 35 mm. For percussion drill holes the diameter of the drilling bit shall be at least 8 mm larger than the diameter of the couplings used for the drill rods.

Only water shall be used for flushing during drilling unless directed otherwise by the Employer's Representative. All holes shall be thoroughly cleaned immediately after drilling using water and/or air under pressure. After washing, downward holes shall be kept plugged until the commencement of grouting operation.

9.10.3 Mixing

All grout mixes shall be prepared using high speed, high shearing action mixers to produce a grout of uniform consistency.

General-purpose cement grout shall be mixed in accordance with the proportions given in Table 14. The water content shall be kept to the minimum required to ensure a smooth, fluid mix.

Table 15: Mix proportions for cement grout

Class	Proportion by mass		
	Cement	Sand	Pulverised Fuel Ash (PFA)
G1	1	-	-
G2	1	3	-
G3	1	10	-
G4	1	-	10
G5	1	-	4
G6	1	-	0,5

When, prior to pumping, mixed grout is to be stored for short periods, purpose made agitator tanks shall be used. Grout shall be used within 1 hour of mixing.

When clay or bentonite additives are used, separate mixing tanks shall be provided for mixing and agitation.

Grouts containing polymer additives shall only be mixed in a colloidal-type mixer.

Water meters shall be provided for accurate measurement of water used for mixing. Pressure gauges, safety valves, by-pass valves etc. shall be provided where required on mixers, agitators, pumps and injection hoses.

Special grouts from proprietary manufacturers shall be mixed and used in accordance with the manufacturers' instructions.

9.10.4 Materials

The following types of grout mixes may be used:

- neat cement grout, possibly with admixture
- cement-sand grout, possibly with admixture
- cement (with silica fume) grout with or without sand
- micro-cement grout
- chemical grouts (polyurethane or epoxy)

General the constituents of the grout (cement, water, sand and admixtures) shall comply with the requirements given in Clause 10.1.3 unless specified otherwise hereinafter.

9.10.4.1 Cement

Cement for grouting purposes shall in general be rapid Portland type in accordance to ENV 197. Micro-cement for grout shall be milled from pure Portland cement clinker and shall have a minimum blaine specific area of 900 m^2/kg with 95% of all particles <10 and with a maximum particle size of 30.

9.10.4.2 Sand

If sand is required in the grout mix design, it shall comply to the following gradation (Table 15).

Table 16: Sand gradation used for grout mix

Sieve size in mm	Percentage passing by weight
2.00	100
1.00	90 - 100
0.50	50 - 80

Sieve size in mm	Percentage passing by weight
0.25	18 - 48
0.125	7 - 25
0.063	0 - 3

9.10.4.3 Additives

Silica fume for grout shall be micro fine powder with an average particle size less than 0.5 um.

Pulverised fuel ash (PFA) shall not be used as a constituent of grouts which contain sulphate-resisting cement.

9.10.4.4 Admixtures

Only admixtures tested prior to the start of grouting work and approved by the Employer's Representative may be used. The approval and Manufacturer's certificates or guarantees will not be accepted as relieving the Contractor of his responsibility for the suitability of any admixture.

If admixtures or chemicals are proposed for use in grout, the Contractor shall transmit all relevant manufactures certificates (including toxicity, health, safety and environmental certification) to the Employer's Representative for review prior to any grouting measures.

Details of accelerating and retarding agents for proposed inclusion within the grout mix shall be submitted to the Employer's Representative for agreement. Any such proposal shall be submitted in conjunction with a statement which outlines the Contractor's interpretation of ground behaviour during tunnel construction.

9.10.5 Grouting

All hoses and piping should be of a small diameter to ensure a high velocity flow without segregation.

Grouting operation shall be performed without major interruptions. In case of an interruption before completion of grouting (plant breakdown), the hole shall be washed with clean water.

Grouting in the tunnel shall be performed in a manner that pressures are equally distributed and do not overstress the initial tunnel lining.

In case of any grout communicating between holes, grouting shall be done simultaneously or holes where grout issues shall be plugged.

Grouting is completed, when the required pressure can be kept constant over a period of 10 minutes.

9.10.5.1 Cavity Grouting of In-situ Lining

The Contractor shall grout all cavities, voids and spaces remaining unfilled outside the in-situ

concrete lining. Grouting of a section of lining will not be allowed until that section has achieved its design strength.

Procedures for cavity grouting of in-situ lining to tunnels and shafts constructed with a waterproof membrane shall be subject to agreement with the Employer's Representative.

Grout for cavity grouting shall be in compliance with this Specification, except where otherwise agreed by the Employer's Representative, who may direct that large voids be filled with other materials. The grout consistency shall be sufficiently fluid, but not more as, to ensure that the grout flows freely under low (<100 kN/m^2) pressure into all parts of the space to be filled via grout pipes or grout holes provided for the purpose.

The injection points shall be provided and used for cavity grouting at an average of at least one per 2.5 linear metres of tunnel and more frequently in any areas of excessive overbreak. Vent pipes shall be provided extending to the highest points of cavities. The injection points for cavity grouting in arched roofs shall be located within 500 mm of the crown unless otherwise agreed by the Employer's Representative.

The Contractor's proposals for the installation of grout pipes shall be submitted to the Employer's Representative for agreement. Grout pipes and grout holes for cavity grouting shall be at least 40 mm internal diameter.

Grouting shall be carried out by equipment similar to that used for segmental tunnel grouting. Grouting pressures shall be such as not to damage the Works or any other property.

Grout pipes shall not remain within 25 mm of a finished concrete internal surface, and when no longer required all injection holes in concrete linings shall be filled with dry pack mortar to within 25 mm of the finished concrete surface and finally made good.

Control grouting, to verify that voids have been completely filled with grout, shall be carried out where directed by the Employer's Representative.

9.10.5.2 Consolidation or strata grouting

Consolidation grouting of the rock shall be carried out in sections of the Tunnel structures as shown on the drawings or as directed. Additionally, consolidation grouting may be required during the excavation works, in order to consolidate the heading face or seal off inflow of groundwater.

Strata grouting shall start with neat cement grout. Depending on the grout consumption the water/cement ratio may be reduced subsequently. In case of large grout consumption, injections shall be continued with cement mortar grout. Final injections shall be done with neat cement grout again.

Grouting of a hole will be considered as complete when the rate of grout consumption at the maximum grouting pressure is less than an amount set by the Employer's Representative, or otherwise directed.

Upon completion of grouting, the packer shall remain in the hole and the pressure maintained until the grout has attained its initial set.

9.11 Testing

9.11.1 Rock Bolts

The required bearing capacity of rock bolts is to be ensured by pull out test procedures, in agreement with the Employer's Representative. The pull out tests shall be conducted with a hydraulic press, in appearance of the Employer's Representative. The test results shall be recorded and forwarded to the Employer's Representative for review.

The equipment for pull out test procedures shall be provided and maintained by the Contractor during the whole construction phase.

9.11.1.1 Suitability Test

A detailed suitability test program elaborated by the Contractor set up on basis of BS EN 1537 shall be approved by the Employees Representative prior to all testing work. Deviations from the European Standard shall be approved by the Employees Representative.

Suitability tests in different ground types and with all types of bolts shall be conducted prior to the commencement of tunnelling. The tests shall be performed in similar geological ground conditions as expected during tunnel excavation. The location of the bolts to be tested shall be selected by the Employees Representative.

A minimum of five bolts of each type shall be tested. Depending on the testing procedure and the test results the Employees Representative may require further bolts to be tested.

Adequate testing equipment shall be provided to record bolt elongation, movement of the bolts and tension forces.

The bolts shall be installed in the designed manner and the external anchor resistance (Ra according to BS EN 1537) shall be determined. The anchor shall be stressed to the external anchor resistance Ra or to the proof load Pp. The proof load Pp is defined to 0,8 Ptk (= characteristic bearing capacity according to BS EN 1537).

For each type of rock bolt information of type, testing equipment, location and installation records, applied testing loads and records of deformation shall be forwarded to the Employees Representative. For failed pull-out tests, the evaluation and interpretation of test results as

specified in BS EN 1537 and proposed action shall be submitted to the Employees Representative.

Based on the suitability tests and considering the economical respects the Constructor shall define the rock bolt types in agreement with the Employees Representative.

With specific order of the Employer's Representative rock bolts with a smaller proof load Pp (according to BS EN 1537), due to smaller shaft friction may be installed. The characteristic anchor resistance Rak of the rock bolt is therefore determined with the factor Ra (according to BS EN 1537) based on the suitability tests. Further quality testing is based on the characteristic anchor resistance Rak.

9.11.1.2 Quality Tests During Tunnel Excavation

The Employees Representative will select 5 % of all rock bolts, which shall be tested.

The test quantity can be reduced to 3 % of all rock bolts, in case of on-going positive test results and in agreement with the Employees Representative. The Employees Representative may order additional quality tests in case of a high failure rate of the rock bolts with no additional costs for the Employer. The quality tests shall be conducted in attendance of the Employees Representative and only with hydraulic presses. The test results shall be documented and forwarded to the Employees Representative for review.

The pre-stressing of rock bolts, chosen by the Employees Representative, shall be tested with adequate torque wrench.

The bearing capacity of rock bolts shall be ensured by pull out tests. The testing stress is 80 % of the critical strength (= characteristic bearing capacity Ptk according to BS EN 1537) of the bolt system.

Bolts which fail the tests or which are pulled out shall be replaced. For each failure, the Employees Representative shall require further bolts to be tested in the vicinity.

9.11.2 Grout Mortar

Prior to acceptance tests of rock bolts, tests with available cements and sands shall be carried out to determine an appropriate mix design to achieve the specified strength and a proper workability in association with the grouting equipment used.

Additives may be used to improve workability. The influence of the additive on the strength development shall be followed by tests. The grout mortar shall be tested on cubes 5 x 5 x 5 cm. The cubes shall be cured in water. Five numbers of cubes shall be prepared for each compressive strength test. The resultant strength is the average evaluated from the three remaining values after elimination of the highest and the lowest value.

During construction, cube sample shall be taken weekly at each five bolts drivage from the grouting hose at the nozzle. Preparation and evaluation shall follow the procedure as described above.

9.11.3 Shotcrete

The testing procedure and quantity of tests shall be in accordance to "Guideline for Sprayed Concrete", Austrian Society for Concrete- and Construction Technology, 2005, Austria.

An Employer's Representative shall be on site at all times to check the consistency of materials and workmanship with the design intent, and to ensure that ground and groundwater conditions are in accordance with design assumptions. The Contractor shall establish a procedure to respond effectively to changes in ground and groundwater conditions from the design assumptions.

The Contractor shall establish and maintain the instrumentation and monitoring required by the design. The Contractor shall establish a procedure that will enable prompt and regular review and effective response to the results from the instrumentation and monitoring. The shotcrete lining designer shall be included in the monitoring review procedure.

9.11.3.1 Strength

The compressive strength of sprayed concrete after 28 days shall be in accordance with BS EN 206-1, with minimum concrete strength class C35/45. According to BS EN 13791 a reduction factor of 0.85 can be applied for cores from in-situ concrete. The early-strength development shall conform to Table 16, unless otherwise specified in the detailed design.

Table 17: Sprayed concrete early strength development for a C35/45 mix,

Age	Uniaxial compressive strength (cube), MPa
1 h	0,5
3 h	2,0
12 h	5
24 h	10
28 d	45

The concrete shall not show any decrease in strength with time.

9.11.3.2 Field suitability tests - preconstruction tests

Prior to first application of shotcrete mixture in the tunnel the field suitability tests under construction conditions using concrete components intended for executing the construction job shall be performed and approved by the Employer's Representative. Field suitability tests determine the early and final strength of the intended shotcrete mixture. If the conditions or the mixture of the shotcrete vary to the tested ones, the field suitability test has to be repeated.

The equipment proposed for the application of concrete in the Works shall be used for the trial. The trial will establish whether the selected equipment is capable of efficiently mixing concrete, accelerator and air at the nozzle, and is capable of positioning the nozzle at a suitable distance and orientation to the surface geometry of the structure to which the concrete is to be applied.

For each mix design a trial mix shall be sprayed into test panels (3 Nos. per trial mix). Different dosages of the accelerating admixture shall be tested following the recommendation of the accelerator manufacturer.

If a particular quality of finish is required other than as sprayed, the trials will evaluate the methods and tools to be used to achieve the required finish and the Employer's Representative will approve the method and quality of finish achieved.

The compressive strength development up to 1.2 N/mm^2 shall be determined indirectly by the Penetrometer using a plunger of 3 mm diameter.

The compressive strength development in the range between 2 and 16 N/mm^2 shall be determined using the bolt-driving method.

The compressive strength above 10 N/mm^2 shall be determined by crushing of cylindrical shotcrete specimens. After spraying, the test panels shall be covered and not be moved for 18 hours after spraying. Cores for strength testing shall be obtained from the panels between 18 hours and 1 day. The cores for determination of final strength shall be stored in water until 3 days before testing. The specimens shall have a diameter of 100 mm and be cut to a height of 100 mm. The average value of five test results shall exceed the strength specified in Clause 9.3.1 by 5 N/mm^2.

If required by the Employer's Representative, the trial shall include the construction of the proposed joints including layer joints and advance joints.

Should any mix fail to produce satisfactory sprayed concrete, the Contractor shall repeat the construction of test panels and test the same mix, plant and labour or make such adjustments as he considers as necessary.

9.11.3.3 Quality Control Tests

The performance requirements shall be set by the Designer.

The strength class of the shotcrete shall be ensured by the quality tests. If the strength class of the tested shotcrete is smaller than the required one, adequate measures shall be performed to secure the shotcrete strength. The Employer's Representative shall, in the event of repeated failure in Quality Control, require the Contractor to adjust the mix to achieve the required strength. A new

quality test shall be performed if differences in the mixture of the shotcrete will be taken.

In sections where the strength class can't be ensured, the thickness of the shotcrete layer may be increased, by order from the Employer's Representative, based on following equation:

F is the required compression strength in N/mm², M is the measured compression strength in N/mm², d is the required theoretical shotcrete thickness in cm and d1 is the additional required shotcrete thickness in cm.

The Contractor shall keep a record, in a form to be agreed with the Employer's Representative, of all tests on sprayed concrete, which shall be kept on site identifying the tests with the section of work to which they relate.

The testing procedure and quantity of tests is according to the Austrian Guideline "Sprayed Concrete". A summarize is given by following clauses.

Site-specific calibration is required for the strength tests of young sprayed concrete as per BS EN 14488-2.

Every 500 m³ of shotcrete delivered to the site, the early strength of shotcrete up to 30 minutes and at 1 day shall be tested. The test results shall comply with the requirements for early strength given in Clause 9.3.

Every 500 m³ of shotcrete delivered to the site, the in-situ final strength of shotcrete shall be tested. The specimens shall be prepared by means of core drilling at random places from the tunnel lining after 1 to 3 days but as close as possible to 24 hours after placing. The specimens shall have a diameter of 100 mm and be cut to a height of 100 mm and water stored until 3 days before testing. The average 28 days strength of five cores shall exceed the strength specified in Clause 9.3

Where the nominal required sprayed concrete thickness is less than 100 mm, the cores for the compressive strength testing shall be taken from areas where the actual thickness is greater than 100 mm. Alternatively additional sprayed concrete thicknesses shall be applied in selected areas agreed by the Employer's Representative for subsequent coring of test specimens.

All required drillings for the testing procedure shall be filled with concrete subsequent.

9.11.3.4 Measures on Strength Failures

Failure of 1-day compressive strength tests:

1) Inform the Tunnel Designer's Representative and the Employer's Representative,

2) Immediate examination of tunnel lining in suspect area,

3) Immediate examination of elements concerned in making, transporting and placing of

shotcrete,

4) Assess the results of the geotechnical monitoring program to determine any correlation between non-conformance and tunnel deformation behaviour,

5) Prepare to take further tests at three days, 6) Take further compression tests as soon as possible,

7) The Contractor may propose measures for strengthening of the area for approval of the Employer's Representative

Failure of final strength:

1) Inform the Tunnel Designer's Representative and the Employer's Representative,

2) Further cores shall be taken from the tunnel lining in the vicinity of the failed specimen to establish the area of non-conformance,

3) Assess the results of the geotechnical monitoring program to determine any correlation between non-conformance and tunnel deformation behaviour,

4) The Contractor shall propose measures - if any - for strengthening of the area for the approval of the Employer's Representative

9.11.3.5 Thickness of Shotcrete

Measures to establish the total thickness of shotcrete shall be set up by the Contractor and approved by the Employer's Representative. These may include visual guides installed prior to shotcreting or holes drilled after completion of shotcreting.

All required drillings for the testing procedure shall be filled with concrete subsequently.

The thickness of shotcrete is defined as a minimum thickness, consequently the shotcrete shall not be less than nominal design thickness at any place. 5 independent tests shall be done per every 500 m^3 of applied shotcrete per construction element (e.g. tunnel lining, shaft lining, slope support...).

9.12 Cross Section Check of Primary Lining

9.12.1 Tolerances

No reduction of the theoretical thickness of the inner concrete lining is permitted unless it is approved by the Employer's Representative. To achieve this requirement, no support elements such as shotcrete, anchor heads, steel ribs etc. may protrude into the theoretical inner concrete lining, as shown on the drawings.

The primary lining must be constructed outside the inner lining and inside the overbreak-line at any point.

In the area of the invert and the foundation beams no rock parts or rock peaks may protrude into the theoretical excavation line.

For tunnel sections with no concreted invert arch the Contractor shall excavate the bottom level of the invert with an accuracy of +0 to -100 mm related to the theoretical excavation line of the invert.

If the bottom excavation level, after the clearing of all detritus material, is more than 100 mm below the designed theoretical excavation line, the Contractor shall backfill such areas up to the designed, theoretical level by means of sub-base material or as directed and approved by the Employer's Representative.

For tunnel sections with a concrete invert arch no reduction of the designed, theoretical thickness of the concrete structure is permitted. Over excavation must be compensated with structural concrete for the invert arch as specified or as directed by the Employer's Representative. The inside face of the invert arch may deviate not more than +/- 50 mm in elevation from the theoretical cross section.

9.12.2 Profile Control

The final geometry of the primary lining shall be checked solely and systematically by the Contractor in order to accommodate the designed nominal thickness of the inner concrete lining. After incremental displacements are smaller than the permitted displacement velocity and prior to the water sealing construction, the Contractor shall measure the excavated profile by electronic means, or another method approved by the Employer's Representative.

Provision is made for the final concrete lining to be cast using a rail mounted shutter running on footing beams constructed to the designed longitudinal alignment levels and cross falls at each side of the tunnel.

It is the Contractor's responsibility to ensure that the minimum clearance for the final lining, as shown on the drawings, is provided. In order to establish deviations from the theoretical profile the Contractor shall provide a gantry furnished with a template set to show the minimum profile required to give the nominal thickness of the final concrete lining. The gantry shall be designed to move along the rail tracks to be used for the movement of the tunnel shutter and is to provide access for the marking out of the areas of the initial lining which protrude into the minimum clearance zone.

The Contractor shall submit full details of the design of the gantry with its template for the

approval of the Employer's Representative. On approval the Employer's Representative will issue instructions with regard to the systematic checking of the geometry of the template during profiling operations.

The Contractor may prefer to use advance surveying techniques and data processing to establish the final clearance profile. The Contractor shall define a method of marling out areas of deviation from the theoretical profile to be approved by the Employer's Representative.

The clearance checking of the primary lining shall not commence until the rate of convergence at any of the adjacent monitoring stations is more than 2 mm per month.

Any deviations from the theoretical clearance profile shall be made good, either by providing extra shotcrete or inner lining concrete in the case of excess clearance, or by re-profiling any parts of the tunnel support protruding into the clearance profile. Contractor is responsible for these Works without any extra payments. The remedial Works shall be in agreement with the Employer's Representative. No re-profiling shall be carried out without approval by the Employer's Representative. If the thickness of the re-profiling layer is more than 1/3 of the primary lining thickness or if an area is larger than 5 m^2 detailed procedures including structural stability proof shall be elaborated and shall be reported in a written document to the Employer's Representative prior to commencement for approval. The Structural safety of the tunnel shall not be endangered due to re-profiling and is secured by geotechnical measurements prior, in between and afterwards. Measurement equipment in the re-profiling area shall be replaced in adequate vicinity.

Records shall be kept for each stage the remedial measures executed.

The final clearance profile shall be recorded at intervals in longitudinal direction and points along the periphery of the tunnel as proposed by the Contractor in agreement with the Employer's Representative.

The final checking of the clearance profile after completion of re-profiling and surface shall be done in presence of the Employer's Representative.

10 CONCRETE WORK

10.1 Concrete

Concrete shall be mixed, charged, applied, cured and tested according to given Specifications which are based on "Specification for tunnelling" by BTS and the Indian Standards. For the tunnel inner lining and where these Specifications do not cover all aspect, "Guideline for Inner Shell Concrete", Austrian Society for Concrete- and Construction Technology, 2006, Austria shall be applied.

10.1.1 General

All structural elements must be designed for fire load if required according to the above-mentioned standards and guidelines.

The final lining cross section geometry shall be checked, and the tolerances shall be in accordance with these Specifications.

If squeezing ground conditions are observed during primary lining construction, stress gauges and pressure cells shall be installed in the final lining to monitor the actual stress-strain condition of the final lining. Minimum three stress gauges and pressure cells shall be installed in cross sections where squeezing ground conditions are encountered or as directed by the Employer's Representative. Records shall be kept available at site and submitted to the Employer's Representative for review.

Concrete and concrete constituents and all materials and operations relating to concrete shall meet the requirements of the Indian Standards Code of Practice for Plain and Reinforced Concrete IS 456 unless otherwise specified herein and as required by the Employer's Representative.

Where concrete is to be placed in aggressive ground, appropriate ground investigation shall be undertaken to identify the nature of the chemical composition of groundwater and ground.

The grade and properties of the concrete used in each part of the work shall be as stated on the drawings or in the Specification.

No material shall be added to ready-mixed concrete at the site unless approved by the Employer's Representative. Full responsibility shall be taken for ensuring that any materials added to ready-mixed concrete on site not causes the concrete to fail the quality control testing requirements of this Specification. Items made from such concrete which fail the quality control testing shall be rectified.

Concrete is not permitted to contact to aluminium during mixing, conveying and placing.

10.1.2 Concrete Requirements

Concrete mixed by the Contractor or any other Sub-Contractor shall comply with the exposition classes and strength classes as defined in the approved detailed design drawings and BS EN 206-1.

The maximum chloride content of concrete shall be in accordance with IS 456.

Chloride content class for concrete containing steel reinforcement shall be Cl 0.20 (maximum Cl content by mass of cement 0.20%) and for concrete containing pre-stressed steel reinforcement Cl 0.10 (maximum Cl content by mass of cement 0.10%), unless otherwise directed by the Employer's Representative.

Consistence of concrete mix, other than concrete mix used for tunnel lining, shall be in compliance with IS: 456.

10.1.3 Concrete Composition

10.1.3.1 Aggregates

Aggregates shall be supplied only from sources approved by the Employer's Representative. The Contractor shall demonstrate compliance with laboratory tests that shall be made at regular intervals to confirm the suitability of aggregate.

Approval of a source shall not be constructed as constituting acceptance of all materials from that source.

The quality of all aggregates used in the work, including processing such as washing, classifying, screening, rescreening crushing and blending, necessary to meet the required Specifications, shall all be subjected to acceptance of the Employer's Representative.

Aggregate shall be free from earth, clay, loam and soft, clayey, shaley or decomposed stone, organic matter and other impurities and shall be hard and dense.

Aggregates shall not contain any other matter likely to affect the long-term durability of the concrete. Reference is to be made to the BRE Digest 330 for guidance in reducing the risk of deleterious alkali-silica reaction to the absolute minimum. Mineral aggregates shall comply with IS: 383 and BS EN 12620 respectively.

Tests shall be carried out in accordance with International Standards, as appropriate, and the results shall comply with the limits given therein, or as otherwise specified. Testing will be carried out to BS EN 932, BS EN 933, BS EN 1097 and BS EN 1744 as appropriate.

If necessary, fine aggregate shall be washed to remove excess fines.

Coarse aggregate shall be washed at the aggregate source. However, further washing at the batch plant may be required if the aggregate is found to be unacceptable to the Employer's Representative.

Coarse aggregate shall be tested for drying shrinkage characteristics in accordance with BS EN 1367-4. The drying shrinkage shall not exceed 0.075%.

Coarse aggregate delivered to the batching plant shall have an uniform and stable moisture content.

The acid-soluble sulphate (SO3) level shall not exceed the values specified in BS EN 12620.

The alkali reactivity of aggregates in combination with the proposed cement shall be tested in accordance with IS 383 and IS 2386.

The maximum permitted level of equivalent acid-soluble chloride ions (Cl-) for any single constituent or combination of the constituents of the concrete in the hardened mix shall not exceed the limits given in BS EN 206-1.

The total estimated sulphate content (SO3) shall comply with the limits given in BS EN 206-1.

The water-soluble chloride ion content of the sand and coarse aggregate, combined in the proportions intended for a particular mix, shall not exceed the values given in IS 23 86; Methods of test for aggregates for concrete.

Hardness and abrasion characteristics of the aggregate will comply with BS EN 12620.

Water absorption shall not exceed the permitted value in BS EN 12620.

Where specific thermal characteristics of the mix are required, the aggregate will be appropriately selected and tested in accordance with BS EN 1367.

Each size of aggregate shall be stored separately in drained concrete-based bins or on stages to prevent intermixing and the inclusion of foreign materials

The size of aggregates shall be in accordance with IS 456 such as to establish the required properties of the concrete best. The grading of aggregates shall conform to IS:383.

10.1.3.2 Cement

The Contractor shall submit cement and cementitious material manufacturers' certificates in accordance with the relevant Standard. Details of all cements and cementitious materials shall be supplied including any alternative sources that might be used. The Contractor shall show that the quantity and quality required can be attained and maintained throughout the construction period. Any cement type proposed for usage in the Works shall be approved by the Employer's

Representative.

Cement shall comply with the requirements as per:

- IS 269 Ordinary Portland Cement, 33 Grade
- IS 8041 Rapid Hardening Portland Cement
- IS 8112 Ordinary Portland Cement, 43 Grade
- IS 12269 Ordinary Portland Cement, 53 Grade
- IS 12330 Ordinary Portland Cement, 33 Grade

Requirements to be met by cement (heat build-up, water segregation, fineness, C3A content, cement temperature) shall comply with BS EN 197.

Where Sulphate resistance is required, the selected cement will be appropriate to the required Design Chemical (DC) class.

Where specified or appropriate to use, blast furnace cements, Portland slag cements and blended ground granulated blast furnace slag (ggbs) cements will comply with the blending proportions specified in BS 8500-2.

Where specified or appropriate to use, Portland limestone cements and blended limestone cements will comply with the blending proportions specified in BS 8500-2.

Cementitious materials shall have a reactive alkali content not exceeding a value of 0.6% by mass and/or the total mass of reactive alkali in the mix shall be calculated and controlled to satisfy the requirements of BS 8500-2 and the British Research Establishment (BRE) Digest 330. Certification will be supplied by the producer to demonstrate compliance with BRE Digest 330.

Cementitious materials shall be supplied in bulk, unless such cementitious materials are to be used for mortar finishing, patching or grouting. Bulk cementitious materials shall be delivered to the Site in bulk carriers which shall be clean and dry prior to loading. All carriers for bulk or bagged cement shall be equipped with watertight closures for all openings.

Immediately upon delivering to the site, cementitious materials shall be stored in dry, watertight, ventilated structures.

Cements which have exceeded the manufacturer's designated shelf life will not be used and appropriate measures shall be taken for its safe disposal or return to the manufacturer.

10.1.3.3 Admixtures

No admixtures shall be permitted without written acceptance of the Employer's Representative.

All admixtures shall be obtained from the same manufacturer to ensure compatibility between the admixtures. Technical details including data of all admixtures proposed to be used shall be forwarded to the Employer's Representative for review. The Contractor shall carry out tests and trial mixes to determine that the admixtures are compatible with the other mix ingredients.

Unless otherwise specified by the Employer's Representative, all admixtures shall be of a liquid type.

Handling and storing of admixtures shall be in accordance with the manufacturer's recommendations. Admixtures shall be stored in weatherproof buildings at a temperature not higher than 35 degree Celsius. Mechanical agitators shall be used for those admixture solutions required by the admixture manufacturer to be agitated prior to and during use.

Admixtures shall be in compliance with IS: 9103. Water-reducing admixtures in liquid form shall comply with BS EN 206 and BS EN 934.

Admixtures shall not be mixed together prior to introduction to the mix.

The use of set-retarding and water-reducing admixtures shall be in agreement with the Employer's Representative, unless otherwise specified in the Contract. Admixtures not covered by International Standards shall not be used.

Concrete containing fly ash shall not be air entrained, unless the Contractor supplies proof (from tests on trial mixes or previous production) that the amount of air entrained can be controlled within specified limits and that the compressive strength of the concrete will be satisfactory.

10.1.3.4 Additions

General suitability as a Type II addition is established for the following:

- fly ash conforming to BS EN 450-1
- silica fume conforming to BS EN 13263-1
- ggbs conforming to BS EN 15167-1
- metakaolin with an appropriate agreement certificate

General suitability as a Type I addition is established for the following:

- filler aggregate conforming to BS EN 12620 or BS EN 13055-1
- pigments conforming to BS EN 12878

10.1.3.5 Water

Water for concrete mixing and curing shall be clean and free from injurious amounts of oil, silt,

salt, organic matter, acid, alkali, sediment or other deleterious substances and shall conform IS 456-1978 and BS EN 206 respectively.

Recycled water may be used provided controls are in place to demonstrate compliance with BS EN 206.

The Contractor shall supply, install, operate and maintain a system for water supply for concrete, mortar, shotcrete and grout manufacture. Not less than 40 days prior to the start of concrete production, shotcrete placement, or grout injection whichever occurs first, the Contractor shall submit to the Employer's Representative details of the method by which the Contractor proposes to ensure a clean and adequate supply of water.

Alternative water storage facilities shall be provided to ensure that concreting, shotcreting and grouting operations will not be hindered by a temporary breakdown in the main water supply system.

The permissible limits for solids when tested in compliance with IS 3025 shall be as given in Table 17.

Table 18: Limits of deleterious material in water for concrete mixing

deleterious material	max. permissible limit
organic	200 mg/lit
inorganic	3000 mg/l
sulphates (SO4)	500 mg/lit
chloride (Cl)	500 mg/lit
suspended matter	2000 mg/lit

The pH value of the water shall not be less than 6.

10.1.3.6 Fibres

Fibres are generally accepted for use in concrete conforming to BS EN 206-1 and BS 8500 if the fibre conforms to BS EN 14889, an European Technical Approval.

Fibre-reinforced concrete will be trialled and tested to ensure it meets the designers' requirements before inclusion in the works. Historical data of the same fibre and dosage will be accepted in place of trials provided the data are deemed appropriate.

10.1.4 Temperature

Every effort shall be made to maintain the temperature of concrete during manufacture, placement and curing as per IS 7861 (Part I & II) unless otherwise specified herein.

The concrete temperature at the time of placing shall not exceed 27°C nor be less than 5°C. Fresh concrete temperatures of 13°C to 18°C are most favourable. Concrete and concrete constituents

may be heated to reach the preferable concrete temperature. Heating of concrete or concrete constituents shall under no circumstances increase the concrete temperature above 27°C.

Aggregates shall be heated uniformly and carefully; all frozen lumps, ice and snow shall be eliminated before entering the concrete mix; average aggregate temperature shall not exceed 60 °C and maximum spot temperature shall be below 100 °C. Frozen aggregates shall not be used.

Mixing water shall not be heated exceeding 60°C.

To avoid surface cracking caused by heat generated during setting of concrete, the temperature difference between a measuring point at the surface and a measuring point in the centre of a concrete body, or 1000 mm inside the surface if the body is more than 2 m thick, shall be less than 20°C, if not otherwise approved by the Employer's Representative. The location of the measuring point at the surface plane shall be defined as 10 mm inside the surface on a perpendicular projection of the structure member's centre point to the surface plane.

Temperature difference across construction joints shall be less than 15 °C at the time of concrete placement.

The maximum temperature during setting of concrete shall not exceed 40 °C except it is approved by the Employer's Representative.

10.1.5 Mix Design

The selection design and quality control of mixes shall be carried out by the Contractor or on his behalf by the manufacturer.

The Contractor shall design concrete mixes for each class of concrete. The concrete mixes shall be designed to produce a workable plastic mixture with the lowest slump that will suit the specified condition at the time of placement and will produce concrete of uniform consistency that conforms to the requirements specified for the various parts of the works.

In order to minimize thermal cracking, the cement content of all classes of concrete shall be the minimum necessary to produce the specified strength, permeability, freeze-thaw resistance and temperature rise requirements.

10.1.6 Mixing and Batching

10.1.6.1 General

The Contractor shall provide at the site, modern and dependable, automatically or semi-automatically controlled batching and mixing plant or plants, in an "as new" condition, capable of supplying concrete in accordance with the Specifications and at a continuous rate adequate to meet the requirements of his schedule for concrete placement. Each plant shall have not less than

two concrete mixers, each with a separate power and drive system with a standby generator and other equipment to ensure a continuous supply of concrete during concrete placement operations.

10.1.6.2 Batching

The Contractor shall provide, operate and maintain all necessary equipment and plant required to determine accurately and to control the amount of each separate ingredient entering the concrete mix. The actual amount of fine aggregate, each size of coarse aggregate, cement, fly ash, admixtures, ice and water entering each batch of concrete shall be determined by automatic weighing of each ingredient separately and not cumulatively. All constituents shall be weighed or metered in compliance with the limits prescribed in BS EN 206.

Proportioning of concrete mixes shall be in accordance with IS 456-1978 and IS 4925.

Admixtures shall only be introduced using purpose-made equipment accurately calibrated. Where such equipment is unavailable, and where agreed with the

Employer's Representative, alternative dosing methods to the manufacturer's recommendations may be adopted.

Water shall not be added to concrete after it has left the mixer unless controlled, recorded and agreed with the Employer's Representative.

Where fibre reinforcement is added to the concrete mix, this shall only be introduced using purpose-made equipment.

All necessary measures shall be taken to prevent charging the batching plant with frozen aggregates. Aggregates in bins at the batching plant shall be kept above zero degrees Celsius at all times. Heating and cooling equipment shall be provided with sufficient capacity to heat or cool the water and aggregates to a uniform temperature so that the concrete will meet the placement temperature requirements.

Free access for testing and inspection of the cementitious materials shall be provided. The batchers shall be arranged that the loading cycle cannot start again as long as materials remain in the batchers.

A thermometer shall be installed in the cement day bin such that the operator can see readily the temperature of the cement at the time of batching.

The plant shall be equipped with a batching recorder which shall print the mass or volume for each material in each batch, identify the concrete mix being batched, the size of each batch in cubic meters, and the time and date of batching. The records shall be submitted to the Employer's Representative at the end of each shift and shall become the property of the Employer's

Representative.

The accuracy of the measuring and weighing equipment shall be maintained so that the indicated mass does not vary by more than 0.6 per cent from the true mass throughout the range of use.

The measuring and weighing equipment shall be capable of being operated to control the delivery of materials so that the combined inaccuracies in feeding and measuring do not exceed the limits in Table 18.

The Contractor shall provide standard certified test weights and any other auxiliary equipment required for checking the operating performance of each measuring and weighing device. Unless otherwise required by the Employer's Representative, check tests of equipment used for measuring water, cement and the admixtures shall be made at intervals not exceeding one month. Check tests of measuring and weighing equipment used for measuring fine and coarse aggregate shall be made at intervals not exceeding two months. The tests shall be made in the presence of the Employer's Representative and the Contractor shall make such adjustments, repairs or replacements as the Employer's Representative may deem necessary to secure satisfactory performance before further use of the measuring or weighing equipment will be allowed.

All aspects of the batching and mixing operation including quantities of aggregates, cement, fly ash, admixtures and water shall be automatically recorded.

Table 19: Batching tolerances

cement	2,0 % per weight
fine aggregates	3,0 % per weight
coarse aggregates	3,0 % per weight
admixtures	2,0 % per weight
water	1,5 % per weight

10.1.6.3 Mixing

The mixing plant shall combine fine aggregates, each size of coarse aggregates, cement, fly ash, admixtures, ice and water into a uniform mass and shall discharge the mixture without segregation.

The batching and mixing plant shall have capacity of batching and mixing concrete at a rate in excess of the Contractor's peak placing requirements. A standby mixer with a capacity of not less than 40% of the peak placing requirements shall be available at all times for use during critical concreting operations.

A mixer timer with an automatic lock which will not release the discharging mechanism until the completion of a pre-set mixing time shall be provided on all mixers.

Separation of coarse aggregate from the mortar shall be avoided by arranging the discharge

mechanism so that the concrete will fall vertically into the receiving container or hopper.

Mixers shall be examined by the Contractor at regular intervals to ensure that wear on the blades and liners does not allow dead spots or agglomerations of mortar around the sides of the mixer. Mixers shall be cleaned of any hardened materials which have built up on the insides. Should a mixer at any time produce unsatisfactory results, in the opinion of the Employer's Representative, its use shall be discontinued until it is repaired or replaced.

Mixer performance tests shall be performed on all mixers, as soon as the equipment is in operating condition at the start of the Work, at least once every 30 days during the course of the Work and at any time the Employer's Representative suspects any type of operating difficulties with the machinery. At the end of the mixing period prescribed by the Employer's Representative for the test, two samples of concrete shall be taken.

When necessary mixing times shall be increased until the required uniformity and consistency of the concrete is adequate. Mixers shall not be used if they produce unsatisfactory concrete.

10.1.7 Conveying

Concrete shall be conveyed from the mixer to the place of final deposit without segregation, contamination, loss of ingredients, loss of entrained air, loss of slump or damage from exposure. Trucks, buckets, belt conveyors, pumps, chutes and drop pipes may be used for conveying concrete and shall be of such size, design and condition as to ensure a continuous and even supply of concrete at the point of delivery. Alternative methods will be required to prove their success in conveying concrete rapidly, without segregation and the loss of materials. All conveying equipment shall be supported independently of the forms.

Concrete conveying equipment shall be checked by means of site trials prior to general use for its ability to deliver uniform concrete as per Clause 10.1.11.1. Slump tests shall be made on samples of concrete taken from the first and last one-tenth of a batch of mixed concrete. If these slumps differ by more than 25 mm, the equipment shall not be approved for use until the condition causing the inconsistency is corrected. Concrete conveying equipment used shall be examined daily for accumulations of hardened concrete or mortar, or for wear of the blades. Where necessary, the uniformity test may be repeated.

The time elapsed between completion of the mixing of the concrete at the plant and its discharge at the forms shall not exceed 45 minutes for concrete agitated while in transit and 30 minutes for non-agitated concrete. These basic limits apply in the case of non-set-retarded concrete. For set-retarded concrete the limits may be increased. Open conveyances shall be covered against the weather when required by the Employer's Representative.

Dispatch tickets or a record direct from the batching plant recorder shall be furnished to the Employer's Representative with each batch of concrete recording the serial number of ticket, date, batch number, truck number, amount and class of concrete, location of placement, and time of mixing. At the end of each day or shift, the Contractor shall supply the Employer's Representative with a written report concerning the quantity of each class of concrete and the number of batches produced.

Equipment to be used to convey the concrete shall not contain hardened concrete or foreign materials.

In general, the use of chutes to convey concrete will not be permitted, except that chutes less than 3 m in total length may be used with acceptance of the Employer's

Representative. The delivery end of the chute shall be as close as possible to the point of deposit. The chute shall be thoroughly flushed with fresh clean water before and after each run, the water used for this purpose being discharged outside the form.

Concrete in the walls and arches of tunnel linings shall be placed by a displacement type pump or by other approved methods by the Employer's Representative. The equipment used in placing the concrete, and the method of its operations, shall be in a way to permit introduction of the concrete into its final location without high-velocity discharge and resultant segregation.

Concrete pumps shall have a variable speed control and shall be capable of pumping concrete containing 20 mm aggregate through delivery lines not less than 75 mm diameter and for a distance required for placement within the works to meet requirements of this Specification.

10.1.8 Placing

10.1.8.1 General

The Contractor shall develop a detailed plan of concrete lifts for each structure which shall show the location of all construction joints and all concrete lifts in the structure and shall take reinforcing steel bars, embedded parts and water stops into account. The submission shall include calculations supported by laboratory and full scale test data showing how the temperature control requirements will be achieved. The plan for each structure, which shall include detailed drawings, shall be submitted to the Employer's Representative not less than 80 days prior to the start of concrete placement in that structure and not less than 20 days prior to the submission of reinforcing steel bar placement drawings, bar bending schedules and bar lists for that structure. The Employer's Representative shall have the right to require the Contractor to move the location of any construction joint if the location proposed by the Contractor will have an adverse effect on the design and performance of the structure.

The construction joints shown on the drawings shall not be moved unless the Contractor can satisfy the Employer's Representative that there is justification for the relocation and that there will be no adverse effect on the performance of the structure.

After the Contractor's plan for construction joints and concrete lifts has been approved by the Employer's Representative no additional joints shall be incorporated into the Works unless approved by the Employer's Representative.

Details of proposed additional joints shall be submitted to the Employer's Representative not less than 60 days prior to concrete placement at the location of the proposed additional joints.

Concrete shall not be placed in any part of the Works until the foundations, previously placed concrete, formwork, reinforcing steel bars, embedded parts and water stops in that area have been inspected by the Employer's Representative and permission has been given by the Employer's Representative for concrete placing to proceed. Concrete shall be placed only in the presence of the Employer's Representative.

All surfaces to be in contact with the in-situ concrete lining shall be thoroughly cleaned and scaled of all loose or defective material.

The surfaces of waterproofing membranes shall be thoroughly cleaned to remove any loose and foreign materials. They shall be cleaned by washing with a stream of air and water, but care shall be taken not to displace the membrane or its fixing and seals.

Concrete shall not be placed in still or running water and shall not be subjected to the action of running water until the concrete has set.

All formwork shall be true to form, securely made and supported, and joints shall be sealed to prevent the loss of cement from the mix. Where required, grout pipes shall be incorporated for pressure relief and subsequent grouting.

Concreting shall not commence until the formwork has been inspected and agreed with the Employer's Representative.

The build-up of water pressure behind uncured linings shall be prevented. Concrete shall be placed continuously in each length of formwork. Concrete shall be protected from rain during placement.

The time between batching and complete discharge shall be less than 90 minutes and shall be such that the concrete can be placed and consolidated without the addition of extra water. The time between batching and complete discharge shall be reduced to a maximum of 60 minutes when the air temperature exceeds 25 degrees Celsius.

In order to reduce bleeding, slump shall not be higher than necessary to achieve proper placement

and consolidation.

The depth of concrete placed in each lift shall be as shown on the Contractor's drawings. All concrete shall be deposited in approximately horizontal layers 50 centimetres in thickness at such a rate that the formation of cold joints will be prevented. Each new lift of concrete shall be placed on the oldest exposed lift.

Hardened or stiff concrete shall not accumulate on reinforcing steel or formwork.

Partially hardened concrete shall not be re-tempered with or without additional aggregate, cement or water.

Once concrete placing has started it shall be carried on as a continuous operation until the placing of the lift is completed. The rate of placing shall be such that each successive layer can be vibrated and bonded into the previous layer.

When concrete is placed on an inclined surface, the placing operation shall begin at the lower end of the slope and shall progress upward.

The sequence of work within the tunnels or shafts shall be arranged as that no damage occurs to permanent linings. The proposed sequences and methods of operations shall be agreed with the Employer's Representative.

Before any concrete is placed for tunnel linings the Contractor shall demonstrate to the Employer's Representative that his concrete mix, equipment and working methods are capable of producing fully compacted concrete to the required surface finish. If required by the Employer's Representative, this shall take the form of a trial length.

10.1.8.2 Preparation

Immediately after the removal of blasted rock, excavated rock surfaces against which concrete will be placed shall be scaled and cleaned to remove unclassified material, loose, broken and detached rock fragments and unsound, slaked, deteriorated and closely fractured rock which remain in the excavated surface of the rock. Where required by the Employer's Representative, scaling and cleaning shall be followed by dental excavation to remove the unclassified material remaining in open and debris filled joints, cracks, fissures, seams, crevices, faults, shear zones and other relatively narrow openings. The purpose of scaling, cleaning and dental excavation is to produce a sound, intact, tightly anchored rock surface.

Scaling, cleaning and dental excavation will require the use of manual labour, with hand held pneumatic tools, shovels, bars, trowels, compressed air jets, high pressure water jets, brooms, brushes and other hand held tools. High pressure water jets shall not be used.

Foundation surface of the rock, concrete and shotcrete shall be protected against weathering and the deleterious effects of frost action, rain, groundwater seepage and construction equipment until concrete placement commences.

Shotcrete in underground works shall be cut back so that no shotcrete protrudes inside the concrete pay line (see 7.6 and 9.12).

Rock, shotcrete and concrete surfaces against which concrete is to be placed shall be kept continuously damp for a period of not less than 24 hours immediately prior to concrete placement.

Surfaces of reinforcing bars, forms and embedded parts shall be cleaned of all dried mortar, grout, oil and all other coatings except epoxy coating and galvanizing.

Immediately before concrete is placed, forms shall be inspected to ensure that the forms are accurately placed to the specified tolerances and are sufficiently rigid and braced to prevent movement during concrete placement and that all reinforcing bars are in the correct position and secured against movement during the placing operation. Chemicals shall not be used to remove ice or hardened concrete from the forms.

In hot weather or concreting on surfaces which are highly water absorbent, the surfaces against which concrete is to be placed, including reinforcement and formwork, shall be lightly sprayed with water to prevent excessive absorption of water from the fresh concrete. Pre-wetted surfaces shall be free from excessive water before concreting.

10.1.8.3 Placing

The concrete shall not be placed until the rate of convergence at any of the adjacent monitoring stations is less than 4 mm per month, unless otherwise approved by the Employer's Representative.

Concrete shall be placed while still sufficiently plastic for adequate compaction and shall be carefully worked around all reinforcement and embedded fixture and corners of the formwork.

Concrete shall be inspected at the point of placing.

There shall be no vertical drop greater than 1.5 m except where equipment such as tremie pipes and chutes satisfactory to the Employer's Representative to use to confine and control the falling concrete. Horizontally movement of concrete exceeding 1.0 m by the use of vibrators is not permitted.

Concrete shall be placed as close as possible to its final position, in continuous near level layers not exceeding 500 mm. Each layer shall be compacted before succeeding layers are placed. The depositing of large quantities of concrete at any one point and running or working it along the

forms will not be allowed.

Placing equipment shall be operated by experienced operators only. In general, the concrete placing shall continue uninterrupted until the structure is filled over the entire length of the formwork. In the event of equipment breakdown or if for any other unavoidable reason placing is interrupted, the Contractor shall thoroughly compact the concrete to a reasonable level or flat slope while the concrete is plastic. The concrete at the surface of such cold joints shall be cleaned with a high-pressure air water jet before the concrete achieves a primary set, to provide an irregular clean surface free from laitance. Prior to restarting concreting, the surface shall be wetted. The work shall be carried out in a way that a sound dense homogeneous structural element is produced.

The concrete which forms the openings to caverns and niches or other recesses shall be placed concurrently with the concrete in the parent tunnel at the same cross section.

Concrete shall not be subjected to disturbance between 4 hours and 24 hours after placing.

10.1.8.4 Consolidation

As concrete is being placed, it shall be compacted thoroughly and uniformly by means of vibrators, supplemented by hand spading, ramming, and tamping to produce dense, homogeneous concrete, that is at its maximum density, that is in complete contact with forms, that is effectively bonded to the reinforcing steel bars and the embedded parts and that has smooth formed surfaces, free of air pockets and blemishes.

Concrete shall be consolidated with the aid of approved immersion type mechanical vibrators complying with IS 2505. Immersion vibrators shall be a minimum of 40 mm in diameter and shall be capable of transmitting vibration to the concrete at frequencies in excess of 150Hz or 4000 rpm and shall visibly affect the concrete at a radius of 300 mm.

At least one vibrator in working order shall be held in reserve for emergency use.

Concrete vibrators shall not be used for moving concrete. Vibrators shall be operated as nearly as practicable in a vertical position. The vibrating head shall be allowed to penetrate under its own weight until it can re-vibrate the top 5 centimetres of the underlying concrete layer. The vibrator shall be withdrawn slowly to avoid the formation of voids and shall be carefully positioned to avoid contact of the vibrating head with the formwork. Vibrators shall be inserted at uniform spacing over the entire area of placement. The distance between insertions shall be approximately 1.5 times the radius of action of the vibrator. Vibrators shall be held stationary until the concrete is consolidated and then withdrawn slowly. The concrete ingredients shall not be allowed to segregate and no laitance shall be allowed to appear on the surface.

Vibrators shall not come in contact with nor disturb embedded parts, waterstops, reinforcing steel bars and formwork.

Particular care shall be taken with the compaction of concrete surrounding water bars to avoid honeycombing and to prevent the displacement of the water bar. Care shall also be taken to avoid displacement of pre-fixed pipes, block-outs, thermocouples and the like.

Where placing concrete for tunnel linings, formwork vibrators shall be used for compacting concrete in the tunnel arch above the highest openings in the formwork. They shall be operated at intervals of not more than 1.2 m behind the advancing slope of the concrete in the shoulders and crown of the arch. The location and operation of the vibrators shall be carefully coordinated with the withdrawal of the discharge line so as to avoid settlement and flow of the concrete from the filled crown.

10.1.8.5 Finishing

The surface of formed and unformed concrete shall be within the specified allowable deviations from the lines, slopes, elevations and dimensions shown on the drawings and shall be smooth and uniform in texture and free from streaks, discoloration and surface irregularities to the extent specified herein.

Any damage to finished concrete resulting from the action of removing from work or any other cause shall be repaired to the satisfaction of the Employer's Representative.

Formed Surfaces:

Table 20: Formed concrete finishes

F1	No specific requirement
F2	The irregularities in the finish shall be no greater than those obtained from the use of wrought thickness square-edged boards arranged in a uniform pattern. Fins shall be removed and imperfections shall be made good.
F3	The resulting finish shall be smooth and of uniform texture and appearance. The formwork lining shall leave no stain on the concrete and shall be so joined and fixed to its backing that it imparts no blemishes. It shall be of the same type and obtained from only one source throughout any one structure. The Contractor shall make good any imperfections in the finish. Internal ties and embedded metal parts shall not be used

All formwork joints for F2 and F3 finish shall form a regular pattern.

Unformed Surfaces:

Table 21: Unformed concrete finishes

U1: Screened finish	The concrete shall be levelled and screeded. No further work shall be applied to the surface unless it is a first stage for a wood float or steel trowel finish.
U2: Wood float	A pre-screeded finish shall be floated with light finish pressure using a wooden float to eliminate surface irregularities.

U3: Steel trowel finish	A steel trowelled finish shall be first wood-floated and then trowelled under firm pressure with a steel float to produce a dense, smooth, uniform surface. The final surface shall be free from trowel marks.

When required by the Employer's Representative and before commencing concreting the Contractor shall prepare a trial panel to demonstrate that the required surface finish can be achieved by the equipment and methods proposed. The panel shall be filled with the proposed concrete compacted by the method to be used in the work. When agreed with the Employer's Representative the trial panel shall be retained and will form the benchmark against which all Works concrete shall be prepared.

Where the concrete surface is to receive waterproofing, it shall be in accordance with the waterproofing system manufacturer's recommendations.

Permanently exposed concrete surfaces shall be protected from rust marks and all kinds of stains.

After removal of the formwork no treatment, other than that approved for curing, shall be applied to the concrete until its surfaces have been inspected by the Employer's Representative.

Where any surface fails to comply with the Specification in respect of finish, dimensional tolerance, or in any other way, the Contractor shall rectify the work as agreed with the Employer's Representative.

The Contractor shall be responsible for preventing any damage to the finished concrete surfaces and shall adopt any necessary protective measures to prevent subsequent staining from any cause.

10.1.8.6 Curing

The concrete shall be protected from damage due to load overstress, heavy shocks, excessive vibrations and the effects of rain and running water particularly during the curing period.

Curing and protection of concrete in cold weather shall be carried out in compliance with IS 7861 Part.

All concrete should be allowed to cure by methods which will ensure the production of concrete of the specified quality.

Curing materials and methods shall be compatible with any subsequent waterproofing.

In general, concrete shall not be placed when the temperature at the location of the Work is below, or likely to fall below, 5°C before the section of work can be completed except in emergencies.

Concrete shall be continuously moist cured from the time that the concrete has hardened sufficiently to prevent damage to the surface finish and shall be continued for not less than 14 days for concrete not containing fly ash and 21 days for concrete containing fly ash or until fresh

concrete has been placed on or against the concrete surface or until a membrane curing compound has been applied. All material and equipment required for adequate curing and protection shall be on hand before concrete placement begins.

Concrete shall be protected from exposure to rain for 12 hours, from exposure to the sun for 72 hours and from exposure to flowing water for 14 days. For concrete surface temperature below 5°C, the duration of curing shall be extended for the number of days the temperature has been below 5°C.

Concrete shall be moist cured by maintaining the surfaces continuously wet for the duration of the specified curing period.

During the curing period concrete shall not be intermittently wetted and allowed to dry.

Curing water temperature shall not exceed 25 grade Celsius or above the expected minimum ambient temperature of the curing period.

At least 14 days prior to the use of curing compound, full details of the proposed compound shall be submitted to the Employer's Representative for review. Such details shall be accompanied by test certificates to show that the compound will give satisfactory results for the proposed application.

Curing compound shall be wax-based compounds and shall be approved by the Employer's Representative. The compound shall be applied in strict accordance with the manufacturer's Specification and shall be applied as soon as the surface water has disappeared.

Curing compounds shall be delivered to the Site in suitably labelled containers to enable identification of the batch number and date of manufacture.

Curing compounds shall comply with the requirements of ASTM C309.

For each curing compound proposed for use in the Works, the Contractor shall obtain a Certificate of Compliance from the supplier, supported by test certificates from a laboratory with appropriate registration, certifying that the curing compound complies with this Specification.

The curing compound shall be applied by a pressurised sprayer to give a uniform cover. The sprayer shall incorporate a device for continuous agitation and mixing of the compound in its container during spraying.

The curing compound shall be applied using a fine spray at a rate of 0.2 litres/m^2 and per coat or otherwise directed by the Employer's Representative. The application rate shall be checked by calculating the amount of curing compound falling on felt mats, each approximately 0.25 m2 in area, placed on the concrete surface.

Two coats shall be applied at the full rate. The curing compound shall be applied to unformed surfaces immediately after completion of all finishing operations, and to formed surfaces within half an hour of the removal of formwork from the section.

10.1.9 Joints

Joints in concrete are either movement (deflection, expansion or contraction) joints or construction joints. All construction joints shall comply with IS 11817.

Joints shall be formed on horizontal or vertical planes except for joints in tunnel linings which shall be formed on radial planes.

Joints in horizontal planes, which intersect with exposed surfaces making an angle of 45° or more with the horizontal, shall be truly horizontal. Joints in horizontal planes, which intersect with exposed surfaces making an angle of less than 45° with the horizontal, shall be formed to provide at least 75 mm of surface normal to the slope of the surface.

Construction joints shall be positioned only where agreed with the Employer's

Representative. The Contractor's proposal on constructions joints shall be given on lift drawings submitted to the Employer's Representative for review.

Formed construction joints shall be formed using purpose-made stop ends. Expanded metal stop ends shall not be used.

Unformed construction joints shall be formed using a grout check or similar so that the exposed edge is a crisp true line.

The joint surface shall be either: brushed using water to remove laitance and expose the aggregate without disturbing it, treated with retarder and then water-jetted to remove laitance and expose the aggregate to a depth of not less than 3 mm without disturbing it, or lightly roughened by light chipping or needle-gunning of set concrete. Hacking of set concrete shall not be permitted.

Construction joints shall be clean and damp, with no standing water, immediately before wet concrete is placed against them.

At horizontal construction joints on exposed surfaces forms shall be constructed with strips to produce a straight joint at the exposed surface, unless otherwise directed.

Movement joints shall be constructed as shown on the drawings. The Contractor shall provide the various joint components and install these in accordance with the drawings and the manufacturer's recommendations, or as directed or approved by the Employer's Representative.

Any material used for expansion joint filler shall be approved by the Employer's Representative.

Sealing compound is applied as surface sealant for movement joints or other boundaries of construction elements. The compound shall be polyurethane-rubber type or other type approved by the Employer's Representative. 56 days prior of any sealing compound is applied, the Contractor shall submit a sample of the proposed sealing compound together with the manufacturer's technical data and the details of the recommended method of application for approval.

10.1.10 Water Stops

Water stops shall be installed as shown on the drawings or as directed by the Employer's Representative.

Detailed information on all water stops, their properties, installation and standard support, shall be submitted to the Employer's Representative for approval. Only approved water stops shall be used in the Works and the manufacturer's regulations and instructions shall be followed.

All joints of sealing strips shall be welded by the appropriate device to the tensile strength at least 80% of the initial material.

Prior to any concrete work the water stops shall be placed as given in the drawings and adequate measures shall be made to prevent a dislocation of water stop due to concreting works.

Thermoplastic sunken sealing strips for construction joints shall be in compliance with DIN 18541.

10.1.11 Quality Check & Tolerances

The Contractor shall keep logs on all his concrete activities, i.e. production, placing, supervision and production control, inspection and testing. These logs shall be available to the Employer's Representative for examination at any time.

The Contractor shall supervise and inspect the concrete works to fulfil the provisions of this Specification. This applies to the inspection of materials and products, of concreting execution, of false work and formwork, of reinforcement, of concreting operations and of pre-cast concrete elements.

The Employer's Representative may at any time, unless critical concrete work is done, inspect and test any Contractor's equipment intended for batching, mixing, transporting, placing and testing concrete.

10.1.11.1 Trial Mix Testing

In conjunction with the design of concrete mixes, the Contractor shall complete a laboratory trial mix program for each class of concrete. The trial mix program will be used to confirm to the satisfaction of the Employer's Representative, that the proposed concrete mix designs will produce

concrete having the properties required by the Specification with minimum cement content.

Unless otherwise agreed with the Employer's Representative, field trial mixes shall be prepared under full-scale site conditions at least 35 days before the commencement of concreting and tested in accordance with IS 10262, BS EN 12350 and BS EN 12390.

For each concrete plant proposed by the Contractor the field trial mixes shall be tested separately.

The field trial mixes shall be tested to determine compliance under statistical evaluation where required by BS EN 206. An acceptable value for the limits of the required properties shall be established during the trials which shall thereafter be used to monitor the Quality Control of the mixes and set the standard of compliance.

In the event quality control tests indicate that concrete below the specified standards is being produced, the Employer's Representative may order such adjustment of mix design, additional quality control, or other measures as it may deem necessary to raise quality to specified standards.

If, at any time during the Work, the Contractor proposes to change or modify the source, type or quality of any concrete material or materials for the selected concrete mix designs, the laboratory testing program shall be repeated for each class of concrete affected by the proposed change.

Detailed test results on the concrete mix designs with changed or modified materials shall be submitted to the Employer's Representative not more than three days after the completion of each test.

The 28 day compressive strength test results and details of the changes or modifications to the concrete mix designs proposed by the Contractor shall be provided to the Employer's Representative before the changed or modified concrete mix designs are used to produce concrete for the works.

The following minimum values of samples shall be taken for trial mix testing:

- nine compression test cylinders (3 for each of 3, 7 and 28 days)
- six shrinkage test prisms
- three test cubes (200 mm) or slabs (200 mm x 200 mm x 120 mm) for water permeability testing according to DIN 1048 Part 5
- one specimen for sulphate and chloride testing

10.1.11.2 Conformity Control of Concrete

In the event the specified strength criteria are not met, the Employer's Representative may, if he

deems it necessary, require that the unacceptable concrete be cut out and replaced.

The conformity control of strength parameters required shall be demonstrated in accordance with BS EN 206-1. Specimens tested to demonstrate compliance will be cubes, cylinders or prisms appropriate to the testing standards and BS EN 206-1.

Test samples shall be made, cured, stored, transported and tested according to BS EN 12350 and BS EN 12390. Spot samples will not be used to evaluate strength parameters.

Concrete cube test results will be acceptable if statistical analysis of the results meets the requirements of BS EN 206-1.

Concrete shall be tested for durability properties by means of absorption and capillary suction (sorptivity) tests where appropriate. An appropriate test method will be agreed by all parties before testing is undertaken.

Compaction factor, slump, Vebe, flow table or other workability tests shall be carried out as required during concreting of permanent works to control workability at the batching plant and at the site of the pour. The degree of workability shall be as specified or as determined during the trial mixes. Permitted tolerances shall be in accordance with BS EN 206. Samples tested will be either spot samples or composite samples taken in accordance with BS EN 12350-1 and the appropriate tolerances for compliance will be applied in each case.

Where inspection reveals non-conformity, appropriate measures shall be taken in accordance to EN206-1 and in agreement with the Employer's Representative.

10.1.11.3 Production Control of Concrete

All concrete shall be subject to production control by the Contractor in accordance to EN 206. All data of production control shall be recorded by the Contractor and made available to the Employer's Representative at any time.

10.1.11.4 Tolerances

Surface finishes shall generally conform to the types and tolerances indicated in Table 21 unless otherwise specified herein, as shown on the drawings or as required by the Employer's Representative.

The Contractor shall carry out a cover meter survey over all reinforced concrete surfaces within 24 hours of removal of formwork. The cover survey shall be undertaken on a 500 mm grid over the whole structure. Access for the Employer's Representative to verify cover meter surveys shall be provided.

The deviation of the inner face of the concrete lining according to the theoretical cross section may

in general not exceed 50 mm to the inner side. At the lower side wall (walkway level/cable duct) the deviation of the inner face is limited to the inner side in order to maintain minimum dimensions of the cable ducts. Pre-cast concrete cover plates for the cable ducts shall be fabricated based on the as-built survey results. No tolerance will be permitted inside of the specified clearance profile for vehicles or pedestrians.

In any case and for all specified deviations permitted, the specified theoretical thickness for the inner concrete lining as well as the specified clearance profile for the roadway and the walkways shall be maintained.

Niches, recesses and similar structures are to be constructed with a tolerance of +/-50 mm related to the designed stationing.

Pre-cast elements and other structural elements are to be constructed and placed with a tolerance of +/-15 mm, related to the theoretical tunnel cross section.

Table 22: Types and tolerances for finishing of concrete surfaces

Type of finishing	General areas of application and method of forming	Tolerances in mm
F1	Formed surfaces of construction joints and other surfaces which will not be permanently exposed, including surface upon or against Which backfill or concrete is to be placed. Minor blemishes caused by entrapped air or water will be accepted. In general the surface will require no treatment after form removal, other than repair of defective concrete and specified curing, or treatment as specified for construction joints.	+10
F2	All permanently exposed formed surfaces for which type F3 finish is not specified. For which sheating or lining shall be placed so that joint marks on the concrete surface will be in general alignment, both horizontally and vertically, and conform to a standard pattern. Immediately on the removal of forms, all unsightly ridges or fines shall be removed, all holes left by removal of ends of form rods shall be neatly filled with mortar and surfaces treated to meet the required tolerances by tooling and rubbing. In general, not more than 50 air voids of 5-15 mm diameter per m' will be accepted. Air voids exceeding 15 mm in diameter shall be repaired. When filling holes and repairing defective areas of permanently exposed surfaces, effort shall be made to match the colour of the concrete. The use of release agents which may permanently stain or discolour the finished surface will not be permitted.	+5 -5
F3	Formed surfaces which will be exposed to flowing water. These surfaces shall be hard, smooth and dense, free from offsets, pits, voids, air holes and irregularities and shall be chipped, ground and thoroughly cleaned as necessary to conform to the required tolerances.	+3 -3
U1	Unformed, screeded surface which will be covered by fill materials, static water or concrete. Type U1 finish shall be used as the first stage. Types U2 and U3 as finishes. Finishing shall consist sufficient levelling and screeded to produce an even, uniform surface meeting the required tolerance.	+10 -10
U2	Unformed surfaces not permanently concealed by fill or concrete or not required to receive Type U3 finish. Floating by means of hand or power driven equipment shall be started as soon as the screeded surfaces has stiffened sufficiently, and	+5 -5

Type of finishing	General areas of application and method of forming	Tolerances in mm
	shall be the minimum necessary to produce a surfaces that is free from screed marks and that is uniform in texture. If type U3 finish is to be applied floating shall be continued until a small amount of mortar without excess water is brought to the surfaces so as to permit effective trawling.	
U3	Unformed, screeded surfaces which will be exposed to flowing water. This finish shall be applied by steel trawling after the concrete has hardened enough to prevent excess of fine materials and water from blemishes, ripples and trowel marks. After the surface has nearly hardened, it shall be trowelled once more until the surface is hard and glossy in appearance.	+3 -3

10.1.12 Repair of Damage

All irregularities on concrete surfaces shall be repaired to produce smooth, uniform surfaces that conform to the tolerances specified herein for the finishes shown on the drawings.

The Contractor shall notify the Employer's Representative not less than 24 hours prior to the start of any concrete repairs.

Surface irregularities shall not be repaired until they have been inspected by the Employer's Representative. The Employer's Representative will inspect the surface irregularities and determine whether the surface irregularities shall be repaired by cutting out the concrete to a depth of 75 millimetres beyond the reinforcing bars and filling the cavity with cement mortar or concrete, or whether the concrete shall be cut out to a shallower depth and the cavity filled or patched with cement mortar or saran latex dry pack mortar or epoxy sand mortar, or an alternative mortar approved by the Employer's Representative. The Employer's Representative will also determine the extent to which concrete shall be cut out, the shape of the resulting cavity, the material that is to be used for the repairs and whether the filling shall be secured with keys, dovetails or anchors. Reinforcing steel bars shall not be cut.

Should the concrete exhibit any form of cracking at 28 days, in excess of 0.15mm width, it shall be brought to the attention of the Employer's Representative. The Employer's Representative may, at his discretion and based on the particular crack location, require that the crack be repaired. Where so instructed, the concrete shall be repaired using an epoxy injection system or other approved method of permanent crack repair. Repairs using an epoxy injection system shall not be performed for at least 56 days from the original date of concrete placement.

Repairs shall be performed only in the presence or on direction of the Employer's Representative.

The Contractor shall repair all leakage spots in concrete joints or elsewhere in agreement with the Employer's Representative.

10.2 Lean Concrete

The strength class C12/15 shall be applied for wet lean concrete. With the following constituents:

- Cement shall be in accordance with Clause 11.4.2.1
- Water/cement ratio shall be in accordance with Clause 11.4.2.2
- Aggregates shall be in accordance with Clause

Consistence shall comply with Clause 11.4.3.1.

Wet lean concrete shall be spread uniformly, without segregation and without varying degrees of pre-compaction. The concrete shall be struck off to a level so that the surcharge is sufficient to ensure that after compaction the surface is at the required level.

The spread wet lean concrete shall be compacted using internal or external vibration, or a combination of both to meet the required density.

At transverse and longitudinal construction joints between two separately constructed slabs, the previously laid slab end or edge shall present a vertical face before construction of subsequent slabs.

Longitudinal joints in wet lean concrete shall be staggered by at least 300 mm from the position of longitudinal joints in any superimposed concrete slab, and by 1m for transverse joints.

Curing of wet lean concrete shall comply BS EN 12390-2 as appropriate.

The density shall be determined as in Clause 11.4.3.3 and sampling shall be as specified therein.

The surface of the wet lean concrete after compaction and finishing and before overlaying shall be free from ridges, loose material, pot holes, ruts or other defects. The surface of wet-laid concrete bases shall be roughened before the application of any curing compound by brushing with a wire brush or stiff broom.

Trial concrete mixes shall conform with BS 8500-2 for designed concretes for strength class C12/15 and above, unless recent data relating entirely to the proposed concrete, satisfies the requirements of the Specification.

At least 10 days before the start of the main wet lean concrete works a trial length of at least 400 m^2 for mechanised construction and 30 m^2 for hand-guided methods shall be constructed. The trial length shall be laid to assess the suitability of the proposed material, plant, equipment and construction methods to meet the requirements of the Specification. The main construction in the Permanent Works shall not start unless the trial length complies with the Specification. If any trial length does not conform to the Specification another trial length shall be constructed. Trial lengths not complying shall be removed unless they can be rectified to comply with the Specification.

After satisfactory completion of the trial, the material, plant, equipment and construction methods shall not be changed unless the Contractor lays a further trial length to assess the suitability of the proposed changes or agrees the changes with the Employer's Representatives.

10.3 No-Fines Concrete

No-fines porous concrete shall be used for the surround of ground water drainage pipes in tunnels at locations indicated on the drawings.

No-fines porous concrete shall be composed of ordinary Portland Cement and 37.5 mm single size aggregate complying with Clause 10.1.3.1.

The ratio of aggregate to cement shall be 8:1 by volume or 10:1 by mass.

The concrete shall be mixed by machine or by hand to a uniform colour and consistency before placing. The quantity of water used shall not exceed that required to coat all of the aggregate particles without forming excess grout.

No-fines concrete shall be compacted by hand.

10.4 Reinforcement

10.4.1 General

The items of work falling within the scope of work under this section shall be in accordance with the Indian and European Standards Specification (Latest edition) given under:

- IS:280-1978: Specifications for mild steel wire for General Engineering purposes
- IS:432-1966/82: Specifications for mild steel and medium tensile steel bars and hard drawn steel wire for concrete reinforcement
- IS:432 (Part I): Mild steel and medium tensile bars
- IS:432 (Part II): Hard drawn steel wire
- IS:456-1978: Code of practice for plain and reinforced concrete
- IS:814-1974: Specifications for covered electrodes for metal arc welding of structural steel
- IS:814 (Part I): For welding products other than sheets
- IS:814 (Part II): For welding sheets
- IS: 1139-1966: Hot rolled mild steel medium tensile steel and high yield strength deformed bar for concrete reinforcement
- IS: 1786-1979: Specifications for cold worked steel high yield strength deformed bars for

concrete reinforcement

- IS:2502-1963: Code for practice for bending and fixing of bar for concrete reinforcement
- IS:5525-1979: Recommendations for detailing of reinforcement in reinforced concrete constructions
- IS:9417-1979: Recommendations for welding cold-worked bars for reinforcement concrete constructions
- BS EN 10080: Steel for the reinforcement of concrete. Weldable reinforcing steel. General
- BS 4449: Steel for the reinforcement of concrete - Weldable reinforcing steel - Bar, coil and decoiled product
- BS 4482: Steel wire for the reinforcement of concrete products. Specification
- BS 4483: Steel fabric for the reinforcement of concrete

The Contractor may adjust the position of lap joints to fit in with available stock lengths, or construction joints, subject to the Employer's Representative's agreement to the altered positions. The Contractor shall amend the bending schedules, as necessary, to allow for such alterations.

Reinforcement shall be obtained from a Certificated Authority for Reinforcing Steels Quality Assurance approved supplier and the Contractor shall provide copies of the manufacturer's certificates of test results relating to the steel reinforcement to be supplied.

Reinforcing steel bars and welded steel wire fabric may be stored outside in an approved manner provided that they do not rust and are placed on sleepers which will prevent the steel from coming into contact with the ground and a protection against contact with aggressive elements is provided.

Reinforcing steel bars shall be free from dirt, oil, flaky rust, loose mill scale and any other coating that would destroy or reduce the bond with the concrete.

Tying wire shall be 1.6 mm diameter soft annealed mild steel, and when fixed shall not project into the concrete cover.

Where the Contract so requires, the Contractor shall produce bending schedules.

10.4.2 Placing and fastening

Placing and fastening of reinforcement shall comply with IS 456 unless specified otherwise herein.

All reinforcement shall be accurately placed, securely fixed and adequately maintained in the positions shown on the drawings. The reinforcement shall be fixed so that the cover specified on

the drawings is achieved, subject to the tolerances specified therein.

Reinforcing steel bars shall be installed as shown on the drawings and shall be solidly attached to the formwork. Reinforcing steel bars shall be tied together with wire ties to form a rigid grid which shall be supported in its required position, on chairs and with spacers and hangers. The wire ties shall be used in a staggered pattern at a spacing not exceeding 60 centimetres. Reinforcing steel bars shall be accurately placed within the specified tolerances and shall be secure against displacement during concrete placement.

Reinforcement shall not be re-bent on site unless agreed with the Employer's Representative.

The minimum clear distance between parallel reinforcing steel bars shall be the nominal diameter of the reinforcing steel bars or 1.25 times the maximum size of the coarse aggregate, whichever is the greater, provided that the minimum clear distance between parallel reinforcing steel bars in beams shall not be less than 30 millimetres and in columns shall not be less than 50 millimetres.

Spacer blocks shall be of comparable strength, durability and appearance to the surrounding concrete and shall be factory produced. Site-produced concrete or mortar cover blocks shall not be used.

Spacers and chairs shall ensure that the reinforcement is correctly positioned, be as small as possible consistent with their purpose, and designed so that they will not overturn or be displaced when the concrete is placed. Wire cast in the block for the purpose of tying it to the reinforcement shall be as specified below.

Prior to placing reinforcement on rock or gravel foundation, the foundation shall be covered with at least 50 mm thick layer of concrete or other approved cover.

Tying wires shall be 1.6 mm soft annealed iron wire unless drawings require the use of stainless steel tying wire. Where stainless steel tying wire is required it shall be 1.2 mm diameter stainless steel wire throughout the structure.

Projecting ends of ties or clips shall not encroach into the concrete cover.

Overlap between adjacent sheets of welded wire fabric shall be a minimum of 2 squares.

Concreting shall not commence until the reinforcement has been inspected in accordance with the Inspection and Test Plan.

10.4.3 Splicing

Joints or splices in reinforcing bars shall generally be made at the positions shown on the drawings, but the contractor would be permitted to make joints or splices at positions other than those shown on the drawings, providing that such positions are approved by the Employer's

Representative-in-Charge and that joints and splices in adjacent bars are staggered if directed by the Employer's Representative-in-Charge.

Approval of such additional splices will generally be restricted to splices not closer than 8 m in horizontal bars or 4 m in vertical bars measured between mid-points of laps. The number of splices shall be kept to a minimum.

If the Contractor proposes to use mechanical couplings for reinforcing bars, he shall submit samples of the proposed coupling to the Employer's Representative for approval not less than 60 days prior to their proposed use.

10.5 Formwork

10.5.1 General

Material and workmanship shall comply with IS 456 and IS 14687.

The supply of all labour, supervisors, Contractor's equipment and materials and the execution of all work necessary to design, supply, fabricate, erect, treat, support, brace, use, remove and dispose of formwork for retaining and forming concrete structures as specified herein and as shown on the drawings shall be provided by the Contractor.

Not less than 60 days prior to the start of fabrication of formwork and falsework for each structure or part of a structure, the Contractor shall submit to the Employer's Representative design calculations and erection drawings showing the formwork and falsework for that structure or part of the structure. The general method and system proposed shall be submitted in detailed drawings of the formwork to the Employer's Representative for agreement.

The erection drawings shall indicate the method and schedule of construction, member sizes and type, grade and quality of materials, the arrangement of joints, splices, liners and locations of temporary openings and embedded parts. Details of mechanical equipment that will operate or be supported on the falsework, shall be submitted with the erection drawings. Design assumptions, loads and allowable stresses shall be indicated on the erection drawings.

All formwork shall be dimensioned, constructed and securely braced as to prevent displacement.

All joints in the formwork and between the formwork and previous work shall be sufficiently tight to prevent loss of liquid from the concrete.

Formers for all chases, grooves, recesses, etc. shall be securely fixed as part of the formwork. No part of the concrete shall be cut away for any such item, or for any other reason, without the Employer's Representative's agreement.

The face of the formwork shall be clean and applied with non-staining release agent. The agent

shall not touch reinforcement, or items to be embedded, and shall not be allowed to collect in the bottom of the formwork, or flow onto previously placed concrete.

Before any concrete is placed, the Contractor shall examine and clean out the formwork and ensure that the specified reinforcement cover is attained.

Where cyclical casting, e.g. in-situ concrete tunnel lining, striking times may be agreed with the Employer's Representative following criteria determined from trial lengths.

10.5.2 Material Requirements

The surface of steel plate formwork and steel faced lumber formwork shall be smooth and free from dents, buckles and other surface irregularities. The sheathing for steel formwork shall be steel plate not less than three millimetres thick. All bolts and rivet heads shall be countersunk. Means shall be provided to ensure a snug fit of steel plate sheathing and steel faced sheathing against previously hardened concrete so as to provide smooth joints.

Lumber used for formwork shall be free from warp, loose knots and decay and shall be sawn straight and dressed smooth.

Plywood shall be non-warping and non-wrinkling and shall be manufactured with waterproof glue. Only plywood sheets with identical length and width shall be used.

Fillers for repairing and reconditioning formwork shall be subject to approval by the Employer's Representative. All filler material shall be sanded flush and sealed with an approved sealer to prevent adhesion to the concrete.

10.5.3 Tunnel Formwork

Formwork for tunnel lining shall be constructed in such lengths that each concrete placement can be completed without cold joints.

Concrete pads, pedestals and other means to support tunnel formwork shall be subject to approval by the Employer's Representative on the basis of the effects of such supports on the structural properties of the tunnel section and on the finish of the lining.

Formwork for tunnel lining above the invert shall be provided with rows of openings along each side. The bottom row shall be located with the centreline of the openings above the longitudinal construction joint at the invert. Successive rows shall be located on two meters centres above the next lower row. The rows of openings shall be staggered. Openings shall permit access for inspection and vibration of concrete being placed behind the formwork. Each row of openings shall be provided with a platform for access to the openings. Openings shall be located at a minimum spacing of 2.5 meters along the tunnel centreline and up the tunnel walls. Openings shall be not

smaller than 45 by 60 centimetres, with the long dimension parallel to the centreline of the tunnel.

10.5.4 Execution

10.5.4.1 Preparation

Formwork shall be constructed in strict accordance with the erection drawings after they have been reviewed by the Employer's Representative and shall produce concrete conforming to the lines, slopes, elevations and dimensions and with the surface finishes shown on the drawings. Joints between formwork sections shall be sufficiently tight to prevent loss of mortar from concrete. Formwork shall be securely tied and anchored to maintain shape and position and to avoid warping and bulging.

Formwork for curved surfaces shall be constructed to conform accurately to the required curvatures of the surfaces within the allowable tolerances specified.

Formwork joints shall fit together without gaps greater than two millimetres at any point. The joint marks on the concrete surface in the water passages shall follow in general the line of water flow. Forms shall be placed so that the joint marks on concrete surfaces will be in alignment both horizontally and vertically and the joint marks between surfaces shall be smooth.

10.5.4.2 Installation

Formwork shall be braced to maintain its position and shape. Formwork and falsework shall be arranged for ease of dismantling and stripping to ensure that its removal will not damage the concrete. Formwork blocking and supports to be left permanently in the concrete shall be fabricated of steel.

The interior surfaces of formwork shall be covered with colourless mineral form oil or other bond breaking compound approved by the Employer's Representative. The bond breaking compound shall be applied before reinforcing steel bars are placed. Form oil or bond breaking compounds shall not come in contact with reinforcing steel bars or with concrete surfaces on which additional concrete, epoxy mortar or any bonded coating is to be placed.

10.5.4.3 Tolerances

Formwork and falsework shall be constructed, located, supported and braced in such a manner that the finished surfaces of concrete structures are within the allowable construction tolerances as defined in Clause 10.1.11.4 of this Specification.

10.5.4.4 Concrete Placement

Temporary openings shall be provided in the formwork at any place where necessary to facilitate concrete placement, insertion of vibrators, cleaning and inspection. The temporary openings shall be closed with removable panels that are flush with the formwork surface on the inside. Immediately before concrete is placed, formwork shall be inspected to ensure that it is accurately placed, rigid, tight, clean and free from foreign matter.

Inspection of formwork by the Employer's Representative and approval to proceed with concrete placement shall not relieve the Contractor of his responsibility for safety and accuracy of the Work. Any repairs of concrete due to faulty or inaccurate formwork shall be done by the Contractor at no additional cost to the Employer.

10.5.4.5 Quality Control

The alignment and position of formwork shall be checked frequently during concrete placement. Any misalignment shall be corrected by wedging and shoring.

Formwork and falsework may be reused, provided that the material is undamaged and the surface in contact with concrete is cleaned and is capable of producing the required surface finish. Timber and plywood formwork shall not be repaired with metal patches.

10.5.4.6 Removal

Formwork shall be removed in such a manner as to prevent concrete spalling and to produce sharp and clean joints.

Formwork shall be eased, struck or removed in such a manner that the structure is not distorted, damaged or overloaded.

Except where otherwise agreed with the Employer's Representative, formwork shall not be eased or struck until:

- the concrete has attained sufficient strength to support itself in the position cast without deformation or
- a minimum period in line with Section 6 of ENV 13670-1
- vertical forms and formwork for tunnel crown lining may be removed when the concrete has attained a compressive strength of min 6 MPa, deduced from the strength development of comparable test specimens cured under similar conditions
- 10 hours after concrete placing unless measures are taken to prevent excessive cooling and drying. These measures shall be agreed with the Employer's Representative

10.5.5 Design and Installation Criteria

Formwork and falsework shall be designed to withstand, safely and without distortion, all loads that will be applied before, during and after concrete placement. The design loads shall include wind, concrete, equipment and personnel. Formwork shall be designed to permit the concrete to be deposited as nearly as practicable directly in its final position and shall have access facilities that will allow inspection, checking and clean-up of the surface of the preceding concrete placement and inspection and vibration of the concrete.

10.6 Design Life and Grade of Concrete Lining in Tunnel

- Minimum Grade of concrete lining M35 conforming to IS 456
- Design life of tunnel lining 100 years

11 PAVEMENT

11.1 General

The Contractor shall furnish all materials, equipment and labour necessary for permanent roadwork as shown on the drawings or as directed. The design for the permanent roadwork will be provided by the Employer.

The Contractor shall design and furnish all materials, equipment and labour necessary for construction roads or tracks to other work sites, to spoil areas, to installation areas and to camps to the extent that he considers necessary for his activities. These roads shall be constructed at the minimum standard necessary for the Contractor to safely execute the Works. The layout and design for all temporary roadwork shall be provided by the Contractor and approved by the Employer before the work commences.

The Contractor shall place compacted and treated, if necessary, selected backfill, either from required excavations or approved borrow areas, to completed structures as shown on the drawings or as directed. The Clause 6.7 for backfill material shall be applied accordingly.

All permanent road work, materials, workmanship, quality, construction tolerances, testing and etc. shall be carried out in accordance with the "Specifications for Road and Bridge Works" by Ministry of Road Transport and Highways (MoRTH 2000), unless otherwise specified in the drawings or as directed by the Employer's Representative. This requirement applies to both the road outside the tunnel or portal buildings/structures as well as that inside these. The main Clauses of the "Specifications for Road and Bridge Works" (MoRTH 2000) which shall be applied are summarized in this Specification.

11.1.1 Tolerances

The design levels of pavement courses shall be calculated from the vertical profile, crossfalls and the pavement course thicknesses as described in relevant drawings. The level of any point on the constructed surface of the pavement courses shall be the design level subject to the appropriate tolerances stated in Table.

Table 23: Tolerances in surface levels of pavement courses

Pavement course	Tolerances
General Adjacent to a surface water channel[11]	± 6 mm + 0-10 mm
Base under concrete pavement surface slabs laid full thickness in one operation by machines with surface compaction	± 10 mm
Unbound sub-base layer	+ 10-30 mm

[1] Where a surface water channel is laid before the adjacent road pavement layer the top of that layer, measured from the top of the adjacent edge of the surface water channel, shall be to the given tolerances.

Notwithstanding the tolerances permitted in surface levels of pavement courses, the cumulative tolerance shall not result in a reduction in thickness of the pavement, excluding the sub-base and filter layer, by more than 15 mm neither from the specified thickness nor a reduction in the thickness of the bituminous surface course by more than 5 mm from that specified.

For checking compliance with this Clause, measurements of the surface levels of all courses shall be taken on a grid pattern in agreement with the Employer's Representative.

The longitudinal regularity of the surfaces of surface courses, binder courses and concrete slabs shall be such that the number of surface irregularities is within the relevant limits stated in Table 19.

An irregularity is a variation of not less than 4 mm or not less 7 mm of the profile of the road surface as measured by the rolling straight-edge set at 4 mm or 7 mm as appropriate or equivalent apparatus capable of measuring irregularities within the same magnitudes over a 3 m length. No irregularity exceeding 10 mm shall be permitted.

Prior to checking any final road surface, it shall be cleaned of loose or extraneous materials. These operations shall be carried out without damaging the surface of the pavement as soon as possible and within 3 days of construction of the pavement.

Compliance with Table 23 shall be checked by the rolling straight-edge along any line or lines parallel to the edge of pavement on sections of 300 m at regular intervals in agreement with the Employer's Representative, whether or not it is constructed in shorter lengths. Sections shorter than 300 m forming part of a longer pavement shall be assessed using the number of irregularities for a 300 m length pro - rata to the nearest whole number.

Pavements shall be measured transversely for irregularities at regular intervals in agreement with the Employer's Representative, by a 3 m long straight-edge placed at right angles to the centre line of the road. The maximum allowable difference between the pavement surface and the straight-edge shall be 3 mm.

A 3 metres long straight-edge shall be used to check longitudinal surface regularity for all lengths of base layers under concrete pavement slabs laid full thickness in one operation by machine with surface compaction.

The maximum allowable difference between the surface and the underside of the straight-edge, when placed parallel with or at right angles to the centre line of the road, shall be:

- 3 mm for pavement surfaces
- 10 mm for bases under concrete pavements

Table 24: Maximum permitted number of surface irregularities

Irregularity limits	Surfaces of each lane of carriageway, each hard strip and each hard shoulder for each irregularity limit				Surfaces of lay-bys, service areas for each irregularity limit			
	4 mm		7 mm		4 mm		7 mm	
Length [m]	300	75	300	75	300	75	300	75
Number of irregularities	40	18	4	2	60	27	6	3

11.1.2 Rectification

Where any pavement area does not comply with the Specification for regularity, surface tolerance, thickness, macrotexture depth, material properties or compaction, the full extent of the area which does not comply with the Specification shall be made good and the surface of the pavement course shall be rectified in the manner described below:

- Unbound base layer: The top 75 mm shall be scarified, reshaped with material added or removed as necessary, and re-compacted. The area treated shall be not less than 30 m long and 2 m wide or such area as necessary to obtain compliance with the Specification.
- Bituminous bases: With coated macadam or asphalt bases, the full depth of the top layer as laid shall be removed and replaced with fresh material laid and compacted in accordance with the Specification. Any area so treated shall be at least 5 m long and the full width of the paving laid in one operation. Alternatively, for low areas in bituminous bases, the Contractor may make up the level with additional binder course material.
- Concrete slabs: Concrete slabs shall be rectified by planning, grinding or bump cutting. Large depressions, which cannot be dealt in this way, shall be rectified by cutting out the surface and replacing by a thin bonded surface repair. Where the slab cannot be rectified as above, the full depth of slab shall be removed and replaced with a slab constructed in compliance with these

Specifications. Remedial works involving the placing of fresh concrete shall be completed in sufficient time for the concrete strength which have to be developed as specified before that section of pavement is opened to traffic.

11.2 Unbound Sub-Base Layer

11.2.1 General

This work shall consist of laying and compacting well-graded material on prepared sub-grade in accordance with the requirements of these Specifications. The material shall be laid in one or more layers as sub-base as necessary according to lines, grades and cross sections shown on the

drawings or as directed by the Employer's Representative.

The sieve size distribution shall be in compliance with Table 24 as per MoRTH (2000).

Table 25: Grading for unbound sub-base layer

Designation	Per cent per weight passing
75.0 mm	-
53.0 mm	100
26.5 mm	70-100
9.5 mm	50-80
4.75 mm	40-65
2.36 mm	30-50
0.425 mm	15-25
0.075 mm	3-10

The unbound mixture shall satisfy the minimum CBR value of 25 when it is compacted and finished.

When directed by the Employer's Representative, this shall be verified by performing CBR tests in the laboratory as required on specimens remoulded at field dry density and moisture content and any other tests for the "quality" of materials, as may be necessary and required by the Employer's Representative.

11.2.2 Laying

Unbound mixtures in a frozen condition shall not be incorporated in the Works but may be used, if acceptable, when thawed. Unbound mixtures shall not be laid on any surface which is frozen or covered with ice.

The unbound mixtures of grading specified herein (Table 24) shall be placed and spread on the prepared surface evenly. Unbound mixtures shall be spread using a paving machine or a suitable spreader box and operated with a mechanism which levels off the material to an even depth.

Material up to 225 mm compacted thickness shall be spread in one layer so that after compaction the total thickness is as specified. Material of compacted thickness greater than 225 mm shall be laid in two or more layers and the minimum compacted thickness of any such layer shall be 110 mm. Where the layers of unbound mixtures are of unequal thickness, the lowest layer shall be the thickest layer.

Moisture content of the loose material shall be checked in accordance with IS:2720 (Part 2) and suitably adjusted by sprinkling water uniformly and at controlled quantities to variable widths of surface or other means approved by the Employer's Representative so that, at the time of compaction, it is from 1 per cent above to 2 per cent below the optimum moisture content corresponding to IS:2720 (Part 8). While adding water, due allowance shall be made for

evaporation losses.

11.2.3 Compaction

Compaction shall be completed as soon as possible after the mixture has been spread and in accordance with the requirements for the individual mixtures.

Compaction of unbound mixtures shall be carried out by a method the Contractor demonstrates at site trials that compacted density achieved is at least 98 % of the maximum dry density for the material determined as per IS:2720 (Part 8).

The surface of any layer of material shall on completion of compaction and immediately before overlaying, be well closed, free from movement under construction plant and from ridges, cracks, loose material, pot holes, ruts or other defects. All loose, segregated or otherwise defective areas shall be removed to the full thickness of the layer, and new material shall be laid and compacted.

11.2.4 Site Traffic

Construction plant and other traffic used on pavements under construction shall be suitable in relation to the material, condition and thickness of the courses it traverses so that damage is not caused to the subgrade or the pavement courses which are already constructed. The wheels or tracks of plant moving over the various pavement courses shall be kept free from deleterious materials.

Final excavation levels (formation level) for pavement construction shall be protected against any wear or deterioration of rock properties following site traffic by backfilling with rock material excavated in the tunnel or similar to a minimum thickness of 0.5 metres.

Ponding water and traffic through ponding water shall not be allowed.

Any deteriorated material shall be removed and replaced prior to pavement works as directed by the Employer's Representative.

The backfill material used for protection purposes shall not be removed until immediately prior to pavement construction works.

No site traffic shall be allowed to run on unprotected invert structures, temporary or final, concrete or shotcrete. Structures as such shall be protected against destruction by backfilling with suitable excavation material from the tunnel or similar with a minimum thickness of 0.5 metres. Backfilling material shall not contain boulders larger than 150 mm diameter.

11.3 Bituminous Base Layer

11.3.1 General

Natural, recycled unbound and manufactured (artificial) aggregates shall be clean, hard and durable and shall comply with BS EN 13043.

Irrespective of source, coarse aggregates for bituminous mixtures shall be considered suitable if:

- the resistance to fragmentation category of the coarse aggregate as defined in clause 4.2.2 of BS EN 13043 shall be LA30 or better for natural aggregates and LA50 or better for blast furnace slag or
- crushed rock aggregate has a Los Angeles Value greater than 30 but less than 35, where evidence can be presented to the Employer's Representative of previous satisfactory use of the source in asphalt.

Natural and manufactured (artificial) aggregates recovered from a previous use in an unbound form shall comply with the requirements of this Clause.

The freezing and thawing (soundness) category, as defined in BS EN 13043, clause 4.2.9.2, shall be MS25 unless otherwise specified herein. The water absorption value of the coarse aggregate shall be determined in accordance with BS EN 13043, clause 4.2.9.1. If the water absorption value of the coarse aggregate is greater than WA242, the soundness test shall be carried out on the material delivered to site. The requirements for water absorption do not apply to blast furnace slag aggregate.

Before work commences, the Contractor shall submit a method statement to the Employer's Representative that includes:

- Laying and compaction procedures for each layer - including paving speed and paved width; size, type and number of rollers; and number of roller passes.
- The joint formation procedures for each layer - including the location of longitudinal and transverse joints; and the method(s) of treating upstanding edges.

11.3.2 Placing

In order to exclude moisture from interfaces and ensure full interlayer bonding, the surface of all bituminous material shall be kept clean and uncontaminated. If any surface becomes contaminated, it shall be made good by cleaning and if this proves impracticable, by rectification.

Prior to placing bituminous material on any new or existing bound substrate, a bond coat or tack coat shall be applied in accordance with Clauses 920 or 942, as appropriate.

Hot bituminous mixtures shall be transported in accordance with the requirements of BS 594987 and shall remain covered whilst awaiting tipping.

Wherever practicable, hot bituminous mixtures shall be spread, levelled and tamped by a self-propelled paving machine. The rate of delivery of material to the paver shall be regulated to enable the paver to operate continuously.

Hand placing of hot bituminous mixtures shall be restricted to the following circumstances:

- For laying regulating courses of irregular shape and varying thickness.
- In confined spaces where it is impracticable for a paver to operate.
- For footways.
- At the approaches to expansion joints at bridges, viaducts or other structures.
- For laying mastic asphalt.

The method of laying shall be such that the finished mat is free from dragging, tearing and segregation of the material.

Dense base course asphalt concrete (formerly macadam) recipe mixtures shall be asphalt concrete conforming to BS EN 13108-1.

Bituminous mixtures shall not be laid on layers with a surface temperature beneath 5°C.

The surface tolerances shall be in compliance with Clause 11.1.1.

11.4 Concrete Pavement

11.4.1 General

The work shall consist of construction of unreinforced, dowel jointed, plain cement concrete pavement in accordance with the requirements of these Specifications and in conformity with the lines, grades and cross sections shown on the drawings. The work shall include furnishing of all plant and equipment, materials and labour and performing all operations in connection with the Work, as approved by the Employer's Representative.

Concrete in rigid or rigid composite pavements shall be of the class C32/40 XF4 and shall confirm to the Clauses of Chapter 10 unless given otherwise below.

Prior to commencement of any concrete works the base layer shall be checked of adequate bearing capacity and elevation the tolerances are given in Clause 11.1.1. The check has to be in appropriate time prior to commencement hence measures shall be taken contemporary and no time delay may occur.

If the thickness of the base layer is not in the range of the tolerances the base layer shall be corrected. If this is not possible, the base layer shall be fully replaced.

The base layer shall be clean and free of deleterious material.

The concrete slab shall be laid in two layers. The surface layer shall be laid monolithically with the lower layer. The surface layer shall be not less than 50 mm thick.

11.4.2 Concrete Composition

The concrete composition shall comply with Clause 10.1.3 unless given otherwise below.

11.4.2.1 Cement

The cement content shall be in accordance to Table 21 and means any of the following materials or combinations below:

- Portland cement CEM I, BS EN 197-1
- Portland slag cement CEM II/A-S and CEM II/B-S, BS EN 197-1
- Blastfurnace cement CEMIII/A, CEM III/B BS EN 197-1
- Portland-fly ash cement CEM II/A-V, CEM II/B-V BS EN 197-1
- Pozzolanic cement CEMIV/A BS EN 197-1
- Portland cement CEM I BS EN 197-1with ground granulated blastfurnace slag (ggbs) for use with Portland cement CEM I
- Portland cement BS EN 197-1
- CEM I with pulverised-fuel ash (pfa) for use as a cementitious component in structural concrete BS EN 197-1

Table 26: Minimum cement or combination contents with 40 mm maximum aggregates

Min. Portland cement CEM I, BS EN 197-1 in [kg/m3]	320
Min. other cements or combinations permitted	340
Maximum proportion of ggbs in [%]	25
Max./min. proportion of pfa in [%]	25/15
Min. CEM I content in [kg/m^2] for combinations with pfa and ggbs	255

For 20 mm maximum size aggregate 20 kg/m^3 cement content per cubic meter fully compacted concrete shall be added, and for < 20mm maximum size 40 kg/m^3 cement content shall be added

If the concrete layer shall be laid in two layers, the cement of the surface layer shall be limited to Class 42.5N/42.5R Portland cement CEM I in accordance to BS EN 197-1. The minimum cement

content of the concrete shall be 375 kg/m3.

The cement content shall not exceed 425 kg/m^3.

11.4.2.2 Water

Water from a water company supply may be used without testing. Water from other sources may be used if it conforms to BS EN 1008. The water content shall be the minimum required to provide the specified consistence for full compaction of the concrete to the required density, as determined by trial concrete mixes or other means. The maximum free water/cement ratio shall be 0.45 for strength classes C32/40 and C25/30 and 0.60 for strength classes C16/20 and C12/15.

If the concrete layer shall be laid in two layers, the free water/cement ratio of the surface layer shall be max. 0.40 for strength classes C32/40 and C25/30.

11.4.2.3 Admixtures

Concrete for pavement slab shall incorporate an air-entraining admixture complying with BS EN 934-2 in at least the top 50 mm of surface slabs.

Plasticisers or water reducing admixtures shall comply with BS EN 934-2. Admixtures containing calcium chloride shall not be used.

11.4.2.4 Aggregates

Aggregates for all pavement concrete, including wet lean, shall comply with IS:383 and BS EN 12620 respectively.

The aggregates shall be free from chert, flint, chalcedony or other silica in a form that can react with the alkalies in the cement. In addition, the total chlorides content expressed as chloride ion content shall not exceed 0.06 per cent by weight and the total sulphate content expressed as sulphuric anhydride (S03) shall not exceed 0.25 per cent by weight.

No aggregate which has water absorption more than 2 per cent shall be used in the concrete mix.

If the concrete layer shall be laid in two layers, the surface layer shall comply with following requirements:

- For 6.3/10 mm coarse aggregate or 4/8 mm coarse aggregate the amount of aggregate retained on the 10 mm sieve and 8 mm sieve respectively shall not exceed 3% by mass. The aggregate passing the 6.3 mm sieve and 4 mm sieve respectively shall not exceed 10% by mass.
- The fine aggregate grading shall comply with the 0/2 (FP) or 0/1 (FP) grading in BS EN 12620 except that not less than 99% of the mass of the material shall pass the 2 mm sieve.
- The coarse aggregate shall comprise at least 60% by mass of the oven dry constituents of the

concrete.

- The polished stone value (PSV) and the aggregate abrasion value (AAV) of the coarse aggregate determined in accordance with BS EN 1097-8 shall be PSV50 and AAV15. The Category of flakiness index of the aggregate is FI15.

The resistance to fragmentation of the coarse aggregate shall be of class LA20. The resistance to freezing and thawing shall be of class F1 for the coarse and fine aggregates.

11.4.3 Concrete Requirements

11.4.3.1 Consistence (Workability)

The consistence shall be determined by the Degree of Compactibility (Compaction Index) test in accordance with BS EN 12350-4, or the Vebe test in accordance with BS EN 12350-3. Alternatively, for concrete class C16/20 or below, consistence may be determined by the slump test in accordance with BS EN 12350-2. The sampling for all concrete classes shall be undertaken in accordance with BS EN 12350-1 and the rate of testing in accordance with Table 12 of BS EN 206-1. Consistence shall be carried out at the point of placing, in conjunction with tests for strength and any tests for air content. The consistence shall be maintained at the optimum within the limits specified in BS EN 206-1.

If any determination of consistence gives a result outside the tolerance, a further test shall be made immediately on the next available load of concrete. The average of the two consecutive results and the difference between them shall be calculated. If the average is not within the tolerance or the difference is greater than 0.1 for CI or 20 mm for slump or 6 seconds for Vebe, subsequent samples shall be taken from the delivery vehicles, which shall not be allowed to discharge into the Works until compliance with the Specification has been established.

11.4.3.2 Air content

The concrete shall meet the requirement for exposure class XF4 in BS EN 206-1. This shall be achieved by the use of an air-entraining agent. The minimum quantity of air in air-entrained concrete as a percentage of the volume of the concrete shall be as in Table 26.

Table 27: Minimum air content with respect to max. aggregate size

Max. aggregate size in [mm]	Min. air content in [%]
20	3.5
40	3

The air content shall be determined at the point of delivery to the paving plant by the pressure gauge method in accordance with BS EN 12350-7, at the rate of one determination per 300 m^2 of slab or at least 6 times per day, whichever is the greater, in conjunction with tests for consistence

and strength. For areas less than 300 m^2 the rate shall be at least one determination to each 20 m length of slab or less constructed at any one time or at least 3 times per day. If the air content is outside the specified limits in BS EN 206-1, the Contractor shall remove the concrete from the Works.

The air-entraining agent shall be added at the mixer by an apparatus capable of dispensing the correct dose within the tolerance for admixtures given in Table 18, to ensure uniform distribution of the agent throughout the batch during mixing.

11.4.3.3 Density (Manual of Contract Documents for Highway Works)

The density of a saturated core cut from the full depth of the concrete pavement shall not be less than 95% of the average density of at least six fully compacted saturated moulded specimens made from the same concrete and tested at the same age.

The density of the concrete pavement shall be determined in accordance with BS EN 13877-2. The density of a saturated core cut from the full depth of the concrete pavement shall be determined in accordance with BS EN 12390-7. The determination of the saturated density of the fully compacted moulded specimens shall be in accordance with BS EN 12350-1, BS EN 12390-1 and BS EN 12390-2.

The core shall have an average diameter of at least four times the nominal maximum aggregate size, and in any case at least 100 mm diameter. Where different concrete mixes are used in separate layers, the density of each layer shall be separately determined by splitting or cutting the cores between the layers.

If the density of any core is below the minimum required, the concrete across the whole width of the slab constructed at the time relating to that core shall be removed. In unreinforced concrete the whole slab length between joints shall be removed. For reinforced slabs, in order to determine the limit of the defective area of concrete which shall be removed, additional cores shall be taken at 5 m intervals on each side of any defective core until concrete of satisfactory density is found. Defective areas shall be made good with new material in accordance with the Specification.

In calculating the density, allowance shall be made for any steel in the cores.

Core holes shall be reinstated with compacted concrete with mix proportions of 1 part of Portland cement CEM I: 2 parts of sand: 2 parts of 10 mm single sized coarse aggregate by mass.

11.4.3.4 Pavement concrete strength

Sampling and testing for and compliance with the specified characteristic core strength of designed concretes shall be undertaken by compressive strength testing in accordance with BS EN

13877-2 on cores cut from the full depth of the slab. No correction for maturity shall be applied to the 7 day or 28 day strength.

Concrete cores of the appropriate size shall be taken, cured and tested in accordance with BS EN 12504-1 with the exception that the core shall be cured under water at 20°C ±2°C as soon as practically possible. The sampling rate shall be as designated in BS EN 13877-2 for Category 2, three cores shall be taken from areas of concrete of up to 3000 m^2 and one additional core for every further 1000 m^2 of concrete laid.

An exception to the above sampling rate is that in the trial slab at least six cores shall be taken, three to be tested at 7 days and three at 28 days.

The end preparation of the core shall be by grinding and the height/diameter (h/d) ratio of the tested specimen shall be between 1 and 2.

If during the construction of the trial length the average corrected core compressive strength, from the three cores, falls below the 7 day corrected core compressive strength given in Table 23, then either the cement content of the concrete shall be increased by 5% by mass, or a further trial slab shall be constructed using an improved compaction technique and/or an increased cement content. The increased cement content shall be maintained at least until the three corresponding 28-day core strength tests have been assessed. If the cement content is increased, the concrete shall be adjusted to maintain the required consistence.

Table 28: 7 day corrected core compressive strength

Concrete Class	7 day corrected compressive strength for CEM I concrete in [N/mm²]	7 day corrected compressive strength for CEM I with pfa or ggbs concrete in [N/mm2]
C32/40	32	26.8
C25/30	25	20
C16/20	16.5	13
C12/15	12	10
C8/10	7.5	6.5
C6/8	5	4

Overlapping groups of four consecutive 28 day corrected core strengths shall be used for assessing the pavement for compliance with the criteria in Table A.1 of BS EN 13877-2. The pavement shall be accepted if the criteria in Table A.1 are satisfied for four results derived from strength tests on cores taken from the constructed pavement. Conformity control of the concrete will be the responsibility of Contractor.

11.4.3.5 Finished Surface Requirements

The finished surface of the pavement shall comply with the requirements of Clause 11.1.1. Where a pavement area does not comply with the Specification in any respect, the full extent of the surface

which does not comply shall be rectified in accordance with Clause 11.1.2.

After the final regulation of the surface of the slab and before the application of the curing membrane, the surface of concrete slabs to be used as running surfaces shall be brush-macrotextured in a direction at right angles to the longitudinal axis of the carriageway. The macrotexture shall be applied evenly across the slab in one direction by a brush not less than 450 mm wide. The macrotexture shall be uniform both along and across the slab.

The macrotexture depth shall be determined by the volumetric patch technique as described in BS EN 13036-1. Tests shall be taken within 100 m of commencement of paving and thereafter at least once for each day's paving at the times after construction as given below and in the following manner: 10 individual measurements of the macrotexture depth shall be taken at least 2 m apart anywhere along a diagonal line across a lane width between points 50 m apart along the pavement. No measurement shall be taken within 300 mm of the longitudinal edges of a concrete slab constructed in one pass.

Macrotexture depths shall be as required in Table 28.

Where the required macrotexture depth is found to be deficient the Contractor shall make good the texture across the full lane width over lengths necessary to comply with the requirements of Table 28, by retexturing the hardened concrete surface as described in Clause 11.4.14.

Table 29: Required macrotexture depth and tolerances

Time of test		Required macrotexture depth in [mm]	
		Specified value	Tolerance
between 24 hours and 7 days after the construction of the slab or until the slab is first used by vehicle	an average of 10 measurements	1.0	±0.25
not later than 6 weeks before road is opened to public traffic	an average of 10 measurements	1.0	+0.25 -0.35

11.4.4 Transverse Joints

11.4.4.1 General

Transverse joints shall be provided in unreinforced and jointed reinforced concrete slabs and shall be contraction, expansion or warping joints at spacing of 25 times the plate thickness and with a maximum of 5.0 m, such that for unreinforced concrete slabs the length/width ratio shall be not greater than 1.5.

Joints in the surface slab and sub-base shall be staggered so that they are not coincident vertically and are at least 1 m apart.

Transverse joints shall be straight within the following tolerances along the intended line of the joint, which is the straight line transverse to the longitudinal axis of the carriageway.

- deviations of the filler board or bottom crack inducer from the intended line of the joint shall be not greater than ± 10 mm;
- the best fit straight line through the joint groove as constructed shall be not more than 25 mm from the intended line of the joint;
- deviations of the joint groove from the best fit straight line of the joint shall be not greater than 10 mm.

Transverse joints on each side of a longitudinal joint shall be in line with each other and of the same type and width.

Concrete pavement layers shall be isolated from fixed structures by expansion joints, or earthworks or a granular layer over the structure, or by bridge-type expansion joints, or by lengths of fully flexible pavement construction. End of pavement surface slabs shall have a transition bay leading into the fully flexible construction.

Transverse joints shall have a sealing groove which shall be sealed in compliance with Clause 11.4.10.

11.4.4.2 Contraction Joints

Contraction joints shall consist of:

- a sawn joint groove complying with Clause 11.4.8
- dowel bars complying with Clause 11.4.6,
- a sealing groove complying with Clause 11.4.10.

11.4.4.3 Expansion Joints

Expansion joints shall consist of:

- a joint filler board complying with Clause 11.4.9,
- dowel bars complying with Clause 11.4.6,
- a sealing groove complying with Clause 11.4.10.

The filler board shall be positioned vertically within the prefabricated joint assemblies along the line of the joint within the tolerances of Clause 11.4.4.1, and at such depth below the surface as will not impede the passage of the finishing beams on the paving machines. The joint filler board together with the sealing groove shall provide a complete separation of adjacent slabs and any

spaces around dowel bars and between the sub-base and the filler board shall be packed with a suitable compressible material after fixing the joint assembly.

11.4.4.4 Warping Joints

Warping joints shall consist of:

- a sawn joint groove complying with Clause 11.4.8,
- tie bars complying with Clause 11.4.7, a sealing groove complying with Clause 11.4.10.

11.4.4.5 Construction Joints

Construction joints made at the end of a working day in unreinforced concrete slabs and jointed reinforced concrete slabs shall be contraction joints. In the event of mechanical breakdown of the concreting machinery, or at the onset of adverse weather, emergency joints may be formed.

Emergency joints in unreinforced concrete slabs shall be contraction joints not less than 2.5 m from the preceding or succeeding joint position. The stop end formwork shall be sufficiently rigid to ensure that dowel bars and tie bars will be held in position in compliance with these Specifications.

11.4.5 Longitudinal Joints

11.4.5.1 General

Sawn or wet-formed longitudinal joints shall be provided in surface slabs between or at the centre of traffic lanes within the allowable positions as shown on the drawings, so that bay widths are not greater than 4.2 m. Joints in the surface slab, base or sub-base shall be staggered so that they are not coincident vertically and are at least 300 mm apart.

Wet-formed longitudinal joints shall consist of:

- wet-formed joint grooves complying with Clause 11.4.8,
- a bottom crack inducer,
- tie bars complying with Clause 11.4.7.

Longitudinal joints shall be constructed within the following tolerances:

- deviations of the bottom crack inducer from the intended line of the joint, parallel to the axis of the road shall be not greater than ± 13 mm;
- the joint groove shall be located vertically above the bottom crack inducers within a horizontal tolerance of ± 25 mm;
- the best fit line along the constructed joint groove shall be not more than 25 mm from the

intended line of the joint;

- deviations of the joint groove from the best fit line of the joint shall be not greater than 10 mm.
- Sawn longitudinal joints shall consist of joint grooves complying with Clause 11.4.8

11.4.5.2 Longitudinal Construction Joints

Longitudinal construction joints between separate slabs shall have tie bars as in Clause 11.4.7 with a joint groove as in Clause 11.4.8.

11.4.6 Dowel Bars

Dowel bars shall be Grade B500 steel conforming to BS EN 13877-3 and shall be free from oil, dirt, loose rust and scale. They shall be straight, free of burrs and other irregularities and the sliding ends sawn or cropped cleanly with no protrusions outside the normal diameter of the bar. For expansion joints, dowel bars shall be 25 mm diameter at 300 mm spacing and 600 mm long for slabs up to 239 mm thick and 32 mm diameter for thicker slabs. For contraction joints, dowels shall be 20 mm diameter at 300 mm spacing and 400 mm long for slabs up to 239 mm thick, and 25 mm diameter at 300 mm spacing and 600 mm long for thicker slabs.

Dowel bars shall be supported on cradles in prefabricated joint assemblies positioned prior to construction of the slab. For contraction joints, as an alternative to prefabricated assemblies, dowel bars may be mechanically inserted with vibration into the concrete by a method which ensures full recompaction of the concrete around the dowel bars and the surface finished by a diagonal finishing beam, or a longitudinal oscillating float travelling across the slab.

Dowel bars shall be positioned at mid-depth from the surface level of the slab ± 20 mm and centred equally about intended lines of the joint within a tolerance of ± 25 mm. They shall be aligned parallel to the finished surface of the slab to the centre line of the carriageway and to each other within the following tolerances:

- for bars supported on cradles prior to construction of the slab and for inserted bars in two layer construction prior to placing the top layer:
  - all bars in a joint shall be within ± 3 mm per 300 mm length of bar;
  - two thirds of the bars shall be within ± 2 mm per 300 mm length of bar;
  - no bar shall differ in alignment from an adjoining bar by more than 3 mm per 300 mm length of bar in either the horizontal or vertical plane;
- for all bars, after construction of the slab:
  - twice the tolerances for alignment as above

- equally positioned about the intended line of the joint within a tolerance of 25 mm.

Dowel bars shall be covered by a flexible polymeric corrosion resistant coating. The coating shall be smooth and free of indentations. During coating, the bar shall be supported at each end. Minimum thickness shall be 0.3 mm. The coating shall also be able to withstand 250 hours immersion in a salt fog cabinet complying with BS EN ISO 7253, without showing any visible crazing or corrosion of the protected bar. The coated bar shall comply with the following pull out test:

Four bars shall be taken at random from stock and shall be coated as required in this Clause without any special preparation. The dowel bars which have been coated shall be cast centrally into concrete specimens 150 x 150 x 450 mm, made of the same concrete mix proportions to be used in the pavement, but with a maximum aggregate size of 20 mm and cured in accordance with BS EN 12390-2. At 7 days a tensile load shall be applied to achieve a movement of the bar of at least 0.25 mm. The average bond stress to achieve this movement shall be not greater than 0.14 N/mm^2.

For expansion joints, a 100 mm long closely fitting cap consisting of waterproofed cardboard or an approved synthetic material like PVC or GI pipe shall be placed over the sheathed end of each dowel bar. An expansion space at least equal in length to the thickness of the joint filler board shall be formed between the end of the cap and the end of the dowel bar by using compressible sponge. To block the entry of cement slurry between dowel and cap it may be taped.

11.4.7 Tie Bars

Tie bars in longitudinal joints shall be deformed steel bars of strength 415 N/m^2.

Tie bars for use across joints shall have corrosion protection in the form of a flexible polymeric corrosion resistant coating, bonded centrally onto 150 mm of the previously cleaned centre section of the bars. Where tie bars are to be cranked for construction joints and later straightened, the coating shall be shown to be capable of being straightened through 90 degrees without cracking.

Tie bars in warping joints and wet-formed longitudinal joints shall be made up into rigid assemblies with adequate supports and fixings to remain firmly in position during the construction of the slab. Alternatively, tie bars at longitudinal joints may be mechanically inserted by vibration from above using a method which ensures recompaction of the concrete around the tie bars.

Tie bars in warping joints shall be positioned from the top surface of the slab within +20, -10 mm of the mid depth of the slab. Tie bars shall be positioned and remain within the middle third of the

slab depth, approximately parallel to the surface and approximately perpendicular to the line of the joint, with the centre of each bar on the intended line of the joints within a tolerance of ± 50 mm, and with a minimum cover of 30 mm below any top crack inducer of joint groove for slabs 200 mm thick or more, or 20 mm for slabs up to 200 mm thick.

11.4.8 Joint Grooves

Transverse contraction or warping joint grooves shall be sawn in the hardened concrete.

Transverse joint grooves which are initially constructed less than the full width of the slab shall be completed by sawing through to the edge of the slab and across longitudinal joints as soon as any forms have been removed and before an induced crack develops at the joint.

Sawn transverse and longitudinal joint grooves: Sawing shall be undertaken as soon as possible after the concrete has hardened sufficiently to enable a sharp-edged groove to be produced without disrupting the concrete and before random cracks develop in the slab. The grooves shall be between 1/4 and 1/3 of the specified depth of the slab and of any convenient width not less than 3 mm. The sealing groove may be sawn to the required width later. Expansion joint sealing grooves shall be sealed as soon as practical after sawing.

Wet formed longitudinal joint grooves: When slabs are constructed in more than one lane width in one operation, a joint groove shall be formed by inserting a groove former ahead of the finishing beams from dispenser. The concrete so displaced shall be recompacted by a vibrating compactor or similar device, at least 300 mm wide operating symmetrically along the line of the joint. After finishing the concrete, the groove forming strip shall be in the correct position and alignment, within 10° of the vertical, and to sufficient depth below the surface to allow for the passage of the finishing beam within the range 0-3 mm below the finished level of the slab. Groove forming strips in wet-formed longitudinal joint grooves shall be left in place.

Construction joint grooves in surface slabs: The grooves shall be formed by fixing a groove-former or strip or cork seal along the top edge of the slab already constructed, before concreting the adjacent slab. Where the edge of the concrete is damaged, it shall be ground or made good before fixing the groove forming strip. Alternatively the subsequent slab may be placed adjacent to the first and a sealing groove sawn later in the hardened concrete to the minimum of 1/4 to 1/3 of the specified slab depth or to the manufacturer's instructions if greater, and to sufficient width to eliminate minor spalling of the joint arris, up to a maximum of 25 mm for longitudinal joints and 40 mm for transverse joints. The joint shall be sealed in compliance with Clause 11.4.10.

11.4.9 Joint Filler Board

Joint filler board for expansion joints and manhole and gully slab joints shall be 25 mm thick unless otherwise shown in the drawings, within a tolerance of ± 1.5 mm. It shall be a self-expanding cork seal or a firm compressible material or a bonded combination of compressible and rigid materials of sufficient rigidity to resist deformation during the passage of the concrete paving plant.

11.4.10 Sealing of Joint Groover

Sealing shall be carried out continuously along the full length of joint in any one rip, except for remedial areas. When hot or cold applied sealants are used the sealant shall be applied within the minimum and maximum drying times of the primer recommended by the manufacturer. Priming and sealing with applied sealants shall not be carried out when the naturally occurring temperature in the joint groove to be sealed is below 10°C except between 8°C and 10°C it may be carried out when the temperature is rising.

11.4.11 Inspection of Dowel Bars

Compliance with tolerances for the position and alignment of dowel bars as per Clause 11.4.6 at contraction and expansion joints shall be checked

When the slab has been constructed, the position and alignment of dowel bars and any filler board shall be measured after exposing them carefully across the whole width of the slab. When the joint is an expansion joint, the top of the filler board shall first be exposed sufficiently in the plastic concrete to permit measurement of any lateral or vertical displacement of the board. During the course of normal working, these measurements shall be carried out at a rate of one joint per 1500 m length of slab or one per 5 days whichever occurs the sooner. For small areas the rate shall be one joint for up to each 100 joints.

If the position or alignment of the bars in a single joint in the slab is unsatisfactory, then the next two joints shall be inspected. If only the one joint of the three is defective, the rate of checking shall be increased to one joint per day until compliance is being achieved. In the event of non-compliance in two or more successive joints, the Contractor shall revert to the construction of trial lengths and make any necessary alterations to the concrete mix, paving plant or methods until the dowel bar position and alignment is satisfactory.

After the dowel bars have been examined, the remainder of the concrete shall be removed 500 mm on each side of the line of the joint and reinstated to the requirements of the Specification. Alternatively, if the dowels are examined in the penultimate joint of a day's work, that joint shall be made a construction joint for the next day's work and the remainder of the concrete in the last slab may be discarded.

11.4.12 Curing

Immediately after the surface treatment described in Clause 1026, the surface and exposed edges of surface slabs shall be cured for a minimum period of 7 days, by the application of an approved resin based aluminised curing compound, or polythene sheeting or an approved sprayed plastic film which hardens into a peelable plastic sheet and which shall be removed before road marking and opening to traffic.

Resin based aluminised curing compound shall contain sufficient flake aluminium in finely divided dispersion to produce a complete coverage of the sprayed surface with a metallic finish. The compound shall become stable and impervious to evaporation of water from the concrete surface within 60 minutes

The curing compound shall not react chemically with the concrete to be cured and shall not crack, peel or disintegrate within three weeks after application.

Prior to application, the contents of any containers shall be thoroughly agitated. The curing compound shall be mechanically applied using a fine spray on to the surface at a rate of at least 0.22 l/m^2 For the sides of slip-formed slabs or when the side forms are removed within 24 hours and for small areas where mechanical application cannot be used, the compound shall be sprayed by hand lance at a rate of at least 0.27 l/m^2. The rate of spread shall be checked during construction of each trial length and for each 1000 m^2 of treated slab.

11.4.12.1 Exposed Aggregate Concrete Surface

In order to obtain a suitable exposed aggregate surface, the main requirement shall be the removal of the surface mortar from the top of the slab to produce an exposed aggregate finish. This objective may be achieved by the application of suitable cement set retarder which is sprayed on the surface of the fresh concrete immediately after it has been levelled and finished. Retarded mortar shall be removed by wet or dry brushing generally not sooner than when the surface concrete has reached a maturity of 16 hours at 20°C or after a suitable interval determined by trial.

The finished surface of the pavement concrete after application of retarder shall be protected against precipitation, moisture loss, contamination and dispersal of the retarder by air movements. This protection shall be applied immediately after the application of the retarder.

Where waterproof sheeting is used, it shall be laid onto the surface of the concrete immediately after the retarder has been sprayed. It shall be retained in position until immediately prior to exposing of the aggregate.

The protection system shall not adversely affect either the finish, the line or the level of the concrete surface or the even distribution of the retarder in any way. Where sheeting is used, any air bubbling or blistering shall be prevented.

Brushing equipment shall be used to expose the concrete surface aggregate. Where the brushing equipment runs on the slab, the concrete shall have gained sufficient strength to avoid any damage to the concrete.

Removal of the protection system shall take place as brushing proceeds. If waterproof sheeting is used as protection system, it shall be maintained in position until immediately in advance of the brushing operation.

The Contractor shall complete the process of exposing the aggregate before the retarder becomes ineffective. Failure to do so shall entail the remedial measures.

Sufficient brushing capability shall always be maintained on site to complete the exposure of the aggregate before the retarder becomes ineffective. An adequate back-up brushing facility shall be available on the site at all times for use in case of a breakdown of the brushing equipment.

Brushing shall be used to produce an even macrotexture on the surface of the slab and shall be carried out in the longitudinal direction of the concrete slab.

The wheels of any brushing equipment which may run on the slab shall be fitted with tyres with a shallow tread pattern and a low inflation pressure and be sufficiently wide to avoid damage to the concrete.

Within one hour of completing exposure of the aggregate the surface shall be dampened with water. A curing compound shall be applied to the entire exposed aggregate surface of the slab. In wet weather the curing compound shall be applied as soon as practicable after the rain stops. The surface may, alternatively, be covered by hessian provided it is maintained in a wet condition at all times during the curing period of the concrete.

During brushing, initial interim spot check measurements of the surface macrotexture depth shall be made as soon as it is considered that the required texture depth has been reached. This shall continue until the specified macrotexture depth has been achieved.

In the event that it is not possible to achieve the specified minimum macrotexture depth by further exposure, the Contractor shall treat the surface in accordance with Clause 11.4.14 to achieve the specified macrotexture depth. This treatment shall not be applied until the concrete has reached an age of 28 days.

Failure to achieve a satisfactory minimum macrotexture depth by mechanical means shall result in removal of the full thickness of the slab to the extent required to permit reconstruction of the slab in accordance with the Specification. Where the maximum macrotexture depth is exceeded suitable remedial measures shall be employed.

11.4.13 Trial Tests

The Contractor shall demonstrate the constituent materials, concrete proportions, plant, equipment and methods of construction that are proposed for concrete paving, by first constructing a trial length of slab, at least 150 m but not more than 300 m long for mechanised construction, and at least 30 m long for hand guided methods. The concrete proportions decided by trial concrete mixes may be adjusted during the trial but shall not be changed once the trial length has been satisfactorily completed unless the Contractor lays a further trial area to assess the suitability of the proposed changes.

The trial length shall be constructed in two parts over a period comprising at least part of two separate working days, with a minimum of 75 m constructed each day when mechanised paving plant is used and a minimum of 15 m on each day for hand guided methods. The trial length shall be constructed at a similar rate to that which is proposed for the main construction in the Permanent Works.

Preliminary trial panels shall be constructed off-line incorporating a top surface of exposed aggregate concrete similar to that specified for the permanent Works. These panels shall be 20 m long and not less than 100 mm deep and the maximum intended paving width. They shall be used to enable the Contractor to determine the required application rate of the retarder and the amount of brushing required to achieve the specified macrotexture depth.

The trial panels may alternatively be constructed on-site, but in this case, they may only form part of the permanent Works if they meet all the requirements of the Specification, otherwise they shall be removed after they have served their purpose.

The surface macrotexture depth shall be determined by volumetric patch technique at approximately 2 m spacings along a diagonal line across each trial panel and shall follow the procedure described in BS EN 13036-1.

The average value of each set of 10 individual measurements shall be taken as the resulting macrotexture depth which shall be assessed against the Specification.

At least two transverse joints and one longitudinal joint of each type that are proposed for unreinforced concrete slabs and jointed reinforced concrete slabs in the main construction in the Permanent Works shall be constructed and assessed in the trial length. If in the trial length expansion joints are not demonstrated, the first 2 expansion joints and at least the first 150 m of longitudinal construction joint for mechanised paving, or 30 m for hand guided method of construction laid in the main construction in the Permanent Works, shall be considered the trial length for these joints.

The trial length shall comply for strength and density with the Specification in all respects, with the following additions and exceptions:

- In checking for compliance with Table 22, the levels shall be taken at intervals of not more than 2.5 m along any line or lines parallel to the longitudinal centre line of the trial length.
- The maximum number of permitted irregularities of pavement surfaces shall comply with the requirements of Table 22 for 300 m lengths. Shorter trial lengths shall be assessed pro-rata based on values for a 300 m length.
- At least 3 cores of minimum diameter 100 mm shall be taken from the slab at joints to check the lateral and vertical location of joint grooves and bottom crack inducers.
- Alignment of dowel bars shall be inspected as described in Clause 11.4.11 in any two consecutive transverse joints. If the position or alignment of the dowel bars at one of these joints does not comply with Clause 11.4.6, but if that joint remains the only one that does not comply after the next 3 consecutive joints of the same type have been inspected, then the method of placing dowels shall be deemed to be satisfactory. In order to check sufficient joints for dowel bar alignment without extending the trial length unduly, the Contractor may construct joints at more frequent joint intervals than the normal spacing required.
- If there are deficiencies in the first expansion joint that is constructed as a trial, the next expansion joint shall be a trial joint. Should this also be deficient, further trial expansion joints shall be made as part of a trial length. Deficient expansion joints shall not form part of the Permanent Works.
- Compliance with Clause 11.4.7 for the position and alignment of tie bars shall be checked by drilling additional cores from the slab unless they can be determined from cores taken for density assessment.

The Contractor shall not proceed with normal working unless the trial length complies with the Specification and any earlier defective trial lengths have been removed, unless they can be remedied to comply with the Specification.

After satisfactory completion of the trial length, the constituent materials, concrete proportions, plant, equipment and construction methods shall not thereafter be changed, except for normal adjustments and maintenance of plant, unless the Contractor lays a further trial length as described in this Clause to demonstrate that the changes will not adversely affect the Permanent Works or in agreement of the changes with the Employer's Representative.

11.4.14 Texturing of Hardened Concrete

Worn, rain damaged or inadequately textured surface slabs shall be macrotextured by sawing grooves in the hardened concrete surface at right angles to the longitudinal axis of the pavement with machines using diamond or other abrasive cutting discs.

Grooves shall be irregularly spaced and shall be not less than 2 mm and not more than 5 mm wide. The sequence of distances between groove centres in mm shall 55, 30, 40, 55, 35, 55. A tolerance of ± 3 mm shall be allowed on each of the spacings. The minimum width of grooving head shall be 500 mm and a head not providing a complete sequence of spacings shall use the number of spacings appropriate to its width commencing at the start of the sequence.

Groove depths shall be measured using a tyre tread depth gauge and measurements shall be taken as follows:

- At 10 locations at least 2 m apart along a diagonal line across a lane width between points 50 m apart longitudinally. No measurement shall be taken within 300 mm of the longitudinal edge of a slab. Where a grooved area is less than 50 m in length the locations where measurements are taken shall be as proportional to the requirements for 50 m.
- At each of the 10 locations the depth of 10 adjacent grooves shall be measured.
- The average of each set of 10 measurements shall be not less than 3 mm nor greater than 7 mm.

Slurry from the sawing process shall be prevented from flowing into joints, drains or into lanes being used by traffic, and all resultant debris from the grooving shall be removed.

11.4.15 Weather Conditions

Road pavement materials in a frozen condition shall not be incorporated in the Works but may be used, if acceptable, when thawed.

Road pavement materials shall not be laid on any surface which is frozen or covered with ice.

The temperature of concrete in any pavement layer shall not be less than 5°C at the point of delivery. These materials shall not be laid when the air temperature falls below 3°C and laying shall not be resumed until the rising air temperature reach 3°C unless all surfaces of the concrete slabs are protected by thermal insulation blankets laid immediately after placing and finishing the concrete. The insulation shall be placed before the temperature of the concrete surface has dropped below 2°C and shall be retained for a minimum of 3 days or until the concrete is assessed to have reached 50% of the specified characteristic compressive strength provided the air temperature is above 0°C and rising at that time. Thermal insulation blankets shall be closed cell polyethylene foam sheets, minimum 10 mm thick with a 'U' value of 4 watts/mC (or K value of 0.04

watts/m Kelvin) or suitable material with an equivalent or lower thermal conductivity. They shall be sufficiently robust and capable of being held in place against variations in wind and weather conditions for the necessary curing time.

11.4.16 Construction Traffic

Construction plant and traffic used on pavements under construction shall be suitable in relation to the material, condition and thickness of the courses it traverses so that damage is not caused to the subgrade or the pavement courses already constructed. The wheels or tracks of plant moving over the various pavement courses shall be kept free from deleterious materials.

Concrete slabs may be used by traffic when the cube compressive strength is assessed to have reached 25 N/mm^2 In the absence of test data establishing compliance, no vehicle with an axle loading greater than 2 tonnes shall run on concrete slabs within a period of 14 days after placing the concrete. Vehicles with rubber tyres with an axle loading less than 2 tonnes, or wheels or tracks of concreting plant, shall not use any part of a newly constructed pavement within 7 days. The above periods before traffic may run on the pavement shall be increased if the 7 days cube strength is below that what is required in the Specification. These periods shall be extended by one day for each night on which the temperature of the layer falls to 0°C or below.

12 WATER PROOFING SYSTEM

12.1 General

Sheet waterproofing membrane systems for the tunnel shall comprise of a geotextile fleece fixed to the primary lining substrate in combination with a sheet waterproofing membrane fastened to this; see Section 12.6 for details of installation.

Waterproofing shall be applied to crown and sidewalls above footing or invert arch level. The waterproofing membrane shall always be located between shotcrete support and final concrete lining. As the underground structures referred to be not immersed below a distinct groundwater table no membrane waterproofing will be provided for tunnel inverts.

The design life of the water proofing membrane shall be minimum 100 years.

Where the waterproofing system is to be divided into sectors, the water stops should be formed of material that can be welded to the sheet waterproofing membrane.

Additional drainage capacity shall be provided in case of water inflows in agreement with the Employer's Representative by studded drainage membrane made from thermoplastic material (dimpled sheet) attached prior to installation of the geotextile fleece or equivalent drainage layer approved by the Employer's Representative.

Waterproof membranes shall not be stored in direct sunlight prior to use. Waterproof membranes shall be protected from damage at all times especially during installation of reinforcement. The water proofing membrane shall have a signal layer to indicate damages due to handling and installation of reinforcement. The integrity of the signal layer shall be checked prior to concreting of final lining.

Fire protection measures during construction of water proofing system are required as but not limited to the following.

- The amount of membrane stored in the tunnel shall not exceed two working day's production to minimise the fire load stored underground.
- The installation length of the water proofing system in advance of the final lining shall not exceed 300 m, unless special measures are considered in agreement with the Employer's Representative.

12.2 Geotextile Fleece

The purpose of the geotextile fleece is to protect the sheet membrane against mechanical puncture and to provide a drainage path for any ground water along the rock side of water proofing system around the tunnel structure.

The geotextile fleece and the membrane shall be combined in accordance to the hydraulic requirements to drain the encountered water inflows. The geotextile fleece only provides low long term drainage capacity. If the hydraulic capacity of the geotextile fleece is not sufficient an additional drainage layer shall be installed.

The geotextile used in combination with dimpled sheet as strip drain is to protect the dimpled sheet and allows the inflow of ground water into the dimpled sheet drainage area.

The geotextile fleece shall be a non-woven fleece and shall provide a minimum weight of 500 g/m² in tunnel vault and 900 g/m² in tunnel invert if required and in c&c tunnels, in accordance to the Specification set forth in Fehler! Verweisquelle konnte nicht gefunden werden.

Table 30: Requirements of geotextile fleece

Description	Standard	Requirement	
		500 g/m²	900 g/m2
Mass per unit area	BS EN ISO 9864	≥ 500 g/m2	≥ 900 g/m2
Nominal weight	BS EN ISO 9864	≥ 556 g/m2	≥ 1000 g/m2
DSC analysis	BS EN ISO 11357-1 & -3	Tolerance of melting temperature <±10%	
Thickness under normal pressure	BS EN ISO 9863-1	Within the tolerances of the manufacturer	
2 kPa			
200 kPa		M.7 mm	≥3.4 mm
Tensile strength in longitudinal and transversal direction to the direction of production	BS EN ISO 10319	≥30 kN/m	≥50 kN/m
Elongation at break in longitudinal and transversal direction to the direction of production	BS EN ISO 10319	Within the tolerances of the manufacture r	
Elongation at maximum tensile force	BS EN ISO 10319	≥50%	
Static puncture	BS EN ISO 12236	≥3kN	≥7kN
Cone drop test	BS EN ISO 13433	<13mm	<7mm
Behaviour during oxidation	BS EN ISO 13438	design life of minimum 25 gears in compliance with EN 13256	
Behaviour in basic environment (p^9)	BS EN 14030 and BS EN ISO 10319	Decrease of tensile strength and elongation at break during design life of 25 years: ≤20%	
	BS EN ISO 11925-2 and BS		
Behaviour during fire	EN 13501-1	Class E	
Permeability in flow			
direction with 200 kPa	BS EN ISO 12958	≥^^^	
Protection	BS EN 14574	^.1 mm	

The geotextile is to provide adequate protection from chemical aggression caused in the curing processes of concrete.

Water transmissivity of the geotextile fleece should be designed to suit expected volume of water ingress.

12.3 Fixing Element

The geotextile is fixed onto the substrate with non-projecting disks. The disks are secured through the geotextile and into the substrate with shot-fired nails.

The disks should be made of a compound that allows the sheet waterproofing membrane to be fully welded to the surface.

In order to prevent stresses being transferred from the secondary lining to the sheet waterproofing membrane, the resistance to failure in shear of the nails and disks must be less than the shear resistance of the sheet membrane itself.

All accessories and compounds of fixing elements, flashing, reinforcement for expansion joints, sealing flanges etc. shall be in accordance to the recommendations of the membrane's manufacturer and compatible with the waterproofing system.

12.4 Layer with higher drainage capacity

If the hydraulic capacity of the geotextile fleece for water drainage is not sufficient due to significant water inflows an additional drainage layer shall be installed.

The layer shall have minimum drainage capacity of 360 l/(m*h) with applied pressure of 200 kPa and hydraulic gradient of 1.

Drainage elements with higher drainage capacity shall be in compliance with requirements laid down in Table 30.

Table 31: Requirements of drainage elements

Description	Standard	Requirement
Mass per unit area	BS EN ISO 9864	within the tolerances of the manufacturer
Tensile strength	BS EN ISO 10319	≥ 10 kN/m
Thickness under normal pressure:	BS EN ISO 963-1 (Method A)	2 kPa: within the tolerances of the manufacturer 200 kPa>4 mm and ≤^mm
Drainage capacity, hydraulic gradient 1, with thickness under normal pressure of 200 kPa (see above)	BS EN ISO 12958	≥360 l/(m*h) and 10-4 m^2/s respectively
Behaviour during fire	BS EN ISO 11925-2 and BS EN 13501-1	Class E

12.5 Waterproof Membrane

The waterproof membrane shall consist of a continuous impermeable heat-welded sheet of one of the following materials:

- soft polyvinyl chloride (PVC) unreinforced

- flexible polyolefin (FPO/TPO) unreinforced

The membrane as supplied shall be of such dimensions and shape as will result in the minimum of on-site seam welds.

The installation of recycled membranes and/or membranes including DEHP (DOP) plasticizer is not permitted.

Unless otherwise stated in the Contract, the membrane shall conform to performance requirements and have properties shown in Table 31.

Table 32: Performance requirements of sheet waterproof membranes

Description	Standard	PVC-P	TPO
Identification	BS EN 13491	manufacturer, type, material, thickness, date of manufacture, CE marking including CE document	
Thickness including signal layer	BS EN 1849-2	min 2.0 mm for seepage water and min 3.0 mm for pressurized water	
Thickness of signal layer	BS EN 1849-2	≤ 0.2 mm	
Density	BS EN ISO 1183-1	tolerance <±0.005 g/cm³	tolerance <±0.02 g/cm3
Appearance	BS EN 1850-2	free from blisters, crack, external capsule and voids	
Straightness	BS EN 1848-2	≤ 50 mm	
Flatness	BS EN 1848-2	≤ 10 mm	
DSC analysis	BS EN ISO 113571 & -3	individual evaluation from diagram	
MFR Index (Melt Flow Index)	BS EN ISO 1133 Method A	tolerance <±15 % of nominal value	-
Tensile strength in longitudinal and transversal direction	BS EN ISO 527-1 & -3	M5 MPa	M2 MPa
Elongation at break	BS EN ISO 527-1 & -3	≥ 500 %	≥ 250 %
Youngs Modulus between 1 % and 2 % elongation in longitudinal and transversal direction	BS EN ISO 527-1 & -3	≤ 65 MPa	≤ 20 MPa
Static puncture	BS EN ISO 12236	≥2.8 kN	≥2.5 kN
Burst strength elongation multi-axial elongation test	BS EN 14151	≥50 % with 0 1.0 m ≥80 % with 0 0.4 m	≥50 % with 0 1.0 m ≥80 % with 0 0.4 m
Impact resistance (500 g), method A	BS EN 12691	nominal thickness 2.1 mm: fall height 750 mm nominal thickness 3.15 mm: fall height 1250 mm	
Long term compression strength	SIA-V 280 Test No. 14	impermeable during test duration of 48 h and 7 MPa	
Folding in cold environment	BS EN 495-5	no requirements	no cracks at -20°C

Description	Standard	PVC-P	TPO
Behaviour during warming: Dimensional change Appearance	BS EN 1107-2 BS EN 1850-2	<2% (1h/100°C) no blistering	<2% (6h/80°C) no blistering
Resistance under water pressure	BS EN 1928 method B	5 bars at 1 hour	
Thermal ageing (70 d with 80°C)	BS EN 1296 (BS EN 1850-2, BS EN 1849-2, BS EN ISO 527-1 & -3)	no requirements	decrease of tensile strength <20% decrease of tensile elongation at break ≤20%
Resistance to oxidation after 90 d with 85°C	BS EN 14575	decrease of tensile strength and elongation ≤20%	values shall be determined in agreement with Employer's Representative
Behaviour after storage in water with 50°C and 8 month	SIA-V 280 Test no 13	no requirements	Change of elongation at break ≤20%, change of mass ≤4%
Behaviour after storage in aqueous solutions (no 2), days with 23°C Ca(OH)2(sat.); NaCl(10%)	BS EN 14415 (BS EN 1847, BS EN ISO 527-1 & -3)	decrease of tensile strength and elongation at break ≤25%	
Behaviour after storage in aqueous solutions (no 3) 90 days with 23°C, H2SO3 (5-6%)	BS EN 1847 (BS EN ISO 527-1 & -3)	decrease of tensile strength and elongation at break ≤20% no cracks at folding at -20°C	
Root resistance	DD CEN/TS 14416	No penetration	
Tear resistance	BS EN 12310-2	80 N/mm	
Water absorption	BS EN ISO 62	<4,0%	
Fire rating	BS EN ISO 119252 BS EN 13501-1	Class E	Class E
Smoke class	BS EN ISO 11925	E	
Welding	DVS 2225-5	accurate	
Peeling strength of welded seam	BS EN 12317-2	≥6 MPa	
Shear strength of welded seam	BS EN 12316-2	Failure shall appear outside welding seam	

Further guidance on test methods and requirements for mechanical properties and durability can be found in BS EN 13492:2004 (E): "Geosynthetic barriers - Characteristics required for use as a fluid barrier in the construction of tunnels and underground structures".

Where reinforced concrete is to be placed against the sheet waterproofing membrane, a signalling layer, to give a visual indication of any mechanical damage, shall be provided on the exposed

surface of the waterproofing membrane. The signalling layer shall be such that it does not adversely affect the seam welds. The signalling layer shall be of the same material as the waterproofing membrane.

An additional waterproofing strip with a width of 50 cm shall be placed around the vault in the area of construction joints between two final lining blocks.

12.6 Installation

The manufacturer's instructions for installation of felt backing and waterproofing membrane, including procedures for preparation, fixing, welding and splicing, flashing shall be followed solely by the Contractor.

Prior to application of the geotextile fleece layer the primary lining shall be surveyed to confirm that it does not encroach into the designed extrados of the secondary lining. Any proposals to rectify areas of the primary lining shall be agreed with the Employer's Representative.

The shotcrete lining shall be constructed in a way that all bolts and anchors are fully covered with shotcrete of the primary lining. The surface shall be prepared in accordance with the manufacturer's instructions. The surface shall be clean, smooth and free from any deleterious material. Except where indicated on the drawings, all fixtures shall be removed from the primary lining prior to application of the geotextile fleece layer. All core holes shall be backfilled with mortar to be flush with the surface of the primary lining.

Shotcrete cover of minimum 50 mm to rock is required.

For sheet waterproof membranes, the profile of the substrate (tunnel surface) shall not have any irregularities that exceed a ratio of length to depth of 5:1 for PVC-P waterproofing membranes and 10:1 for flexible TPO waterproofing membranes. The minimum radius shall be 200 mm. Transitions and intersections of tunnel profiles such as niches and cross passages shall be rounded off with a minimum radius of 500 mm. The substrate surface shall be free from protrusions or sharp edges which may lead to membrane puncture. Crushed aggregates of a grain size greater than 8 mm shall not be used.

Groundwater penetrating through the primary tunnel lining shall be collected and drained by appropriate measures. This drainage shall be maintained throughout the membrane placing process and shall be so arranged that excess water pressure behind the membrane cannot develop.

All shotcrete surface shall finally be smoothened with fine-graded shotcrete (rounded aggregates, grain size 0 - 8 mm), applied in a layer of 30 mm minimum thickness.

A layer of protective geotextile shall be attached to the substrate by suitable non-projecting

fastenings installed directly through the geotextile fleece. When fixing the geotextile fleece overhead, sufficient fixings (minimum 2 to 4 elements per sqm) shall be installed to ensure the fleece is in close contact with the substrate and is self-supporting. The sheets shall overlap by at least 200 mm and jointed by point weld or equivalent method as approved by the Employer's Representative.

When placing the sheet waterproof membrane, no other Works shall be carried out in the vicinity which may cause personnel or equipment to come into contact with the sheet waterproof membrane before it has been protected. If it is likely that excessive dust may be generated in the vicinity of the Works (vehicle movements etc.), then dust suppression measures shall be put in place.

The sheet waterproof membrane shall be fixed to the tunnel structure by means of fastening devices which preserve the integrity of the sheet waterproof membrane. Sufficient fixings shall be installed to ensure the fleece is in close contact with the substrate and is self-supporting. No perforation of the membrane shall be allowed for installation purposes. The waterproofing membrane shall be laid with the signal layer towards the inside and with sufficient slack to prevent overstressing during concreting. All sheet waterproof membrane overlaps shall be welded in accordance with the membrane manufacturer's instructions.

Where waterproof membrane has been installed in the tunnel invert, it shall be protected from any damage as soon as possible after testing.

Radial joints between sheets of sheet waterproof membrane shall be welded using flat-faced fillet welds. Two lines of weld shall be used on each joint forming a double seam of at least 15 mm wide, with the minimum sheet waterproof membrane overlap 80 mm for manual welding and 100 mm for automatic welding.

All welding personnel shall have certificate in compliance with the qualification testing of welders as per BS EN 13067.

If protrusions through the membrane are required, they shall be fitted with collars to maintain the water tightness of the system.

Star or cross joints shall be avoided.

The length of material roll shall be procured to enable a complete extrados to be installed as a continuous length. Longitudinal joints shall be avoided.

The placing of inner lining concrete sequence and processes shall be such that they do not displace or damage the geotextile fleece or sheet waterproofing membrane.

12.7 Checking

12.7.1 Field Trials

Field trials shall be made to demonstrate the capability of the equipment, workmanship, materials and application methods under field conditions.

The testing programme shall be started sufficiently early prior to installing the membrane to ensure that the required water-tightness can be achieved and allow repetition of the trials should the initial results prove unsatisfactory. All trials and acceptance tests shall be completed satisfactorily by the time installation commences.

Prior to construction, trials shall be carried out in order to establish the speed and temperature of joint welding required to achieve welds which are acceptable to the Employer's Representative. If hand-welded joints are proposed at junctions, then this type of weld shall be pre-tested and agreed with the Employer's Representative.

12.7.2 Construction Testing

On-going inspection of the waterproofing system shall be carried out and documented by the Contractor. The inspection documents shall be made forwarded to the Employer's Representative for review and approval.

A visual inspection of the sheet waterproof membrane shall be carried out as specified in Table 32. Areas where the sheet waterproof membrane is damaged shall be marked up, repairs carried out and tested in accordance with the manufacturer's instructions.

All welded joints shall be tested in accordance with Table 32. Any joints that fail the test and require repair shall be marked with a permanent marker, at the time of the test.

Repairs and hand-welded joints shall be tested by hand-held vacuum chamber in accordance with Table.

Table 33: Construction testing for sheet waterproof membrane

Parameter	Test Method	Frequency	Pass Criteria
Coverage	Visual	A visual inspection to be carried out continuously while the membrane is applied	100% coverage
Double welded seam joints	DIN 16726	Every joint	Pressure drop not to be greater than 10% when a 2 bar (PVC-P) and 3 bar (TPE-O/TPO) pressure is applied for 10 minutes
Hand welding and repairs	ASTM D5641-94 (2006)	Every hand-weld and repair	Pressure drop not to be greater than 20% when a 0.3 bar pressure is applied for 10 minutes

A visual inspection of the fleece shall be carried out. Areas in which the substrate is still visible, or where the fleece is damaged, shall be marked up and an additional layer of fleece applied with a minimum lap of 200 mm around the area.

12.7.3 Failure Measures

Where tears, rips or defective joints in the geotextile fleece are noted, these shall be repaired with a minimum overlap of 200 mm.

Where tears, rips or defective joints in the sheet waterproof membrane are noted, these shall be repaired in accordance with manufacturer's recommendations. These shall be tested by hand-held vacuum chamber in accordance with Table 32.

Any sheet waterproof membrane not meeting specified requirements shall be removed and replaced including any associated water management measures or smoothing layer. The cause of the problem shall be rectified before placing any further sheet waterproof membrane.

MEP SYSTEM

DRY TYPE TRANSFORMER

Illustration



Basic Information

50 Hz three-phase dry type transformer cast under vacuum in filled epoxy resin. Indoor type
Includes active filler, essentially composed of trihydrated alumina, a fire suppressant.

Technological Description

thermal class F;
ambient < 40°C, altitude < 1000m;
natural air cooling type AN;
It complies with standards: IEC 76-1 to 76-5; IEC 726 (1982);

Technical Data

insulation level: 17.5 kV and 24 kV

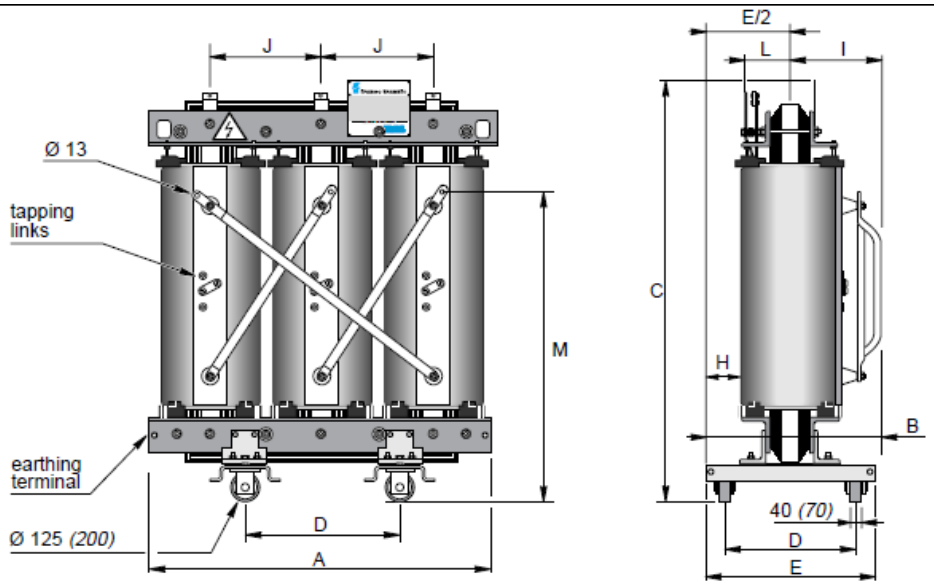
rated power (kVA) (1) (*)		160 (2)	250	315 (2)	400	500 (2)	630	800	1000	1250	1600	2000	2500	3150
rated primary voltage (1)		20 kV												
rated insulation level (3)		24 kV												
frequency (1)		50 Hz												
maximum ambient temperature		40°C												
secondary voltage at no load (1)		400 V												
HV tapping range (off-circuit) (1)		± 2.5 %												
vector group		Dyn 11 (delta, star neutral brought out)												
losses (W)	no load losses	650	880	1030	1200	1400	1650	2000	2300	2800	3100	4000	5000	6300
	load losses at 75°C	2300	3300	4000	4800	5700	6800	8200	9600	11500	14000	17500	20000	23000
	load losses at 120°C	2700	3800	4600	5500	6500	7800	9400	11000	13100	16000	20000	23000	26000
rated impedance voltage (%)		6	6	6	6	6	6	6	6	6	6	6	6	7
no-load current (%)		2.3	2	1.8	1.5	1.5	1.3	1.3	1.2	1.2	1.2	1.1	1	1
switching current	Ie/In (peak value)	10.5	10.5	10	10	10	10	10	10	10	10	9.5	9.5	9.5
	time constant	0.13	0.18	0.20	0.25	0.25	0.26	0.30	0.30	0.35	0.4	0.4	0.5	0.6
noise level (4)	acoustic power LWA	62	65	67	68	69	70	72	73	75	76	78	81	81
dB(A)	acoustic pressure LPA at 1 metre	50	53	55	56	56	57	59	59	61	62	63	66	65

(*) the rated power is defined by natural air cooling (AN). Should there be particular constraints, it may be increased by 40% by forced cooling addition (AF). Please consult us.
(1) other possibilities upon request, consult us.
(2) non standard ratings available on request.
(3) reminder of insulation levels:

rated insulation level (kV)	7.2	12	17.5	24
kV r.m.s. 50 Hz - 1 mn	20	28	38	50
kV B.I.L. 1.2/50 µs	60	75	95	125

(4) according to CEI 551

Basic Dimensional Sketch



insulation level: 17.5 kV and 24 kV - low voltage 400 V

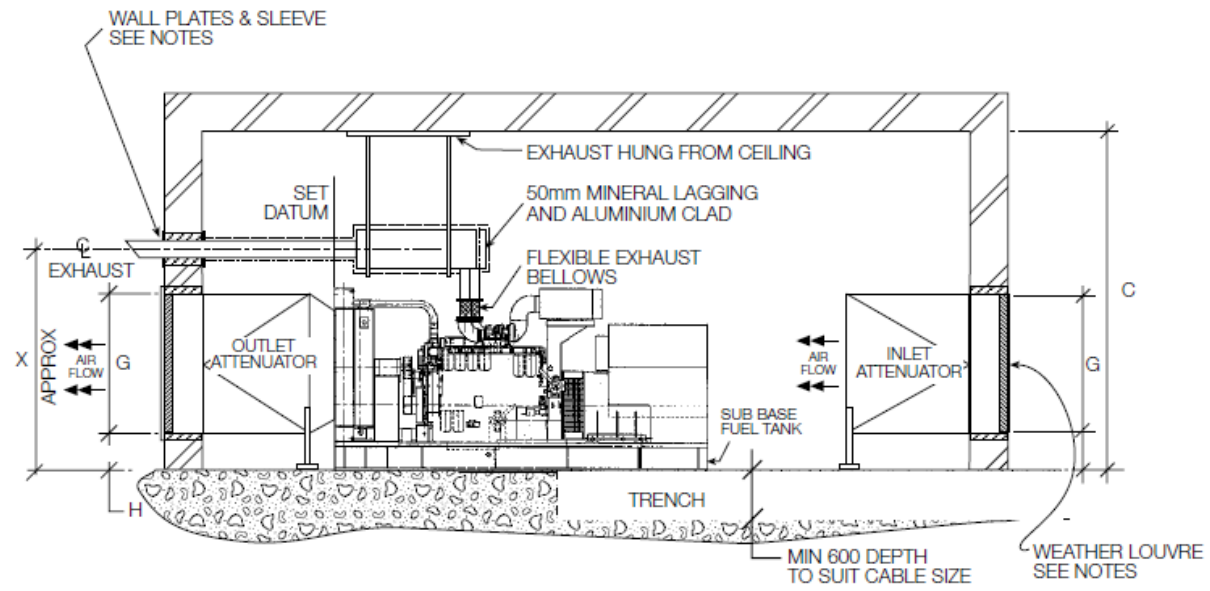
rated power (kVA) (1) (*)		160	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150
dimensions (mm)	A	1070	1140	1170	1230	1300	1340	1400	1560	1610	1700	1950	2030	2200
	B	680	690	795	795	795	800	805	945	945	945	1195	1195	1195
	C	1320	1350	1510	1490	1580	1690	1720	1920	2030	2170	2380	2440	2600
	D	520	520	670	670	670	670	670	820	820	820	1070	1070	1070
	E	650	650	800	800	800	800	800	950	950	950	1200	1200	1200
	H	160	150	220	210	190	190	180	230	220	210	290	290	300
	I	360	370	370	380	400	400	410	430	440	460	450	460	460
	J	360	380	390	410	440	450	470	510	530	560	630	640	690
	L	180	180	190	200	210	210	220	250	250	260	310	320	380
	M	890	930	1090	1070	1110	1210	1240	1410	1510	1650	1770	1750	1750
weights (kg)		780	950	1140	1290	1520	1730	1990	2480	2810	3430	4720	5980	7300

DIESEL GENERATOR	
Illustration	**Basic Information**
	A diesel generator (also known as diesel genset) is the combination of a diesel engine with an electric generator to generate electrical energy. This is a specific case of engine-generator. A diesel compression-ignition engine is usually designed to run on diesel fuel, but some types are adapted for other liquid fuels or natural gas.
Technological Description	
Generator sets in emergency power applications are required to start and pick up all emergency loads within 10 seconds of a power failure Prime Power Output available with varying load for an unlimited time. Average power output is 70% of the prime power rating. Typical peak demand of 100% of prime-rated ekW with 10% of overload capability for emergency use for a maximum of 1 hour in 12. Overload operation cannot exceed 25 hours per year.	

Technical Data

Prime Rating KVA	Type of ENGINE	TA Luft	Generator Model	Room dimensions			Set back	Set C/L position	Exhaust		Attenuator Dimensions			Uplift	Cable trench position		
				Length A	width B	height C	D	P	Offset E	Height X	F	Y	G	H	L	M	N
575	VTA28G5		460DFGA	8400	3450	3450	400	1725	400	2950	1500	1500	2000	400	775	500	5150
640	VTA28G5		512DFGB	8400	3450	3450	400	1725	400	2950	1500	1500	2000	400	775	500	5150
750	VTA28G6		600DFGD	8400	3450	3450	400	1725	400	2950	1500	1500	2000	400	775	500	5150
725	QST30G1	4g	580DFHA	8400	3640	3700	500	1820	400	3150	2400	1200	2400	400	920	500	5100
800	QST30G2	4g	640DFHB	8400	3640	3700	500	1820	400	3150	2400	1200	2400	400	920	500	5100
939	QST30G3		751DFHC	8400	3640	3700	500	1820	400	3150	2400	1200	2400	400	920	500	5100
1000	QST30G4		800DFHD	8450	3640	3800	500	1820	450	3150	2700	1200	2400	200	920	500	5100
725	QST30G6	2g	580DFHE	8400	3640	3700	500	1820	400	3150	2400	1200	2400	400	920	500	5100
800	QST30G7	2g	640DFHF	8400	3640	3700	500	1820	400	3150	2400	1200	2400	400	920	500	5100
939	QST30G8	2g	751DFHG	8400	3640	3700	500	1820	400	3150	2400	1200	2400	400	920	500	5100
936	KTA38G3		748DFJC	9500	3800	3800	500	1900	450	3100	1950	1800	2200	200	920	500	3655
1019	KTA38G5		815DFJD	9500	3800	3800	500	1900	450	3100	1950	1800	2200	200	920	600	3655
1256	KTA50G3		1005DFLC	10360	3800	3800	500	1900	450	3100	1950	1800	2200	200	920	600	4375
1405	KTA50G8		1125DFLE	11700	4000	4500	500	2000	500	3500	2450	2100	2600	200	920	600	5000
1500	KTA50GS8		1200DFLF	11700	3800	3800	500	1900	500	3100	2450	2100	2600	200	920	600	5000
1256	KTA50G6	4g	1005DFLG	10360	3800	3800	500	1900	450	3100	1950	1800	2200	200	920	600	4375
1256	KTA50G7	2g	1005DFLH	10360	3800	3800	500	1900	450	3100	1950	1800	2200	200	920	600	4375
1875	QSK60G3		1500DQKC	12650	4500	4500	600	2250	693	3800	2800	2400	2600	325	645	600	5000
2000	QSK60G4		1600DQKD	12650	4600	4500	600	2250	693	3920	3150	2400	3100	250	645	600	5000
1875	QSK60G3	2g	1500DQKE	11200	4000	4500	800	2000	693	3800	2700	1500	2500	325	645	600	3800
2000	QSK60GS3	2g	1600DQKF	11200	4000	4500	800	2000	693	3800	2700	1500	2600	325	645	600	3800

Basic Dimensional Sketch



UNINTERRUPTIBLE POWER SUPPLY SYSTEM (UPS)

Illustration	Basic Information
	Highly efficient, easy-to-deploy 3-phase uninterruptible power supply (UPS)

Technological Description

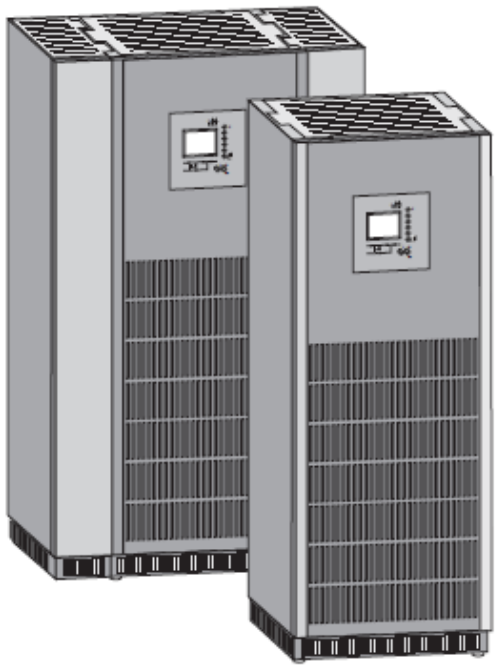
Robust operation - No power derating in kW up to 40 degrees C
Parallel-capacity capable
Topology: Double Conversion Online

Technical Data

UPS rating	20 kVA	30 kVA	40 kVA	60 kVA	80 kVA	100 kVA	120 kVA
Input voltage (V)	380 - 400 - 415						
Input voltage range permitted by the standard according to the curve below (V)	250 to 470 for a standard UPS 342 to 470 for a UPS with backfeed protection						
Input frequency (Hz)	45 to 65						
Rated current[1] Normal AC input (A)	32	45	57	87	115	143	171
Maximum input current (A) for 400 V	33	46	58	88	116	145	173
Input current (A) for 400V, overload= 1.25 In limited to 10 min.	39	56	72	108	145	181	217
Input current (A) for 400V, overload=1.5 In limited to 1 min.	47	68	87	130	174	217	260
THDI	< 6% at full load < 8% at 25–75% load						
Maximum short circuit withstand (kA)	20				30		
Input fuse ratings (A)	80	80	80	125	160	315	315

Basic Dimensional Sketch

UPS cabinet



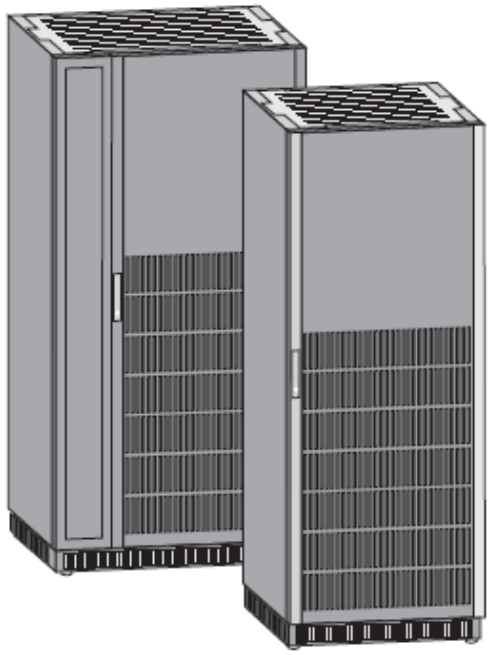
Dimensions

UPS power rating (kVA)	Dimensions (H x W x D)
20/30/40/60 without battery	1900 x 712 x 848 mm
80/100/120 without battery	1900 x 712 x 848 mm
20/30/40/60/80 with internal battery	1900 x 1112 x 848 mm

Weight in kg (UPS without battery or with built-in battery)

Backup time	UPS power rating (kVA)				
	20 30	40	60	80	100 120
Without battery	400	400	400	520	520
5 min	808	808	958	1120	
10 min	808	958	1045		
15 min	958	1045			
30 min	1045				

External battery cabinet / auxiliary cabinet



Dimensions (H x W x D) and weight

Cabinet 710 mm wide	1900 x 712 x 848 mm 135 kg
Cabinet 1000 mm wide	1900 x 1012 x 848 mm 150 kg

Weight in kg (cabinet alone)

Backuptime	UPS power rating (kVA)				
	40	60	80	100	120
Cabinet 710 mm wide without batt	135	135	135	135	135
Cabinet 1000 mm wide without batt	150	150	150	150	150
5 min				885	980
10 min			885	1142	1307
15 min		885	1142	1307	1764
30 min	882	1307	1764	2439	2742

JET FAN

Illustration	Basic Information
	Uni-directional jetfan for longitudinal tunnel ventilation. The uni-directional jet fans, with asymmetrical blades, are designed to optimize their performance in one direction (forward). The jet fans are installed inside the tunnel, either hanging them from the ceiling by means of a suspensions system or placing them on top of small base frames fixed to the lateral walls of the tunnel. The standard configuration of jet fans includes two tubular silencers at both ends of the jet fan unit, so the noise level generated when the jet fans are in operation, especially at full speed, is reduced.

Technological Description

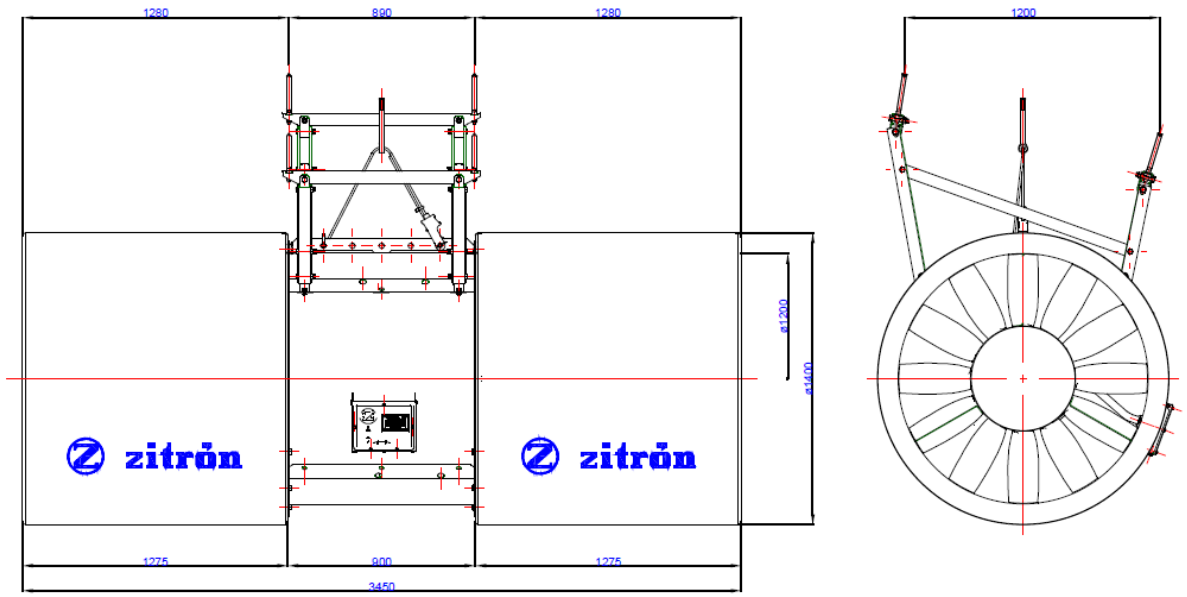
Axial fan (jet-fan type) for installation inside tunnel. Tested and certified to operate at high temperature conditions according to Standard EN 12102-3. High temperature rating: 400ºC during 2 hours.

Technical Data

Thrust Nominal	*Airflow*	*Air speed*	*Fan Diameter*	*Motor Rating / Rotation speed*	*Power Supply*	*High Temperature Rating*	*Reversibility*
[N]	*[m^3/s]*	*[m/s]*	*[mm]*	*[kW / rpm]*	*[Volt/ph/Hz]*	*[ºC / h]*	*[-]*
1441	*37.5*	*33.2*	*1200*	*37 / 1500*	*400/3/50*	*400 / 2*	*Unidirectional*

- Fan casing made of Carbon steel S-275 JR
- Impeller with aluminium alloy blades
- Electric motor WEG 400 V, 37 kW, 50 Hz, S-1, TEAO, IE1, B30, 4 poles, class H (400º-2h).
- Silencers made of Carbon steel S-275 JR (2 Nos.)
- Suspension system included
- Vibration sensor and anti-condensation heater included
- Dynamic balancing included

Basic Dimensional Sketch



COMBINED NO ,NO2, CO AND VISIBILITY MONITOR

Illustration



Basic Information

Single sensor tunnel monitor for measuring visibility, CO, NO NO2 and NOX within a road tunnel or other enclosed space. These measurements can be used to help ensure the effective ventilation of the tunnel and validate its air quality management system.

Technological Description

Sensor that uses a combination of differential optical absorption and infrared spectroscopy to measure nitrogen dioxide (NO2) nitric oxide (NO) and carbon monoxide (CO), and the standard light transmission obscuration technique to calculate visibility.

Technical Data

NO_2 Measurement Performance

No.	Parameter	Units	Min	Max	Comment
1	Path Length	m	5	12	Optimum 10m
2	Measurement Range	ppm (ppb)	0	10	User selectable (Option)
3	Resolution	ppm		0.01	Display resolution
4	Accuracy	%	-5	+5	Of Reading (at 10m path length)
5	Detection Limit	ppm		0.05	At 10m path length
6	Damping	s	1	999	Default setting is 20s
7	Temperature Stability	ppm	-0.05	+0.05	At 10m path length

Visibility Measurement Performance

No.	Parameter	Units	Min	Max	Comment
8	Measurement Range				User selectable
	Transmission	T	0	1.000	
	Extinction Coefficient (k)	m^{-1}	0	0.1000	
	Meteorological Optical Range (MOR)	m	0	15000	
	Opacity	%	0	100	
	Particulate Density (Dust)	mg/m^3	0	100	With density scale factor =1.0
9	Resolution				Display resolution
	Transmission	T		0.001	
	Extinction Coefficient (k)	m^{-1}		0.0001	
	Meteorological Optical Range (MOR)	m		1	
	Opacity	%		0.1	
	Particulate Density (Dust)	mg/m^3		0.1	
10	Accuracy	%			
	Extinction Coefficient (k)	m^{-1}	-0.0005	+0.0005	At 10m path length
	Opacity	%	-0.5	+0.5	
11	Damping	s	1	999	Default setting is 3s
12	Temperature Stability				
	Extinction Coefficient (k)	m^{-1}	-0.001	+0.001	At 10m path length
	Opacity	%	-1	+1	

CO/NO (NO_x) Measurement Performance

No.	Parameter		Units	Min	Max	Comment
13	Display range		ppm	0	500	User selectable
14	Resolution		ppm		0.1	Display resolution
15	Accuracy	CO	%	-5	+5	Of Reading
		NO (NO_x)	%	-10	+10	Instrument calibrated in-situ
16	Detection Limit	CO	ppm		1	
		NO (NO_x)	ppm		2	
17	Damping	CO	s	100		
		NO (NOX)	s	200		
18	Temperature Stability		ppm	-2	+2	At 10m path length

Temperature Measurement Performance

No.	Parameter	Units	Min	Max	Comment
19	Display range	ºC	-40	+100	User selectable
20	Resolution	ºC		0.1	Display resolution
21	Accuracy	ºC	-2	+2	

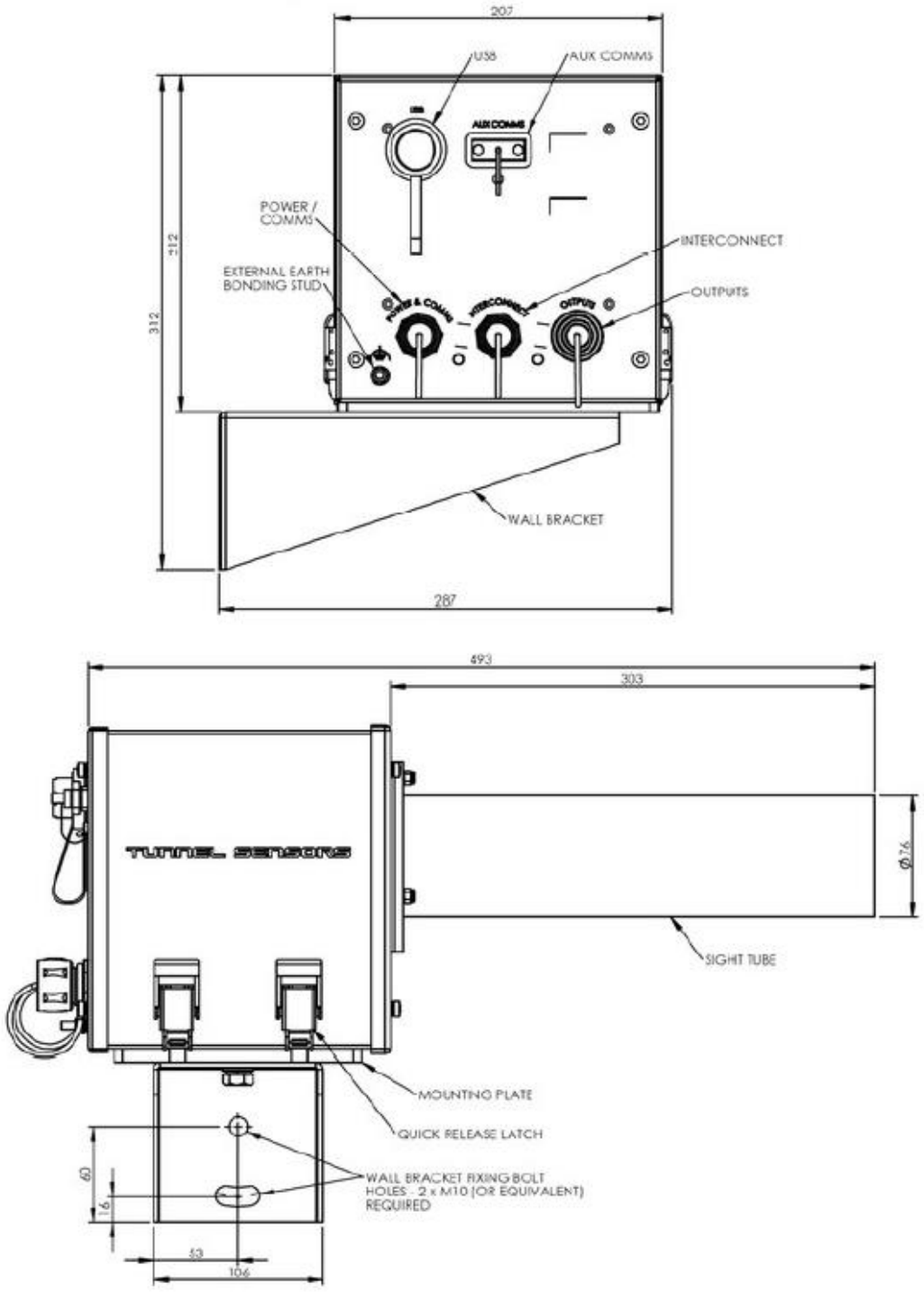
Power

22	Voltage	Vdc	+24		
23	Voltage Tolerance	%	-10	+10	
24	Nominal Current Consumption	A		2	
25	Power Up Current Consumption	A		3	

Physical					
29	Ingress Protection			IP67	
30	Operating Temperature	°C	-20	+55	
32	Operating Humidity	%		100	
33	Regulatory Compliance				2014/30/EU (Electromagnetic Radiation) 2014/35/EU (Low Voltage)
34	Materials				Stainless Steel (powder coated)
35	Dimensions	mm	180 x 210 x 200		Each head (without sight tubes)
36	Weight	kg		5.3	Each head
37	Warranty	Months	24		Return to base warranty. Extensions available.

Compliance & Design					
27	Design Life	Years	20		
28	MTBF	Years	>10		
29	Warranty	Months	24		Return to base warranty. Extensions available.

Basic Dimensional Sketch



ANEMOMETER	
Illustration	**Basic Information**
	Tunnel monitor using ultrasound technology to measure the speed and direction of air movement within the tunnel environment. These measurements can be used as part of an air quality management system for ventilation control within a tunnel or other confined space
Technological Description	
Self-contained transceiver which works by measuring the change in transit time of a sound wave due to the flow of air in the direction of the sound wave. The system contains four ultrasound transceivers from which ultrasonic signals are emitted. These ultrasonic signals are bounced off the "reflection roof" and the reflected signals are then received by the transceivers. The time taken for the ultrasound to travel this reflected path is accurately measured, enabling the velocity and direction of moving air to be measured.	

Technical Data

Parameter	Comment
Measuring principle	Ultrasonic transit time (fixed path)
Measurement reading	Air flow in m/s Also available as ft/min or kph (user selected)
Measuring range	± 60 m/s (user configurable)
Resolution	0.01 m/s
Accuracy	± 2 %
Lower detectable limit	0.02 m/s
Response time	1...100 s (user configurable)

Power

Voltage	+24 Vdc (100...240 Vac with optional PSU)
Nominal current consumption	200 mA
Power up current consumption	200 mA

Interface options

Serial comms	ModBus RTU via RS485 External USB
Analogue output (two)	0/2/4...20.0 mA (isolated and scalable)
Relay contacts (five)	3A @ 30 Vdc (programmable)

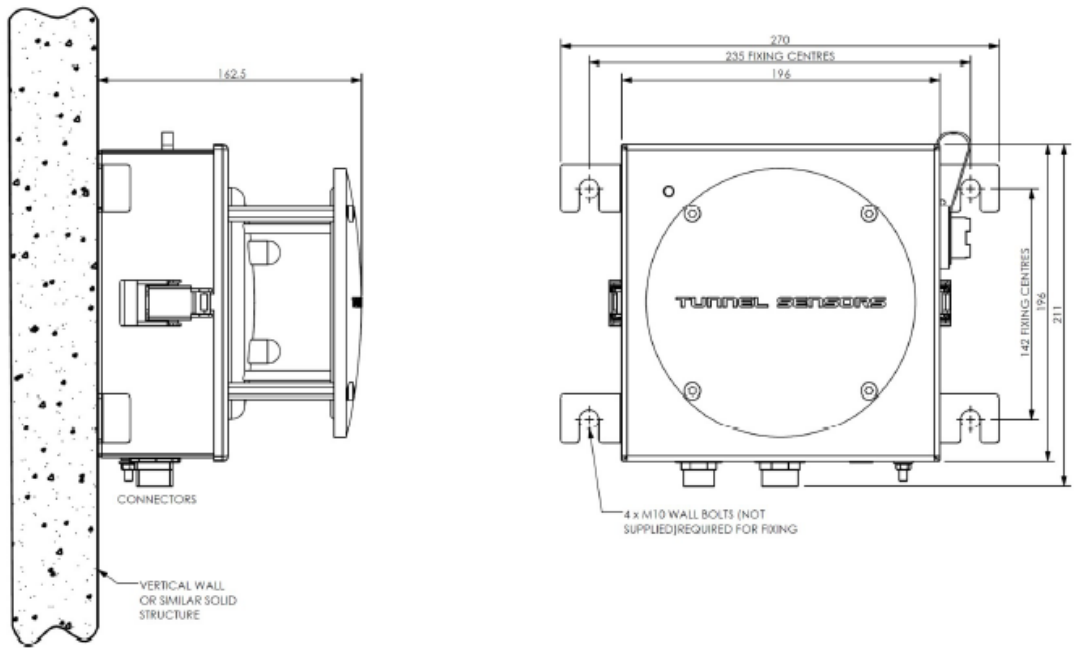
Physical

Ambient operating temperature	-20...+70 °C
Ambient operating humidity	0...100 %
Ingress protection	IP67
Materials Enclosure Transceiver	 316 stainless steel Flame retardant UL rated polycarbonate
Dimensions	200 x 200 x 160 mm
Weight	2.4 kg

Compliance & design

Electrical compliance	CE mark 2014/30/EU (electromagnetic radiation) 2006/95/EC (low voltage)
Design life	> 20 years
MTBF	> 10 years
Warranty	24 months

Basic Dimensional Sketch



WEATHER STATION	
Illustration	**Basic Information**
	Compact weather station with measurement of temperature, relative humidity, precipitation intensity, precipitation type, precipitation quantity, air pressure, wind direction, wind speed and radiation.
Technological Description	
- Measurement technology: Ultrasonic/Wind, NTC/T, Capacitive/RH, MEMS capacitive/Pressure, Thermopile/Radiation, Radar/Precipitation - Interfaces RS485 with supported protocols UMB-Binary, UMB-ASCII, Modbus-RTU, Modbus-ASCII, XDR and optional SDI-12	

Technical Data

General	
Dimensions	Ø approx. 150 mm, height approx. 317 mm
Weight	Approx. 1.5 kg
Interface	RS485, 2 - wire, half - duplex
Power supply	4...32 VDC
Operating temperature	-50...60°C
Operating rel. humidity	0...100% RH
Heating	40 VA at 24 VDC
Cable length	10 m
Protection level housing	IP66
Mast mounting suitable for	Mast diameter 60 - 76 mm

Temperature	
Principle	NTC
Measuring range	-50...60 °C
Unit	°C
Accuracy	±0.2°C (-20...50 °C), otherwise ±0.5 °C (> -30 °C)

Relative humidity	
Principle	Capacitive
Measuring range	0 ... 100 % RH
Unit	% RH
Accuracy	±2 % RH

Air pressure	
Principle	MEMS capacitive
Measuring range	300 ... 1200 hPa
Unit	hPa
Accuracy	±0.5 hPa (0...40 °C)

Wind direction	
Principle	Ultrasonic
Measuring range	0 ... 359.9 °
Unit	°
Accuracy	< 3° RMSE > 1.0 m/s

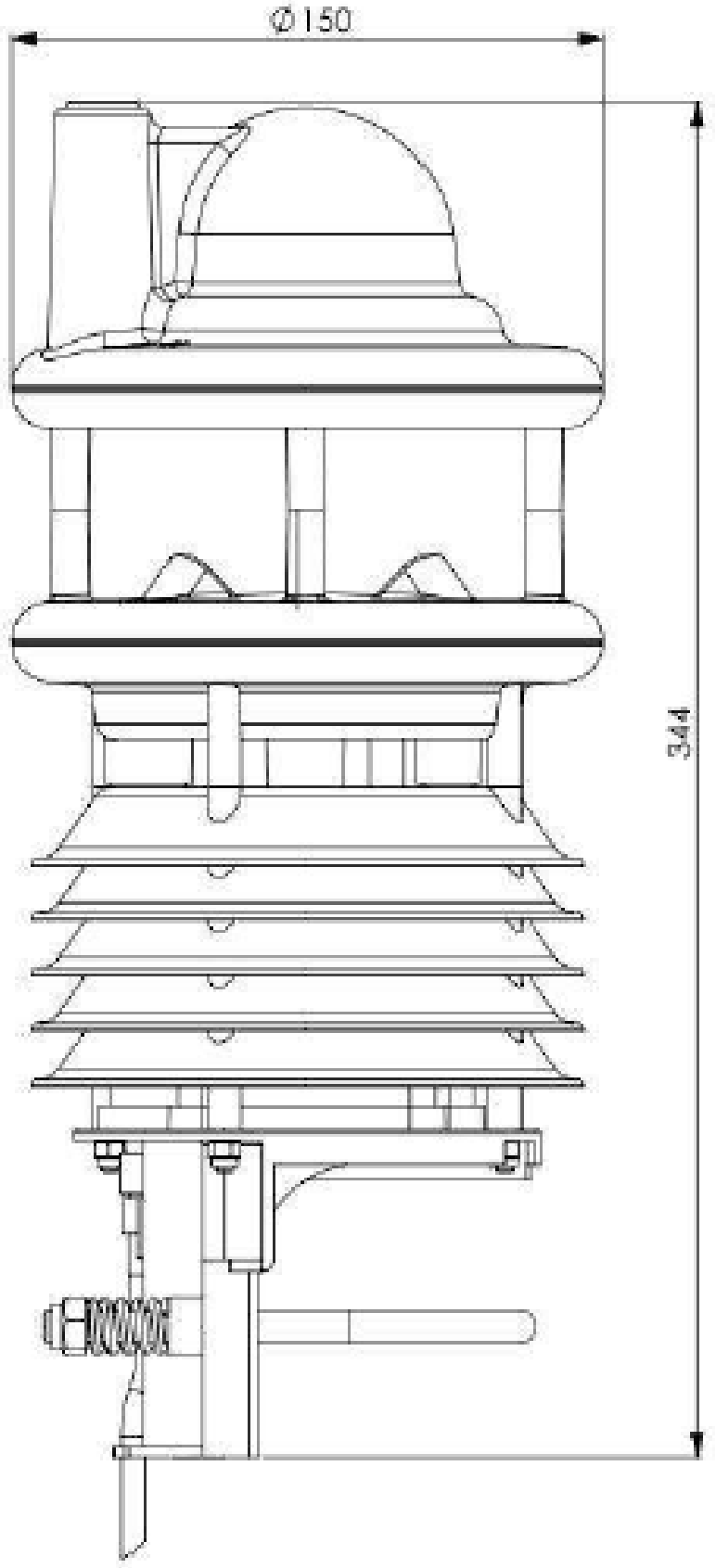
Wind speed	
Principle	Ultrasonic
Measuring range	0 ... 75 m/s
Unit	m/s
Accuracy	±0.3 m/s or ±3 % (0...35 m/s) ±5 % (>35 m/s) RMS
Resolution	0.1

Precipitation intensity	
Resolution	0.1 mm/h

Precipitation quantity	
Resolution	0.01
Reproducibility	Typical >90 %
Measuring range drop size	0.3...5 mm
Type of precipitation	Rain/snow

Radiation	
Unit	W/m^2
Accuracy	5%
Response time (95%)	< 1 s
Spectral range	300 to 1100 nm
Measuring range	1400 W/m^2

Basic Dimensional Sketch



CROSS-PASSAGES VENTILATION

Illustration	Basic Information
 -	Fan to manage overpressure in the cross passages with L=800 mm silencer. The motor has C2 painting according to EN ISO 12944-2 standard.

Technological Description

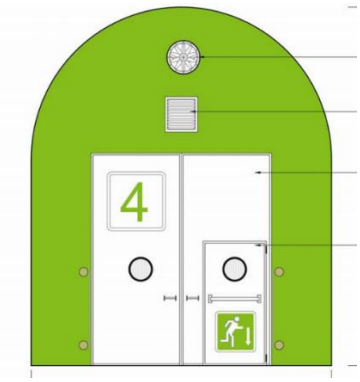
The motor of the fan has a nominal intensity of 15.5 A, a start intensity that is 8 times higher and a nominal voltage over frequency of 400/50 U/Hz.

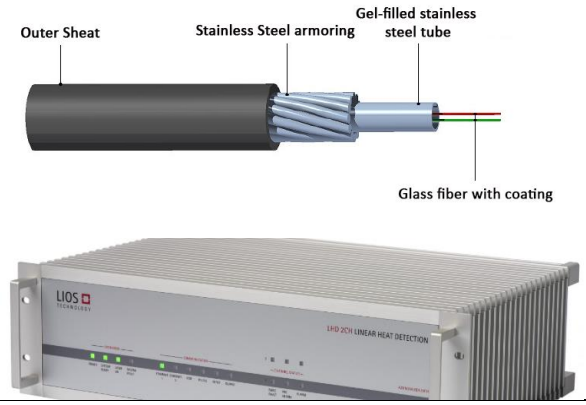
Technical Data

Fan: Volumetric flux: 6.6 m^3/s
Immobile wind force: 250 N
Mobile wind force:
Weight (without motor): 49 kg
Flux velocity: 33.4 m/s

Motor: Nominal revolution: 2920 1/min
Rated power: 7.5 kW
Protection: IP55
Weight: 41 kg

Basic Dimensional Sketch



FIRE DETECTION SYSTEM	
Illustration	**Basic Information**
	Based on a standard multi-mode and single-mode telecom fibers Quick fire detection and precise localization of the source Information on magnitude and direction of the fire spread Alarm and pre-alarm for each zone Selectable alarm and pre-alarm criteria Maintenance-free (essential for underground inaccessible areas)
Technological Description	
Embedded inside the HV/EHV insulated power cable Small, flexible and purely passive sensor element immune to electromagnetic interference and aggressive atmospheric conditions.Sampling interval down to 0.25 m. 10,000 m detection range	
Technical Data	
MECHANICAL DATA Controller 19" rack / 3 units of height Dimensions (HxWxD) 13.5x44.9x29 cm Weight 13 kg ELECTRICAL DATA Operating Voltage (DC Controller) DC 12 ... 48 V Mains Voltage (AC Controller) Ac 100 ... 240 V Power Consumption (DC Controller) <25W (max. 45 W/60°C) Communication interfaces LON, TCP/IP, Modbus, RS232, USB OPTICAL DATA Fiber type Gradient index 62.5/125 µm multimode Optical Connector E2000 / APC ENVIRONMENT CONDITIONS Storage Temperature -35 ... +75°C Operating Temperature -10 ... +60°C Humidity (non condensing) ≤95% rel. Protections class (IEC 60529) IP51 APPROVALS VdS (pr EN 54-22) G 211030, response classes A1N, BN, CN UL S25135	
Basic Dimensional Sketch	
-	

FIRE HYDRANT

Illustration	Basic Information
	Fire hydrant type C (according to EN 14384 standard) with impact protection. The design and manufacturing favours the robustness of the fire-fighting system.

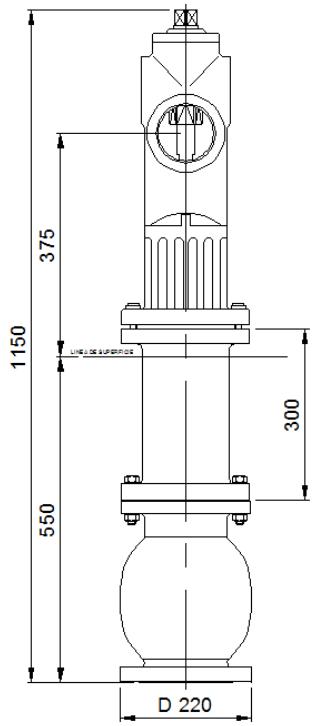
Technological Description

Fire hydrant type C (according to EN 14384 standard) with anti-icing system, automatic drainage, helical spring closure and oil bath activation mechanism with waterproof sump.

Technical Data

Output connections: 2 x 2 ½ ’’ + 1 x 4’’
Nominal pressure: 16 bar
Certificate: EN 14384
Assembly depth: 550 mm
Vertical input: BRIDA DIN PN16
MOT: 120 N·m
mST: 250 N·m
Kv 2 ½’’ outputs: 115
Kv 4’’ outputs: 200

Basic Dimensional Sketch



HOSE CONNECTION	
Illustration	**Basic Information**
	Fire-fighting system equipment with two outputs and one input, coloured in red. It has been designed and manufactured to guarantee high quality conditions, resistant to adverse external conditions such as humidity, low temperatures, etc.
Technological Description	
Hose connection manufactured in cast aluminium alloy with a 70º angle between the two outputs. With a ball valve in each output to regulate the flux	
Technical Data	
2 external thread outputs: 2½'' thread 1 internal thread input: 3'' Body material: Cast aluminium alloy Painting: Red polyester RAL3002 Pressure: 25 bar 70º corner between outputs	
Basic Dimensional Sketch	
-	

FIRE-FIGHTING PUMPING GROUP

Illustration	Basic Information
	The projected fire-fighting pumping group is composed of three pumps that have been previously evaluated to meet the requirements of the installation.

Technological Description

Technical Data

Components:

- Electric Pump:
  - Axial suction, radial impulsion
  - Stainless steel shaft
  - 2 poles three-phase asynchronous motor (400 V, 50 Hz)
  - Protection: IP55
  - Power: 110 kW
- Diesel Pump:
  - Tank capacity: 440 L
  - Dual battery kit
  - Power: 110 kW
- Auxiliary Jockey Pump:
  - Linear suction and impulsion
  - Material: Stainless steel /
  - Power: 4 kW
  - Protection: IP55
  - Shaft isolation with mechanical closure
  - 2 poles asynchronous motor
- Hydropneumatic tank (24/16):
  - Metallic bench
  - Cut valve and check valve in each pump
  - Impulsion manifold DN150

Basic Dimensional Sketch

-

PERMANENT LIGHTING

Illustration	Basic Information
	LED technology lighting fixture. All components analysed to fulfil high quality standards in order to guarantee a long lifetime of the elements and a high system efficiency.

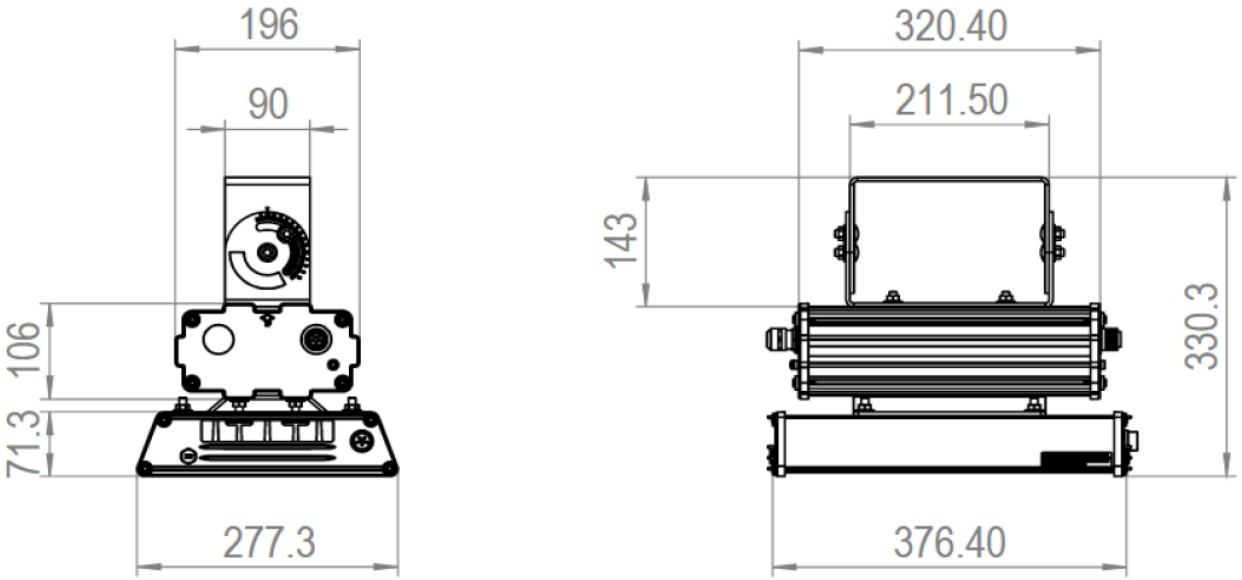
Technological Description

LED fixture made in aluminium (resistant to corrosion), with strong design and easy maintenance. Flexible solution for easy installation, overheat protection and long system lifetime (100,000 hrs).

Technical Data

Cover: anodize aluminium and injecting aluminium
Symmetry: asymmetric
Power: 95 W
Operating current: 600 mA
Flux: 10741 lm
Colour temperature: 4000 K
Efficiency: 113 lm/W
Protection: IP66
Operating temperature: -40ºC to 50ºC

Basic Dimensional Sketch



EMERGENCY LIGHTING

Illustration	Basic Information
	LED fixtures installed in both walls of the tube. They are normally placed every 10 m, at a height of 1 m. The housing of the modules are made of polycarbonate. Its operating mode is no permanent and it has a superficial installation.

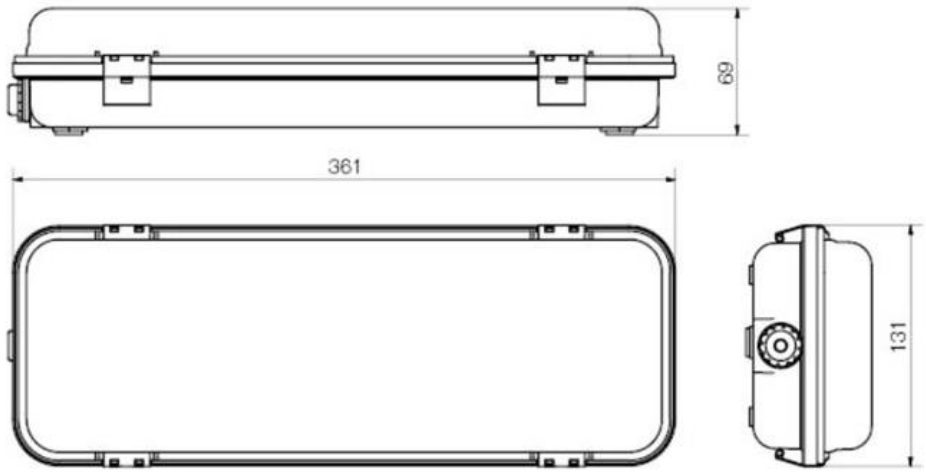
Technological Description

This optical sidewalk indication has been developed to mark the emergency way to exit the tunnel. It consists of a lighting system that will start operating in case there is an emergency in the tunnel. They will be connected to an Uninterruptible Power Supply.

Technical Data

Housing material: Polycarbonate
Dimensions: 360 x 131 x 69 mm
Flux: 110 - 200 lm
Autonomy: 1 hour
Supply: 230 V, 50 Hz
Protection: IP65
Ni-Cd battery, 3.6 V/750 mAh

Basic Dimensional Sketch



SELF-ILLUMINATING LIGHT MODULES (OUTDOOR LIGHTING_TC ACCESS ROADS)

Illustration	Basic Information
	Optimized solution for outdoor lighting, saving up to 80% energy compared to conventional fixtures. It includes the identification of the fixture with Service tag for a faster and easier maintenance. Valid for any application due to its optimized optical distribution and the LEDGINE-0.21 optical platform. Its design is focused on future integrations, it is functional and it can easily be adapted to high lighting requirements projects.

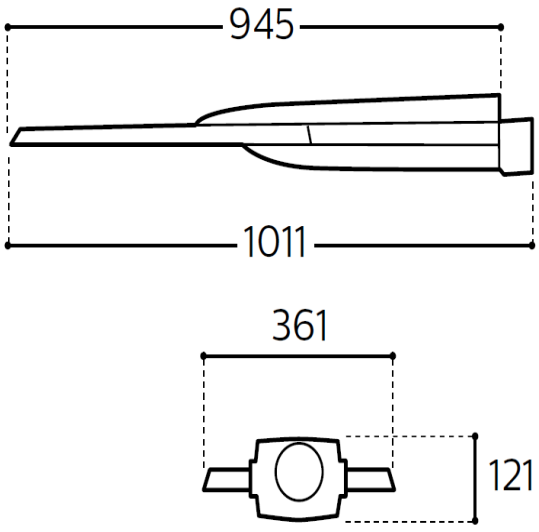
Technological Description

LED mast luminaire, aluminium cover, tempered glass closure, 12 meters high, reversible fixation, PMMA optics, symmetric light characteristic, overheat protection, long system lifetime (100,000 hrs).

Technical Data

Cover: high pressure aluminium injection
Symmetry: symmetric distribution
Flux: 29240 lm
Colour temperature: 4000 K
Overvoltage protection: 4 kV/6 kV, 10 kV
Nominal voltage: 230 V, AC, 50Hz
Area against wind: 0.0902 m^2
Approval Protection rating: IP66
Certification: CE, ENEC in preparation

Basic Dimensional Sketch



SELF-ILLUMINATING LIGHT MODULES
(OUTDOOR LIGHTING_TC SURROUNDINGS)

Illustration	**Basic Information**
	Optimized solution for outdoor lighting, saving up to 80% energy compared to conventional fixtures. It includes the identification of the fixture with Service tag for a faster and easier maintenance. Valid for any application due to its optimized optical distribution and the LEDGINE-0.21 optical platform. Its design is focused on future integrations, it is functional and it can easily be adapted to high lighting requirements projects.

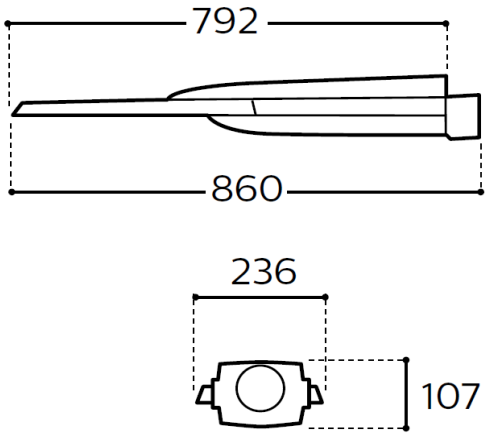
Technological Description

LED mast luminaire, aluminium cover, tempered glass closure, 6 meters high, reversible fixation, PMMA optics, symmetric light characteristic, overheat protection, long system lifetime (100,000 hrs).

Technical Data

Cover: high pressure aluminium injection
Symmetry: symmetric distribution
Flux: 9680 lm
Colour temperature: 4000 K
Overvoltage protection: 4 kV/6 kV, 10 kV
Nominal voltage: 230 V, AC, 50Hz
Area against wind: 0.0726 m^2
Approval Protection rating: IP66
Certification: CE, ENEC in preparation

Basic Dimensional Sketch



REFLECTIVE EVACUATION SIGN

Illustration	Basic Information
	Evacuation route signs show people in the tunnel the safe way to escape from the tunnel in the case of an emergency. Therefore, they show the distances to the closest exit in the left and right direction in metres.

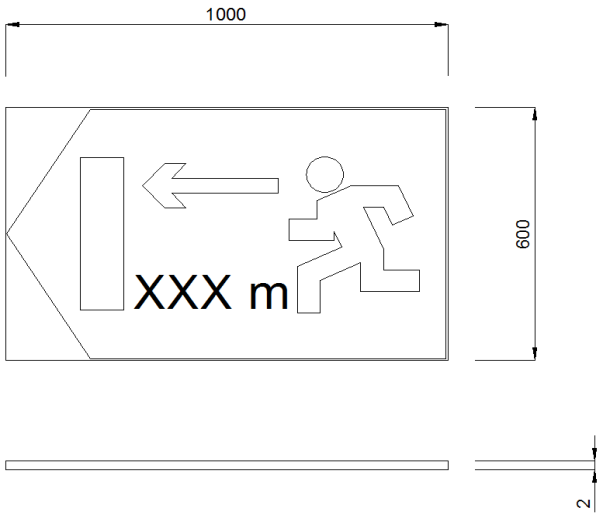
Technological Description

Reflective evacuation route signs are installed on the tunnel walls on both sides of the tunnel, in a height of about 1.0 m above the sidewalk. They are situated in distances of about 25 m to each other. They are made of aluminium to withstand the conditions in the tunnel, like corrosion, exhaust and moisture.

Technical Data

Material: Aluminium
Dimensions: 1000 x 600 mm
Thickness: 2 mm
High quality painting (UV rays resistant)
Luminance: 215 mcd/m^2 (10 min) / 30 mcd/m^2 (60min)
Certificate: AENOR, EN 71-3, etc.

Basic Dimensional Sketch



THREE COLOURED TRAFFIC LIGHTS

Illustration	Basic Information
	3-colured LED traffic light.

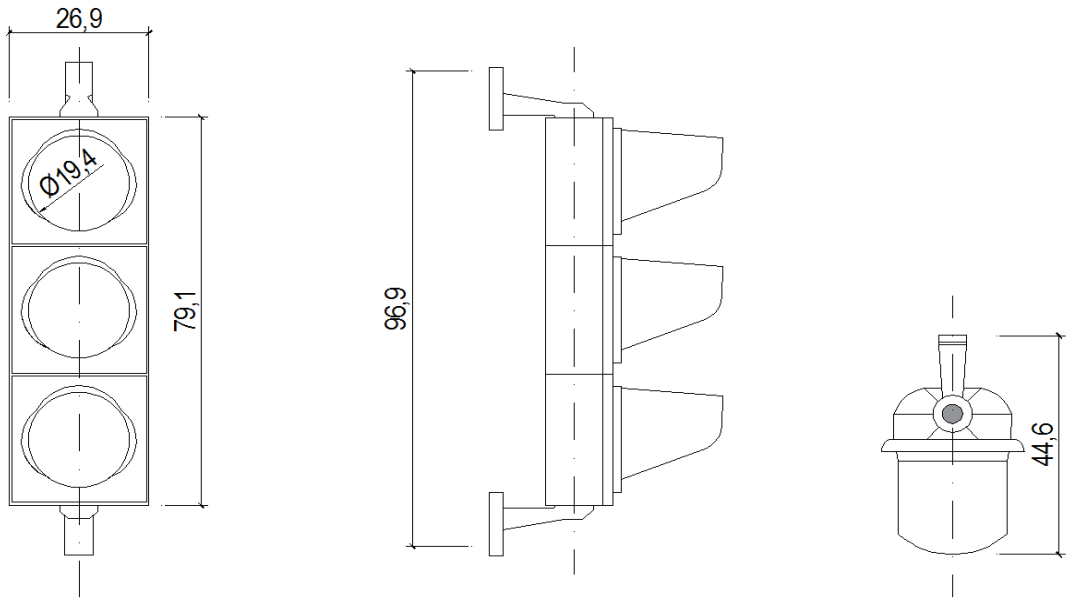
Technological Description

The optic ensures highest energy efficiency, optimized strength and stability, cannot be opened by unauthorized persons, available in different colours and colour combinations, can be mounted vertically as well as horizontally, available with integrated frame to fix backing boards, LED optic ensures highest energy efficiency.

Technical Data

Material: UV-stabilized polycarbonate
Diameters: 100, 200, 300 mm 1, 2, 3 as standard; more aspects on request
Optic: 100 / 210 / 300 mm
Mounting: Two point fixing
Backing Boards: fixation via basic frame or ALU/PC Composite
Housing colours: black (RAL 9005),light grey (RAL 7032),fir green (RAL 6009),orange (RAL 2000)
Impact resistance: acc. to EN60598-1; class IR 3 acc. to EN12368
Change of temperature: EN60068-2-14 passed

Basic Dimensional Sketch



TWO COLOURED TRAFFIC LIGHTS (A-A)

Illustration	**Basic Information**
	2-colured LED traffic light (amber-amber)

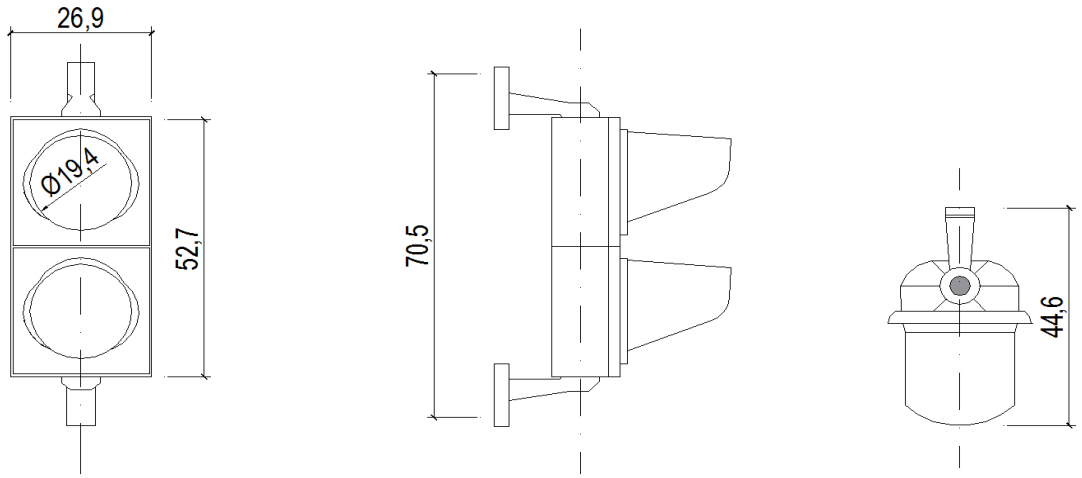
Technological Description

The optic ensures highest energy efficiency, 5 mm LEDs (high light intensity), LED optic ensures highest energy efficiency, long system lifetime (80,000 hrs), the lights can be seen from 300 m. It includes polycarbonate hooks to affix the traffic lights to any pole or wall.

Technical Data

Material: UV-stabilized polycarbonate
Diameters: 200 mm
Voltage range: 85-265 VCA
Mounting: Two point fixing
Power consumption: 7 W
Lamps: 61 LED in each lamp
Protection: IP54

Basic Dimensional Sketch



AUTOMATIC BARRIERS

Illustration	Basic Information
	Automatic barrier designed to operate under hardest and most unfavourable conditions.

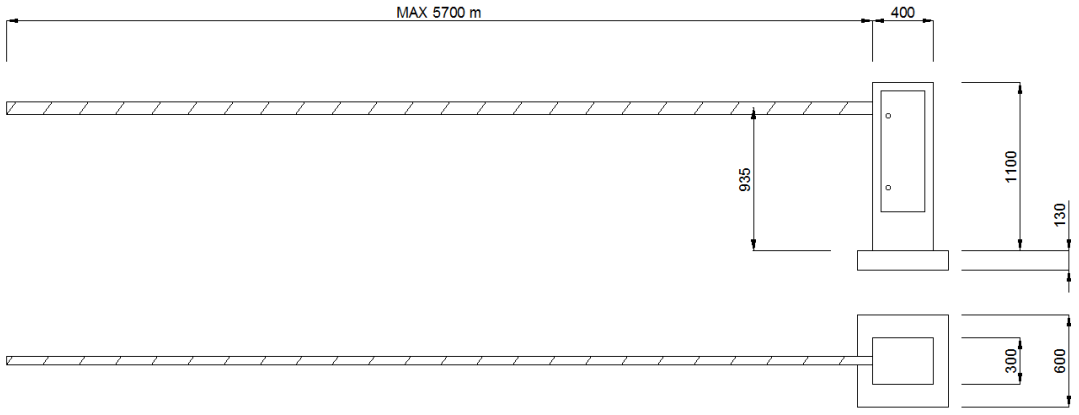
Technological Description

The automatic barriers have a three-phase synchronous motor, power 0.25 CV, and the internal control is conducted by means of relays. The mechanism is protected by an anti-corrosive treatment based on an electrolytic bath. The use of low maintenance materials and the simple and effective mechanical design, provide these barriers incomparable performance in terms of opening speed (1.5 sec), low maintenance, and long equipment life 5,000.000 cycles).

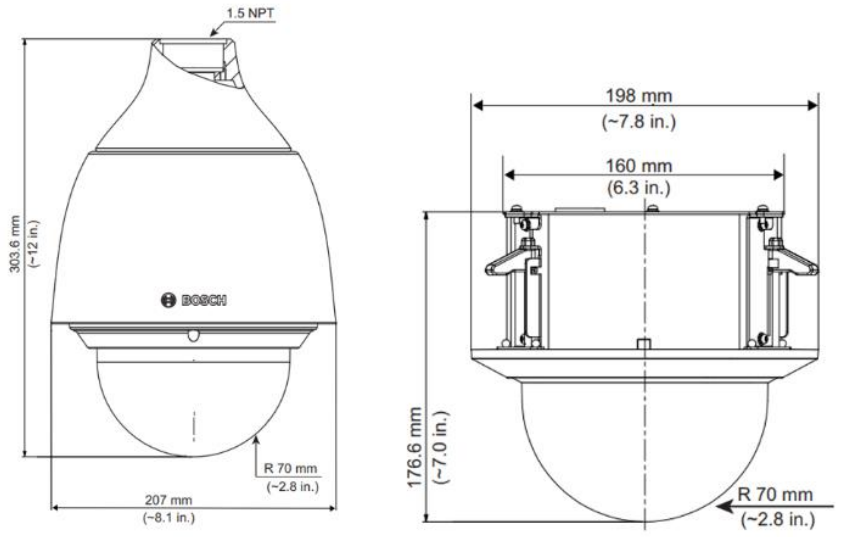
Technical Data

Supply voltage: three-phase 380 VAC / 220 VAC, 50-60 Hz
Motor velocity: 850 rpm
Operational temperature: -20ºC to 75ºC
Weight: 45 kg
Opening/closing speed: 1.5 s
Maximum length: 5.7 m
Protection: IP-44

Basic Dimensional Sketch



INDOOR CCTV CAMERA WITH AID SYSTEM	
Illustration	**Basic Information**
	Compact, rugged camera solution for automatic incident detection. Combines full HD visual imaging with advanced video analytics. Generates traffic data and incident detection information for tunnels, including alerts on stopped vehicles, wrong-way drivers, and lost cargo. High quality sensor 1/2.8" Sony CMOS, with high dynamic range to see in both, light and dark spaces. Bilinx communication for remote configuration and control. Easy to install
Technological Description	
Easy installing CCTV system camera with different colour options and a relation signal/noise higher than 54 dB.	
Technical Data	
Image sensor: 1/2.8" Sony CMOS sensor Nominal tension: 12 VCC / 24 VCA Nominal frequency: 50 / 60 Hz Power consumption: Max. 13W heater off Max. 23W heater on Total pixels: 1920 × 1080 Operating temperature: -30 ºC to 55ºC Housing: 316L stainless steel Protection: IP66 and 67 requirements against dust and water ingress/immersion Certificate: UL, FCC, CSA	
Basic Dimensional Sketch	
190 × 110 × 77mm	

REVOLVE CCTV CAMERA	
Illustration	**Basic Information**
	Dynamic camera unit with universal qualities, high efficiency in low light conditions. High-quality video technology, the system is capable of detecting a person at a maximum distance of 180 m. Two available models, one suspended and another anchored to the ceiling.
Technological Description	
CCTV camera with a revolving range of 360º, aluminium cover, plastic exterior cover with IP51/IP66 protection. The camera has a shutter speed from 1/1 to 1/10000 s.	
Technical Data	
Certification: CE, FCC, cULus Power Consumption: 14 W/24 W Signal-to-Noise Ratio: >55 dB Day/Night Mode: Colour, Mono, Auto Dimensions (⦰ x H): 198 mm x 176.6 mm / 207 mm x 303.6 mm Weight: approx. 2.1 kg / 3.25 kg Temperature range extended: -40 up to +60 °C	
Basic Dimensional Sketch	
	

LOUDSPEAKER
(PA/VA SYSTEM)

Illustration	Basic Information
	The exponential loudspeaker has been designed for noisy zones, this is why it is optimal for indoor and outdoor areas in tunnels. It can resist in the outdoor. The speaker provides a high sound pressure level and a very low distortion.

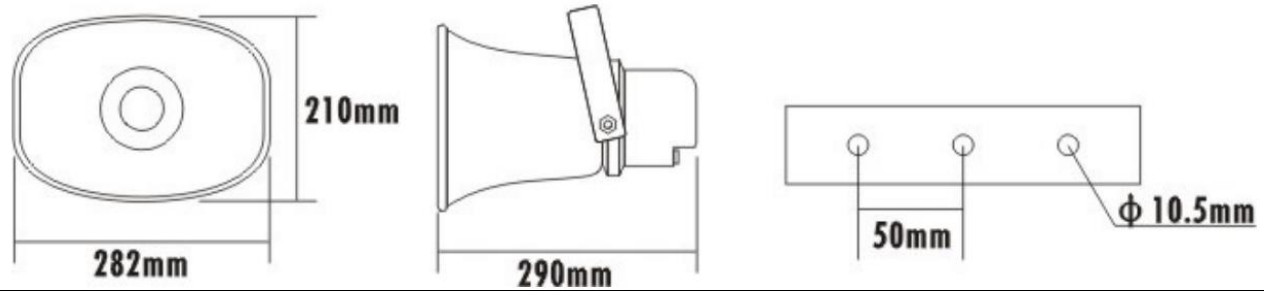
Technological Description

The loudspeaker has an integrated transformer (70 V/100 V), a huge scope and a metallic anchoring. It is outdoor resistant and it has a white ABS cover.

Technical Data

Power Consumption: 30 W (100 V)
Protection: IP66
Dimensions: 282 x 210 x 290 mm
Weight: 2.1 kg
SPL (1 W/1 m): 103 dB
SPL (nominal W/1 m): 118 dB
Frequency response (-10 dB): 300 Hz – 13 Hz

Basic Dimensional Sketch



COAXIAL CABLE	
Illustration	**Basic Information**
	Foam Coaxial Cable 1/2", corrugated copper, Low Smoke Halogen-free, Fire-retardant (Z).
Technological Description	
½'' foam coaxial cable with an attenuation from 3.22 dB/100 m (100 MHz) to 20.90 dB/100 m (3000 MHz)	
Technical Data	
Inner conductor material: Copper-Clad Aluminium Wire Dielectric material: Physical Foam Polyethylene Outer conductor material: Corrugated Copper Tube Jacket material: Black PE or Low Smoke Halogen-free Fire-retardant Minimum number of bends: 15 Tensile strength: 650 N Inner conductor diameter: 3.60 mm Dielectric diameter: 8.7 mm Outer conductor diameter: 12.00 mm Diameter over jacket: 13.30 mm Capacitance: 80.0 pF/m Impedance: 50 ± 1 Ω Velocity: 83% Peak power rating: 19 kW Insulation resistance: 5000 MΩ-km	
Basic Dimensional Sketch	
-	

SOS STATION

Illustration	Basic Information
	The IP SOS tunnel station is an assistance tunnel equipment, useful for help communication. This technological station has hands-free device and high power audio output. Besides, The SOS station presents different models, permitting the installation of extinguishers or hoses.

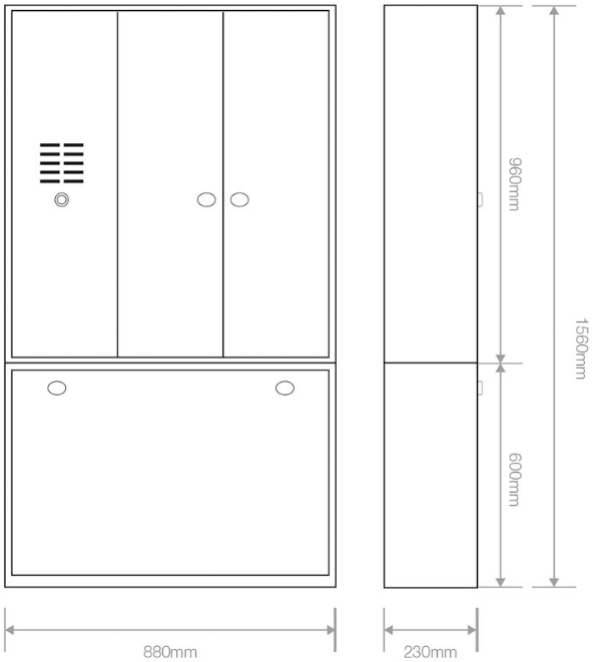
Technological Description

The SOS station offers the possibility of having one or two extinguishers. In addition, it is possible to install a camera unit with VGA, QVGA or QQVGA resolution and a SD card for audio recording. The box has security lock and hidden metallic hinges.

Technical Data

Housing material: Steel covered by corrosion resistant painting
Nominal power consumption: 1 W
Supply voltage: 5 V to 24 V
Industrial temperature range: -40ºC to 85ºC
Operating IP protocols: ARP, IP v4, ICMP, TCP, UDP, DHCP, DNS, SIP, SNMP, HTTP, Telnet, etc.
Body dimensions: 880 x 960 x 230 mm
Base dimensions: 880 x 600 x 230 mm

Basic Dimensional Sketch



TUNNEL VARIABLE LANE SIGN (red cross / green arrow)

Illustration	Basic Information
	Luminous signal composed by a LED graphic zone showing the symbols: red cross (prohibition of lane) and green arrow (availability of lane). High availability of designs and configurations, adaptable to different projects and necessities. These signs have been designed in order to be easily installed in a metallic framework or fixed to the ceiling. The electronic panels have been developed with low consumption technology and they need very reduced maintenance.

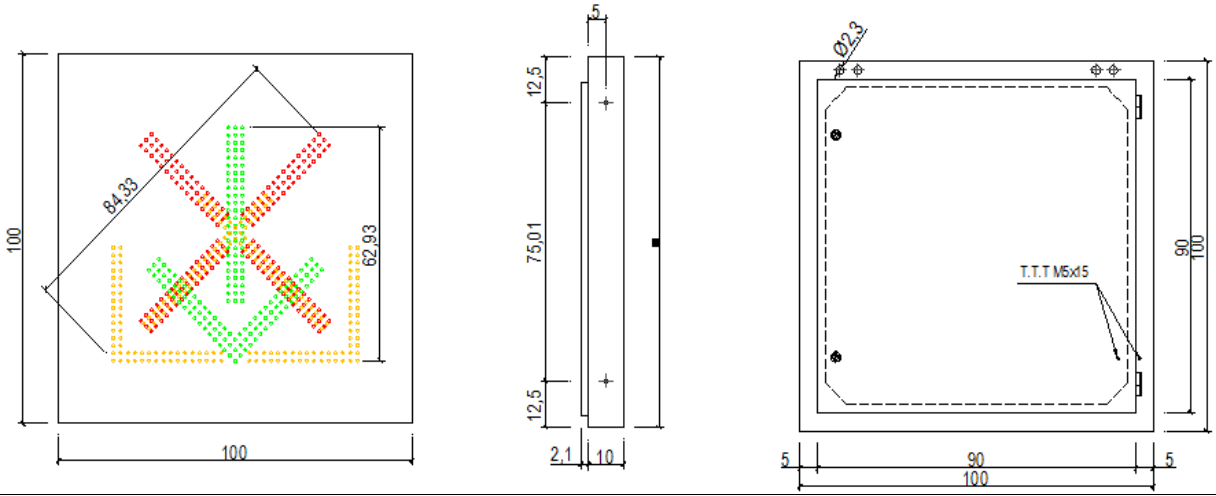
Technological Description

The tunnel variable lane sign is composed by permanently supervised LEDs, even if switched off; the status can be reported to the traffic center or local control. The brightness can be adjusted in both, automatic and manual way, and the long LED life cycle results in extended maintenance intervals.

Technical Data

Light source: High Power LEDs
Housing: Aluminium / Galvanised steel
Protection: IP65 / IP55
Beam width: B2 / B4
Luminance: L3
Interfaces: Ethernet IP, RS-232, RS-485, optical fiber, GPRS, WiFi
Distance between pixels: 14 mm, 20 mm…
Power supply: AC single-phase
Dimensions: 700 x 650 mm / 1000 x 1000 mm / 1200 x 1200 mm
Weight (Galvanised steel): 24 kg / 40 kg / 55 kg
Weight (Aluminium): 15 kg / 24 kg / 32 kg
Power (high power): 25 W / 40 W / 60 W
Power (low power): 7 W / 11 W / 15 W
Certification: CE, EN-12966-2005, 2002/95/CE

Basic Dimensional Sketch



TUNNEL VARIABLE SPEED LIMIT SIGN (red cross / green arrow)

Illustration	Basic Information
	There are three basic models of the VSLS, each one with the capability to display two (2D) or three (3D) digits. The models' classification is based on the circle ring dimensions and the displaying digit heights. The model choice is based on the motorway typical speed limit and the required maximum reading distance that depends on the displaying digit heights. Every VSLS model can display all possible speed limits in increments of 10.

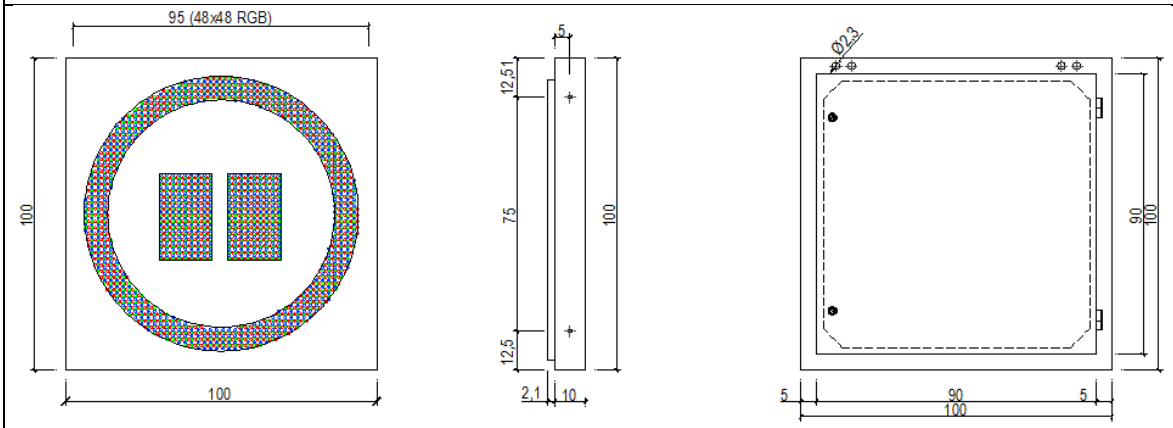
Technological Description

VSLS signs are usually integrated in a Traffic Management System (TMS SCADA), where all signs are controlled according to traffic scenarios and automations. Alternatively smaller scale integrations can be easily performed via the relay inputs. The communication method varies according to project network infrastructure and local communication interfaces.

Technical Data

In-Tunnel / Outdoor installation
SCADA integration
Automatic fault and error detection and
Automatic and manual brightness control in 16 discrete levels
Ability to increase LED gain
Minimal brightness reduction over lifetime due to strictly controlled LED driving conditions
Static 1:1 driving
Ability to display flashing speed limits
Contrast Enhancement Technology
Cover: Aluminium / Stainless steel
Communication interfaces: RS485, RS232, Ethernet, 4 digital inputs for PLC communication
Certification: CE, EN-12966
Protection: IP65
External luminance: 40.000 lux
Beam width: B4
Operational Temperature: -20ºC to +60ºC

Basic Dimensional Sketch



INDOOR VARIABLE MESSAGE PANEL

Illustration	Basic Information
	LED variable message sign designed with Low Power Technology. It has a mixed configuration formed by an alphanumeric zone and one or two graphic zones.

Technological Description

These panels have been designed in order to have minimum maintenance procedures and they can be installed in the ceiling or on metallic structures.

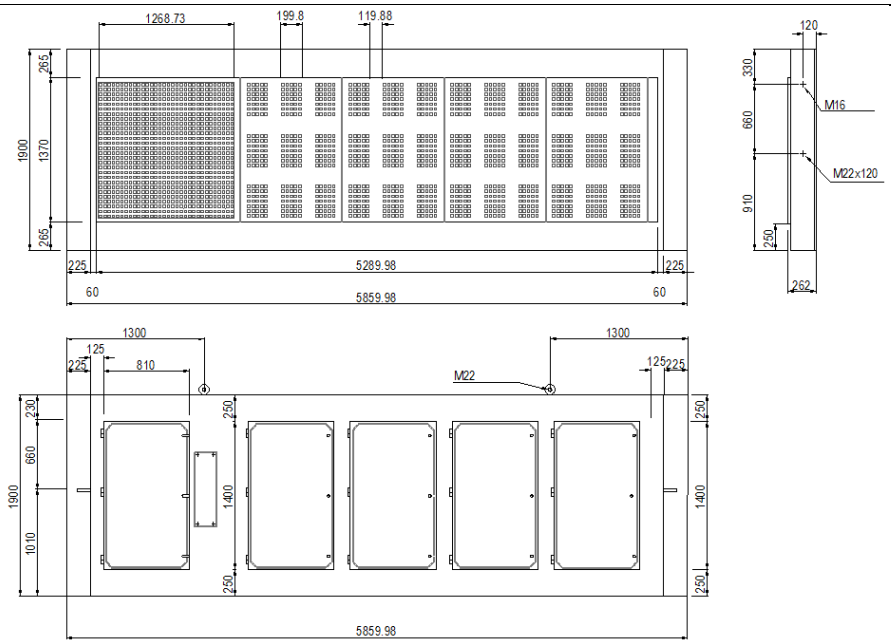
Technical Data

Usual configurations:

- 2 text lines of 12 characters each
- 1 graphic zone + 2 text lines of 12characters each (4580 mm x 1000 mm)
- 1 text line of 16 characters

Graphic area resolution: 32 x 32 pixels RGB / RGBY
Character height: 220 mm, 320 mm, 400 mm…
Housing: Aluminium / Galvanised steel
Protection: IP65 / IP55
Beam width: B2 / B4
Luminance: L3T
Interfaces: Ethernet IP, RS-232, RS-485, optical fiber, GPRS, WiFi
Distance between pixels: 20 mm, 25 mm, 40 mm…
Power supply: AC (single-phase / three-phase), DC

Basic Dimensional Sketch



OUTDOOR VARIABLE MESSAGE PANEL

Illustration



Basic Information

LED variable message sign designed with Low Power Technology. It has a mixed configuration formed by an alphanumeric zone and one or two graphic zones. The graphic area allows the integration of text as an extended part of the alphanumeric area.

Technological Description

These variable message signs have a maximum consume of 350 W, its maintenance procedure is minimum and they can be installed anywhere in the world due to its adaptability to any communications protocol and to the different standards.

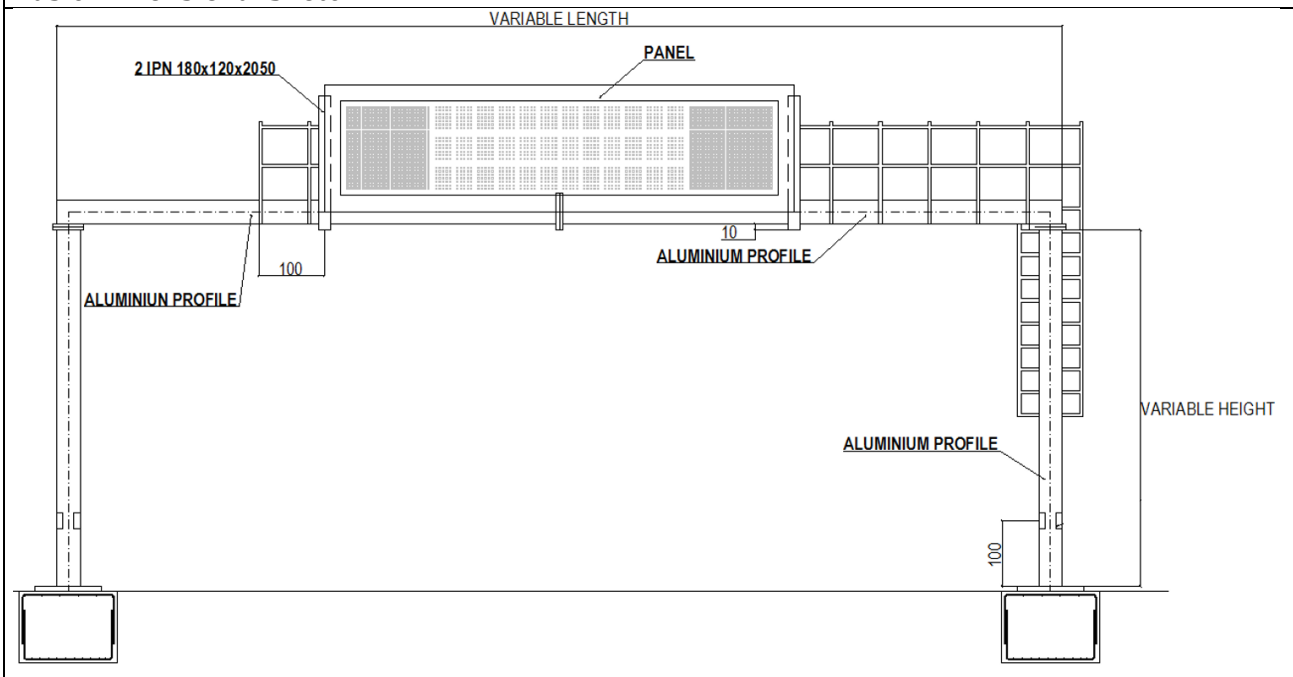
Technical Data

Usual configurations:

- 1 graphic zone + 3 text lines with 12/16/18 characters each (5800 mm x 1920 mm)
- 2 graphic zones + 3 text lines with 12/16 characters each (7140 mm x 1920 mm)

Character height: 220 mm, 320 mm, 400 mm…
Housing: Aluminium / Galvanised steel
Protection: IP65 / IP55
Beam width: B2 / B4
Luminance: L3
Interfaces: Ethernet IP, RS-232, RS-485, optical fiber, GPRS, WiFi
Distance between pixels: 20 mm, 25 mm, 40 mm…
Power supply: AC (single-phase / three-phase), DC
Certification: CE, EN-12966-2005, 2002/95/CE, EU 305/2001.E13

Basic Dimensional Sketch



[DOCUMENT TITLE]

[Document subtitle]

[DATE]

[COMPANY NAME]
[Company address]

Index

DRY TYPE TRANSFORMER 3
DIESEL GENERATOR 5
UNINTERRUPTIBLE POWER SUPPLY SYSTEM (UPS) 7
JET FAN 9
COMBINED NO ,NO2, CO AND VISIBILITY MONITOR 11
ANEMOMETER 13
WEATHER STATION 16
CROSS-PASSAGES VENTILATION 19
FIRE DETECTION SYSTEM 20
FIRE HYDRANT 21
HOSE CONNECTION 22
FIRE-FIGHTING PUMPING GROUP 23
PERMANENT LIGHTING 24
EMERGENCY LIGHTING 25
SELF-ILLUMINATING LIGHT MODULES (OUTDOOR LIGHTING_TC Access Roads) 26
SELF-ILLUMINATING LIGHT MODULES (OUTDOOR LIGHTING_TC Surroundings) 27
REFLECTIVE EVACUATION SIGN 28
THREE COLOURED TRAFFIC LIGHTS 29
TWO COLOURED TRAFFIC LIGHTS (A-A) 30
AUTOMATIC BARRIERS 31
INDOOR CCTV CAMERA WITH AID SYSTEM 32
REVOLVE CCTV CAMERA 33
LOUDSPEAKER 34
COAXIAL CABLE 35
SOS STATION 36
TUNNEL VARIABLE LANE SIGN 37
TUNNEL VARIABLE SPEED LIMIT SIGN 38

INDOOR VARIABLE MESSAGE PANEL.....39

OUTDOOR VARIABLE MESSAGE PANEL.....40

DRY TYPE TRANSFORMER

Illustration



Basic Information

50 Hz three-phase dry type transformer cast under vacuum in filled epoxy resin. Indoor type Includes active filler, essentially composed of trihydrated alumina, a fire suppressant.

Technological Description

thermal class F;
ambient < 40°C, altitude < 1000m;
natural air cooling type AN;
It complies with standards: IEC 76-1 to 76-5; IEC 726 (1982);

Technical Data

insulation level: 17.5 kV and 24 kV

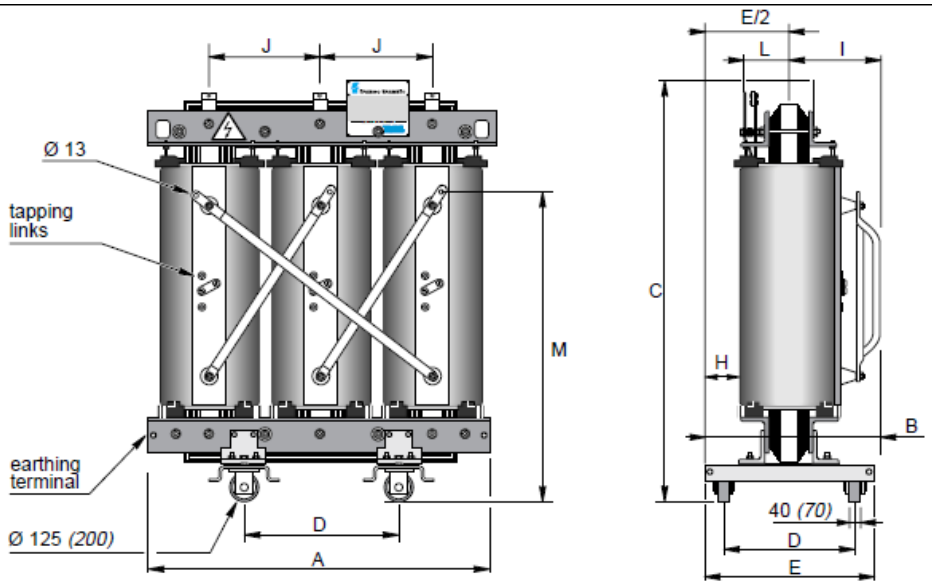
rated power (kVA) (1) (*)		160 (2)	250	315 (2)	400	500 (2)	630	800	1000	1250	1600	2000	2500	3150
rated primary voltage (1)		20 kV												
rated insulation level (3)		24 kV												
frequency (1)		50 Hz												
maximum ambient temperature		40°C												
secondary voltage at no load (1)		400 V												
HV tapping range (off-circuit) (1)		± 2.5 %												
vector group		Dyn 11 (delta, star neutral brought out)												
losses (W)	no load losses	650	880	1030	1200	1400	1650	2000	2300	2800	3100	4000	5000	6300
	load losses at 75°C	2300	3300	4000	4800	5700	6800	8200	9600	11500	14000	17500	20000	23000
	load losses at 120°C	2700	3800	4600	5500	6500	7800	9400	11000	13100	16000	20000	23000	26000
rated impedance voltage (%)		6	6	6	6	6	6	6	6	6	6	6	6	7
no-load current (%)		2.3	2	1.8	1.5	1.5	1.3	1.3	1.2	1.2	1.2	1.1	1	1
switching current	Ie/In (peak value)	10.5	10.5	10	10	10	10	10	10	10	10	9.5	9.5	9.5
	time constant	0.13	0.18	0.20	0.25	0.25	0.26	0.30	0.30	0.35	0.4	0.4	0.5	0.6
noise level (4)	acoustic power LWA	62	65	67	68	69	70	72	73	75	76	78	81	81
dB(A)	acoustic pressure LPA at 1 metre	50	53	55	56	56	57	59	59	61	62	63	66	65

(*) the rated power is defined by natural air cooling (AN). Should there be particular constraints, it may be increased by 40% by forced cooling addition (AF). Please consult us.
(1) other possibilities upon request, consult us.
(2) non standard ratings available on request.
(3) reminder of insulation levels:

rated insulation level (kV)	7.2	12	17.5	24
kV r.m.s. 50 Hz - 1 mn	20	28	38	50
kV B.I.L. 1.2/50 µs	60	75	95	125

(4) according to CEI 551

Basic Dimensional Sketch



insulation level : 17.5 kV and 24 kV - low voltage 400 V

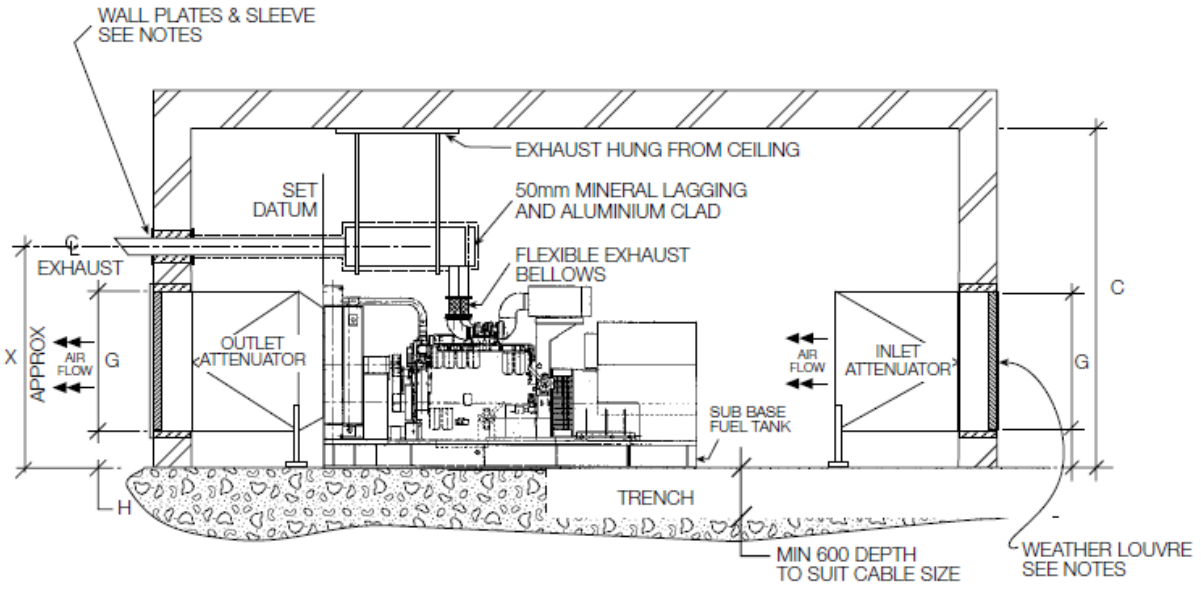
rated power (kVA) (1) (*)		160	250	315	400	500	630	800	1000	1250	1600	2000	2500	3150
dimensions (mm)	A	1070	1140	1170	1230	1300	1340	1400	1560	1610	1700	1950	2030	2200
	B	680	690	795	795	795	800	805	945	945	945	1195	1195	1195
	C	1320	1350	1510	1490	1580	1690	1720	1920	2030	2170	2380	2440	2600
	D	520	520	670	670	670	670	670	820	820	820	1070	1070	1070
	E	650	650	800	800	800	800	800	950	950	950	1200	1200	1200
	H	160	150	220	210	190	190	180	230	220	210	290	290	300
	I	360	370	370	380	400	400	410	430	440	460	450	460	460
	J	360	380	390	410	440	450	470	510	530	560	630	640	690
	L	180	180	190	200	210	210	220	250	250	260	310	320	380
	M	890	930	1090	1070	1110	1210	1240	1410	1510	1650	1770	1750	1750
weights (kg)		780	950	1140	1290	1520	1730	1990	2480	2810	3430	4720	5980	7300

DIESEL GENERATOR	
Illustration	**Basic Information**
	A diesel generator (also known as diesel genset) is the combination of a diesel engine with an electric generator to generate electrical energy. This is a specific case of engine-generator. A diesel compression-ignition engine is usually designed to run on diesel fuel, but some types are adapted for other liquid fuels or natural gas.
Technological Description	
Generator sets in emergency power applications are required to start and pick up all emergency loads within 10 seconds of a power failure Prime Power Output available with varying load for an unlimited time. Average power output is 70% of the prime power rating. Typical peak demand of 100% of prime-rated ekW with 10% of overload capability for emergency use for a maximum of 1 hour in 12. Overload operation cannot exceed 25 hours per year.	

Technical Data

Prime Rating KVA	Type of ENGINE	TA Luft	Generator Model	Room dimensions			Set back	Set C/L position	Exhaust		Attenuator Dimensions			Uplift	Cable trench position		
				Length A	width B	height C	D	P	Offset E	Height X	F	Y	G	H	L	M	N
575	VTA28G5		460DFGA	8400	3450	3450	400	1725	400	2950	1500	1500	2000	400	775	500	5150
640	VTA28G5		512DFGB	8400	3450	3450	400	1725	400	2950	1500	1500	2000	400	775	500	5150
750	VTA28G6		600DFGD	8400	3450	3450	400	1725	400	2950	1500	1500	2000	400	775	500	5150
725	QST30G1	4g	580DFHA	8400	3640	3700	500	1820	400	3150	2400	1200	2400	400	920	500	5100
800	QST30G2	4g	640DFHB	8400	3640	3700	500	1820	400	3150	2400	1200	2400	400	920	500	5100
939	QST30G3		751DFHC	8400	3640	3700	500	1820	400	3150	2400	1200	2400	400	920	500	5100
1000	QST30G4		800DFHD	8450	3640	3800	500	1820	450	3150	2700	1200	2400	200	920	500	5100
725	QST30G6	2g	580DFHE	8400	3640	3700	500	1820	400	3150	2400	1200	2400	400	920	500	5100
800	QST30G7	2g	640DFHF	8400	3640	3700	500	1820	400	3150	2400	1200	2400	400	920	500	5100
939	QST30G8	2g	751DFHG	8400	3640	3700	500	1820	400	3150	2400	1200	2400	400	920	500	5100
936	KTA38G3		748DFJC	9500	3800	3800	500	1900	450	3100	1950	1800	2200	200	920	500	3655
1019	KTA38G5		815DFJD	9500	3800	3800	500	1900	450	3100	1950	1800	2200	200	920	600	3655
1256	KTA50G3		1005DFLC	10360	3800	3800	500	1900	450	3100	1950	1800	2200	200	920	600	4375
1405	KTA50G8		1125DFLE	11700	4000	4500	500	2000	500	3500	2450	2100	2600	200	920	600	5000
1500	KTA50GS8		1200DFLF	11700	3800	3800	500	1900	500	3100	2450	2100	2600	200	920	600	5000
1256	KTA50G6	4g	1005DFLG	10360	3800	3800	500	1900	450	3100	1950	1800	2200	200	920	600	4375
1256	KTA50G7	2g	1005DFLH	10360	3800	3800	500	1900	450	3100	1950	1800	2200	200	920	600	4375
1875	QSK60G3		1500DQKC	12650	4500	4500	600	2250	693	3800	2800	2400	2600	325	645	600	5000
2000	QSK60G4		1600DQKD	12650	4600	4500	600	2250	693	3920	3150	2400	3100	250	645	600	5000
1875	QSK60G3	2g	1500DQKE	11200	4000	4500	800	2000	693	3800	2700	1500	2500	325	645	600	3800
2000	QSK60GS3	2g	1600DQKF	11200	4000	4500	800	2000	693	3800	2700	1500	2600	325	645	600	3800

Basic Dimensional Sketch



UNINTERRUPTIBLE POWER SUPPLY SYSTEM (UPS)

Illustration



Basic Information

Highly efficient, easy-to-deploy 3-phase uninterruptible power supply (UPS)

Technological Description

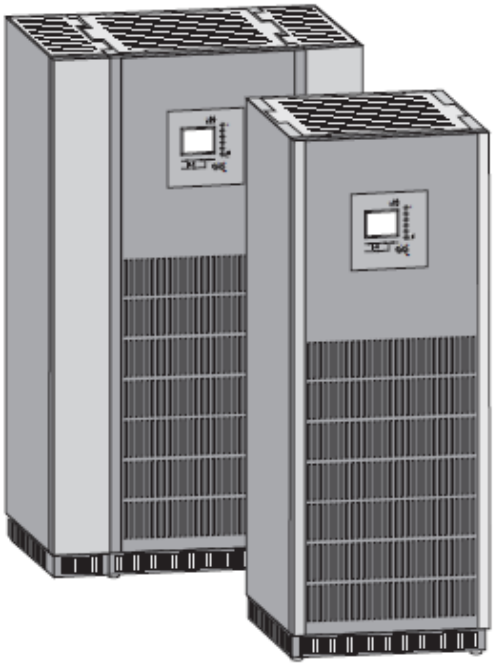
Robust operation - No power derating in kW up to 40 degrees C
Parallel-capacity capable
Topology: Double Conversion Online

Technical Data

UPS rating	20 kVA	30 kVA	40 kVA	60 kVA	80 kVA	100 kVA	120 kVA
Input voltage (V)	380 - 400 - 415						
Input voltage range permitted by the standard according to the curve below (V)	250 to 470 for a standard UPS 342 to 470 for a UPS with backfeed protection						
Input frequency (Hz)	45 to 65						
Rated current[1] Normal AC input (A)	32	45	57	87	115	143	171
Maximum input current (A) for 400 V	33	46	58	88	116	145	173
Input current (A) for 400V, overload= 1.25 In limited to 10 min.	39	56	72	108	145	181	217
Input current (A) for 400V, overload=1.5 In limited to 1 min.	47	68	87	130	174	217	260
THDI	< 6% at full load < 8% at 25–75% load						
Maximum short circuit withstand (kA)	20				30		
Input fuse ratings (A)	80	80	80	125	160	315	315

Basic Dimensional Sketch

UPS cabinet



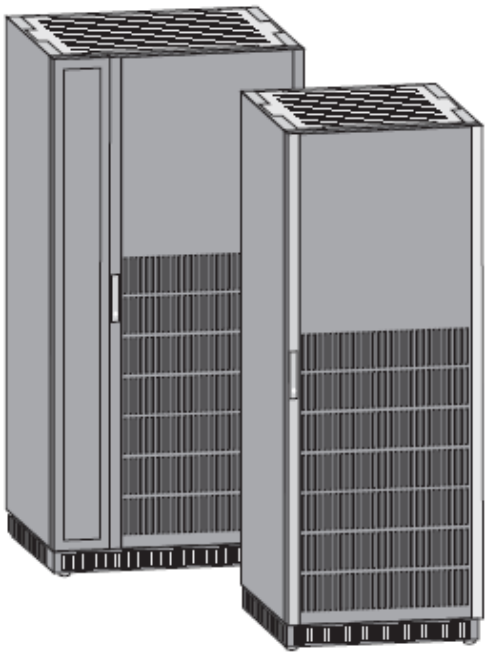
Dimensions

UPS power rating (kVA)	Dimensions (H x W x D)
20/30/40/60 without battery	1900 x 712 x 848 mm
80/100/120 without battery	1900 x 712 x 848 mm
20/30/40/60/80 with internal battery	1900 x 1112 x 848 mm

Weight in kg (UPS without battery or with built-in battery)

Backup time	UPS power rating (kVA)				
	20 30	40	60	80	100 120
Without battery	400	400	400	520	520
5 min	808	808	958	1120	
10 min	808	958	1045		
15 min	958	1045			
30 min	1045				

External battery cabinet / auxiliary cabinet



Dimensions (H x W x D) and weight

Cabinet 710 mm wide	1900 x 712 x 848 mm 135 kg
Cabinet 1000 mm wide	1900 x 1012 x 848 mm 150 kg

Weight in kg (cabinet alone)

Backuptime	UPS power rating (kVA)				
	40	60	80	100	120
Cabinet 710 mm wide without batt	135	135	135	135	135
Cabinet 1000 mm wide without batt	150	150	150	150	150
5 min				885	980
10 min			885	1142	1307
15 min		885	1142	1307	1764
30 min	882	1307	1764	2439	2742

JET FAN

Illustration



Basic Information

Uni-directional jetfan for longitudinal tunnel ventilation.

The uni-directional jet fans, with asymmetrical blades, are designed to optimize their performance in one direction (forward).

The jet fans are installed inside the tunnel, either hanging them from the ceiling by means of a suspensions system or placing them on top of small base frames fixed to the lateral walls of the tunnel.

The standard configuration of jet fans includes two tubular silencers at both ends of the jet fan unit, so the noise level generated when the jet fans are in operation, especially at full speed, is reduced.

Technological Description

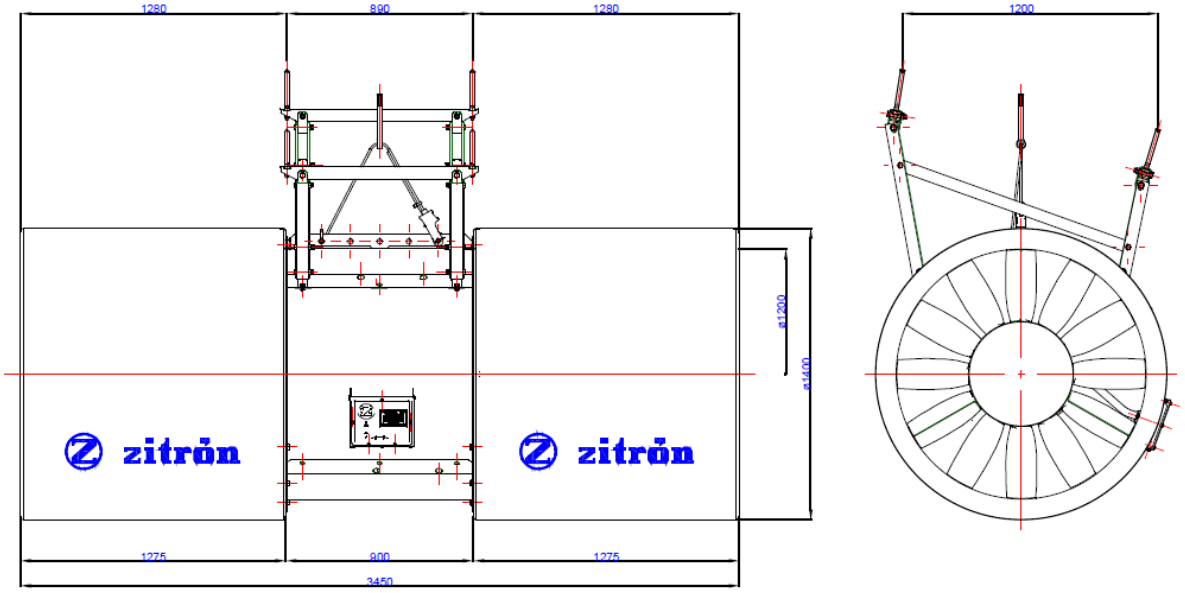
Axial fan (jet-fan type) for installation inside tunnel. Tested and certified to operate at high temperature conditions according to Standard EN 12102-3. High temperature rating: 400ºC during 2 hours.

Technical Data

Thrust Nominal	*Airflow*	*Air speed*	*Fan Diameter*	*Motor Rating / Rotation speed*	*Power Supply*	*High Temperature Rating*	*Reversibility*
[N]	*[m^3/s]*	*[m/s]*	*[mm]*	*[kW / rpm]*	*[Volt/ph/Hz]*	*[ºC / h]*	*[-]*
1441	*37.5*	*33.2*	*1200*	*37 / 1500*	*400/3/50*	*400 / 2*	*Unidirectional*

- Fan casing made of Carbon steel S-275 JR
- Impeller with aluminium alloy blades
- Electric motor WEG 400 V, 37 kW, 50 Hz, S-1, TEAO, IE1, B30, 4 poles, class H (400º-2h).
- Silencers made of Carbon steel S-275 JR (2 Nos.)
- Suspension system included
- Vibration sensor and anti-condensation heater included
- Dynamic balancing included

Basic Dimensional Sketch



COMBINED NO ,NO2, CO AND VISIBILITY MONITOR

Illustration



Basic Information

Single sensor tunnel monitor for measuring visibility, CO, NO NO2 and NOX within a road tunnel or other enclosed space. These measurements can be used to help ensure the effective ventilation of the tunnel and validate its air quality management system.

Technological Description

Sensor that uses a combination of differential optical absorption and infrared spectroscopy to measure nitrogen dioxide (NO2) nitric oxide (NO) and carbon monoxide (CO), and the standard light transmission obscuration technique to calculate visibility.

Technical Data

NO_2 Measurement Performance

No.	Parameter	Units	Min	Max	Comment
1	Path Length	m	5	12	Optimum 10m
2	Measurement Range	ppm (ppb)	0	10	User selectable (Option)
3	Resolution	ppm		0.01	Display resolution
4	Accuracy	%	-5	+5	Of Reading (at 10m path length)
5	Detection Limit	ppm		0.05	At 10m path length
6	Damping	s	1	999	Default setting is 20s
7	Temperature Stability	ppm	-0.05	+0.05	At 10m path length

Visibility Measurement Performance

No.	Parameter	Units	Min	Max	Comment
8	Measurement Range				User selectable
	Transmission	T	0	1.000	
	Extinction Coefficient (k)	m^{-1}	0	0.1000	
	Meteorological Optical Range (MOR)	m	0	15000	
	Opacity	%	0	100	
	Particulate Density (Dust)	mg/m^3	0	100	With density scale factor =1.0
9	Resolution				Display resolution
	Transmission	T		0.001	
	Extinction Coefficient (k)	m^{-1}		0.0001	
	Meteorological Optical Range (MOR)	m		1	
	Opacity	%		0.1	
	Particulate Density (Dust)	mg/m^3		0.1	
10	Accuracy	%			
	Extinction Coefficient (k)	m^{-1}	-0.0005	+0.0005	At 10m path length
	Opacity	%	-0.5	+0.5	
11	Damping	s	1	999	Default setting is 3s
12	Temperature Stability				
	Extinction Coefficient (k)	m^{-1}	-0.001	+0.001	At 10m path length
	Opacity	%	-1	+1	

CO/NO (NO_x) Measurement Performance

No.	Parameter		Units	Min	Max	Comment
13	Display range		ppm	0	500	User selectable
14	Resolution		ppm		0.1	Display resolution
15	Accuracy	CO	%	-5	+5	Of Reading
		NO (NO_x)	%	-10	+10	Instrument calibrated in-situ
16	Detection Limit	CO	ppm		1	
		NO (NO_x)	ppm		2	
17	Damping	CO	s	100		
		NO (NOX)	s	200		
18	Temperature Stability		ppm	-2	+2	At 10m path length

Temperature Measurement Performance

No.	Parameter	Units	Min	Max	Comment
19	Display range	°C	-40	+100	User selectable
20	Resolution	°C		0.1	Display resolution
21	Accuracy	°C	-2	+2	

Power

22	Voltage	Vdc	+24		
23	Voltage Tolerance	%	-10	+10	
24	Nominal Current Consumption	A		2	
25	Power Up Current Consumption	A		3	

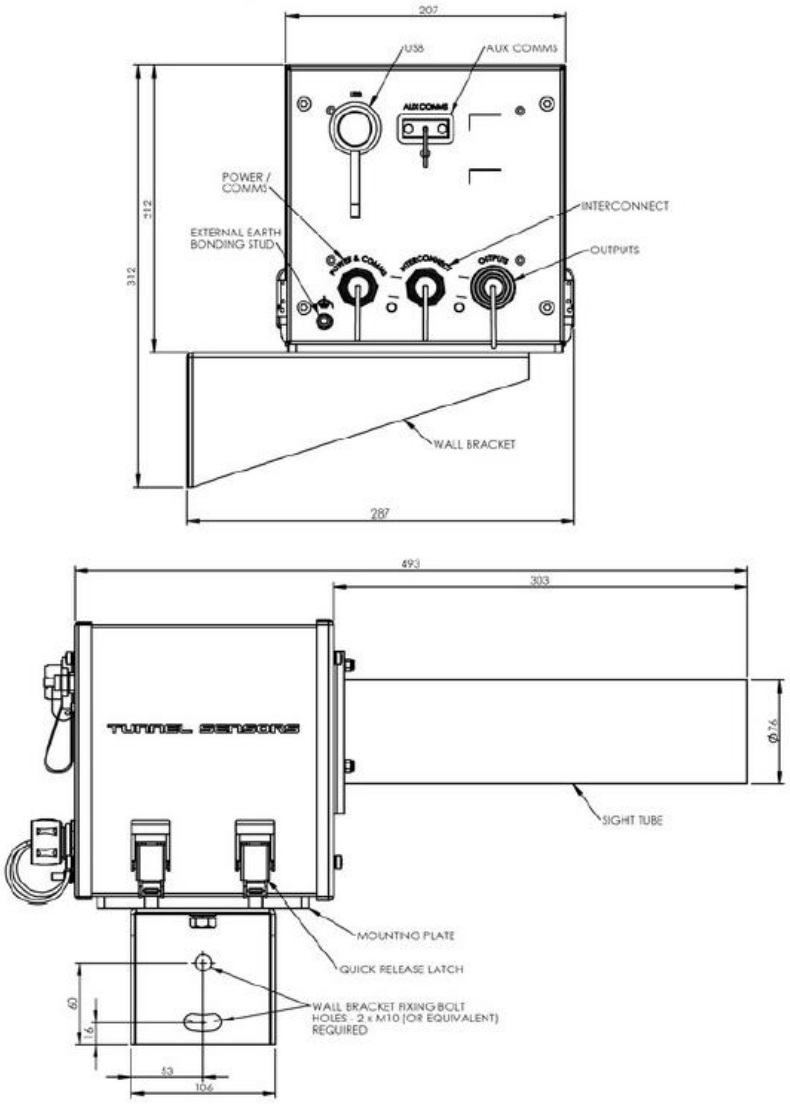
Physical

29	Ingress Protection			IP67	
30	Operating Temperature	°C	-20	+55	
32	Operating Humidity	%		100	
33	Regulatory Compliance				2014/30/EU (Electromagnetic Radiation) 2014/35/EU (Low Voltage)
34	Materials				Stainless Steel (powder coated)
35	Dimensions	mm	180 x 210 x 200		Each head (without sight tubes)
36	Weight	kg		5.3	Each head
37	Warranty	Months	24		Return to base warranty. Extensions available.

Compliance & Design

27	Design Life	Years	20		
28	MTBF	Years	>10		
29	Warranty	Months	24		Return to base warranty. Extensions available.

Basic Dimensional Sketch



ANEMOMETER	
Illustration	**Basic Information**
	Tunnel monitor using ultrasound technology to measure the speed and direction of air movement within the tunnel environment. These measurements can be used as part of an air quality management system for ventilation control within a tunnel or other confined space
Technological Description	
Self-contained transceiver which works by measuring the change in transit time of a sound wave due to the flow of air in the direction of the sound wave. The system contains four ultrasound transceivers from which ultrasonic signals are emitted. These ultrasonic signals are bounced off the "reflection roof" and the reflected signals are then received by the transceivers. The time taken for the ultrasound to travel this reflected path is accurately measured, enabling the velocity and direction of moving air to be measured.	

Technical Data

Parameter	Comment
Measuring principle	Ultrasonic transit time (fixed path)
Measurement reading	Air flow in m/s Also available as ft/min or kph (user selected)
Measuring range	± 60 m/s (user configurable)
Resolution	0.01 m/s
Accuracy	± 2 %
Lower detectable limit	0.02 m/s
Response time	1...100 s (user configurable)

Power

Voltage	+24 Vdc (100...240 Vac with optional PSU)
Nominal current consumption	200 mA
Power up current consumption	200 mA

Interface options

Serial comms	ModBus RTU via RS485 External USB
Analogue output (two)	0/2/4...20.0 mA (isolated and scalable)
Relay contacts (five)	3A @ 30 Vdc (programmable)

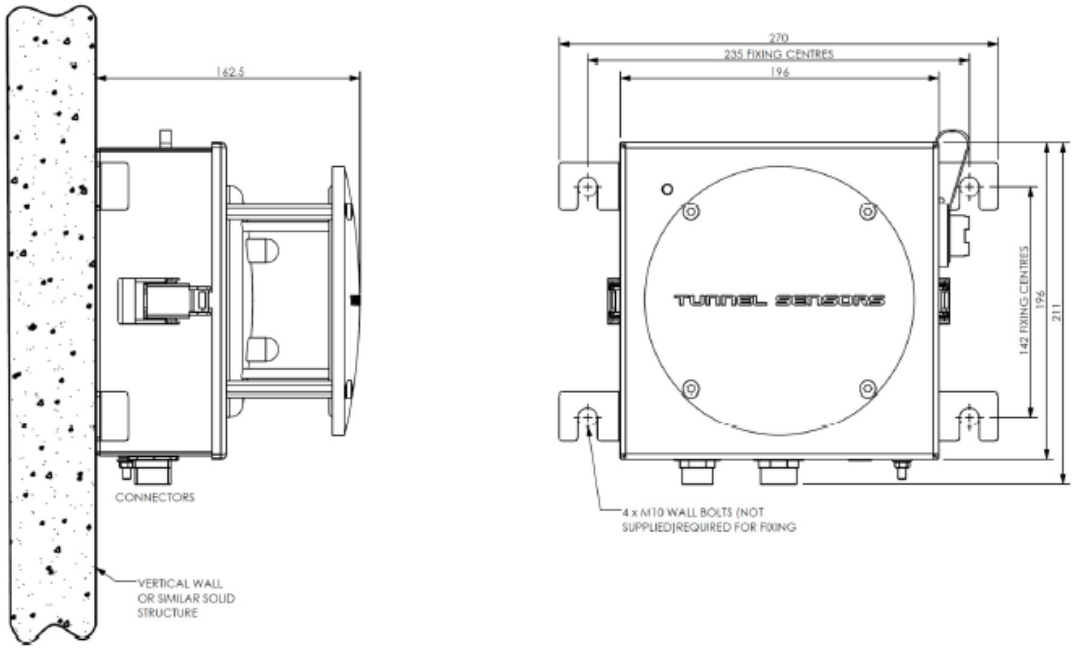
Physical

Ambient operating temperature	-20...+70 °C
Ambient operating humidity	0...100 %
Ingress protection	IP67
Materials Enclosure Transceiver	 316 stainless steel Flame retardant UL rated polycarbonate
Dimensions	200 x 200 x 160 mm
Weight	2.4 kg

Compliance & design

Electrical compliance	CE mark 2014/30/EU (electromagnetic radiation) 2006/95/EC (low voltage)
Design life	> 20 years
MTBF	> 10 years
Warranty	24 months

Basic Dimensional Sketch



WEATHER STATION	
Illustration	**Basic Information**
	Compact weather station with measurement of temperature, relative humidity, precipitation intensity, precipitation type, precipitation quantity, air pressure, wind direction, wind speed and radiation.
Technological Description	
- Measurement technology: Ultrasonic/Wind, NTC/T, Capacitive/RH, MEMS capacitive/Pressure, Thermopile/Radiation, Radar/Precipitation - Interfaces RS485 with supported protocols UMB-Binary, UMB-ASCII, Modbus-RTU, Modbus-ASCII, XDR and optional SDI-12	

Technical Data

General	
Dimensions	Ø approx. 150 mm, height approx. 317 mm
Weight	Approx. 1.5 kg
Interface	RS485, 2 - wire, half - duplex
Power supply	4...32 VDC
Operating temperature	-50...60°C
Operating rel. humidity	0...100% RH
Heating	40 VA at 24 VDC
Cable length	10 m
Protection level housing	IP66
Mast mounting suitable for	Mast diameter 60 - 76 mm

Temperature	
Principle	NTC
Measuring range	-50...60 °C
Unit	°C
Accuracy	±0.2°C (-20...50 °C), otherwise ±0.5 °C (> -30 °C)

Relative humidity	
Principle	Capacitive
Measuring range	0 ... 100 % RH
Unit	% RH
Accuracy	±2 % RH

Air pressure	
Principle	MEMS capacitive
Measuring range	300 ... 1200 hPa
Unit	hPa
Accuracy	±0.5 hPa (0...40 °C)

Wind direction	
Principle	Ultrasonic
Measuring range	0 ... 359.9 °
Unit	°
Accuracy	< 3° RMSE > 1.0 m/s

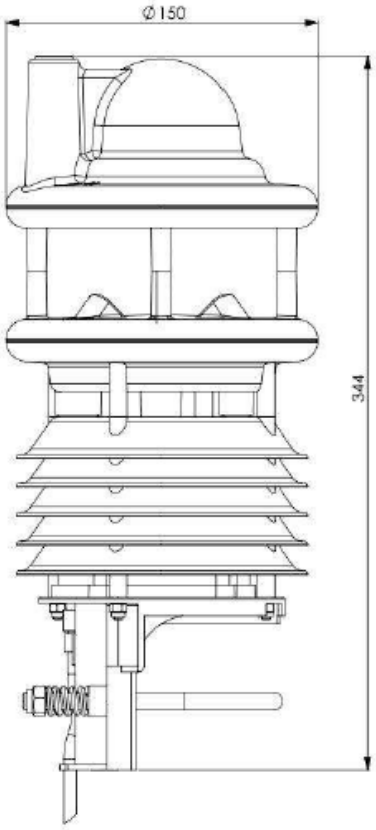
Wind speed	
Principle	Ultrasonic
Measuring range	0 ... 75 m/s
Unit	m/s
Accuracy	±0.3 m/s or ±3 % (0...35 m/s) ±5 % (>35 m/s) RMS
Resolution	0.1

Precipitation intensity	
Resolution	0.1 mm/h

Precipitation quantity	
Resolution	0.01
Reproducibility	Typical >90 %
Measuring range drop size	0.3...5 mm
Type of precipitation	Rain/snow

Radiation	
Unit	W/m^2
Accuracy	5%
Response time (95%)	< 1 s
Spectral range	300 to 1100 nm
Measuring range	1400 W/m^2

Basic Dimensional Sketch



CROSS-PASSAGES VENTILATION

Illustration	Basic Information
 -	Fan to manage overpressure in the cross passages with L=800 mm silencer. The motor has C2 painting according to EN ISO 12944-2 standard.

Technological Description

The motor of the fan has a nominal intensity of 15.5 A, a start intensity that is 8 times higher and a nominal voltage over frequency of 400/50 U/Hz.

Technical Data

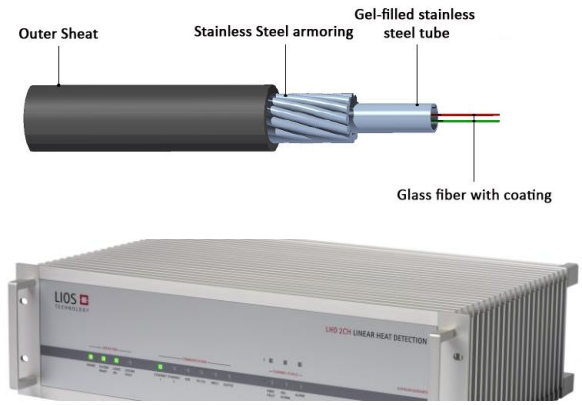
Fan: Volumetric flux: 6.6 m^3/s
Immobile wind force: 250 N
Mobile wind force:
Weight (without motor): 49 kg
Flux velocity: 33.4 m/s

Motor: Nominal revolution: 2920 1/min
Rated power: 7.5 kW
Protection: IP55
Weight: 41 kg

Basic Dimensional Sketch



FIRE DETECTION SYSTEM

Illustration	Basic Information
	Based on a standard multi-mode and single-mode telecom fibers Quick fire detection and precise localization of the source Information on magnitude and direction of the fire spread Alarm and pre-alarm for each zone Selectable alarm and pre-alarm criteria Maintenance-free (essential for underground inaccessible areas)

Technological Description

Embedded inside the HV/EHV insulated power cable
Small, flexible and purely passive sensor element immune to electromagnetic interference and aggressive atmospheric conditions.Sampling interval down to 0.25 m. 10,000 m detection range

Technical Data

MECHANICAL DATA
Controller 19" rack / 3 units of height
Dimensions (HxWxD) 13.5x44.9x29 cm
Weight 13 kg
ELECTRICAL DATA
Operating Voltage (DC Controller) DC 12 ... 48 V
Mains Voltage (AC Controller) Ac 100 ... 240 V
Power Consumption (DC Controller) <25W (max. 45 W/60°C)
Communication interfaces LON, TCP/IP, Modbus, RS232, USB
OPTICAL DATA
Fiber type Gradient index 62.5/125 µm multimode
Optical Connector E2000 / APC
ENVIRONMENT CONDITIONS
Storage Temperature -35 ... +75°C
Operating Temperature -10 ... +60°C
Humidity (non condensing) ≤95% rel.
Protections class (IEC 60529) IP51
APPROVALS
VdS (pr EN 54-22) G 211030, response classes A1N, BN, CN
UL S25135

Basic Dimensional Sketch

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FIRE HYDRANT

Illustration	Basic Information
	Fire hydrant type C (according to EN 14384 standard) with impact protection. The design and manufacturing favours the robustness of the fire-fighting system.

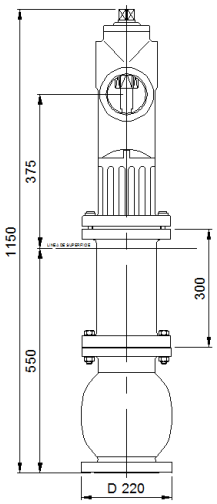
Technological Description

Fire hydrant type C (according to EN 14384 standard) with anti-icing system, automatic drainage, helical spring closure and oil bath activation mechanism with waterproof sump.

Technical Data

Output connections: 2 x 2 ½ '' + 1 x 4''
Nominal pressure: 16 bar
Certificate: EN 14384
Assembly depth: 550 mm
Vertical input: BRIDA DIN PN16
MOT: 120 N·m
mST: 250 N·m
Kv 2 ½'' outputs: 115
Kv 4'' outputs: 200

Basic Dimensional Sketch



HOSE CONNECTION	
Illustration	**Basic Information**
	Fire-fighting system equipment with two outputs and one input, coloured in red. It has been designed and manufactured to guarantee high quality conditions, resistant to adverse external conditions such as humidity, low temperatures, etc.
Technological Description	
Hose connection manufactured in cast aluminium alloy with a 70º angle between the two outputs. With a ball valve in each output to regulate the flux	
Technical Data	
2 external thread outputs: 2½'' thread 1 internal thread input: 3'' Body material: Cast aluminium alloy Painting: Red polyester RAL3002 Pressure: 25 bar 70º corner between outputs	
Basic Dimensional Sketch	
-	

FIRE-FIGHTING PUMPING GROUP	
Illustration	**Basic Information**
	The projected fire-fighting pumping group is composed of three pumps that have been previously evaluated to meet the requirements of the installation.

Technological Description

Technical Data

Components:

- Electric Pump:
  - Axial suction, radial impulsion
  - Stainless steel shaft
  - 2 poles three-phase asynchronous motor (400 V, 50 Hz)
  - Protection: IP55
  - Power: 110 kW
- Diesel Pump:
  - Tank capacity: 440 L
  - Dual battery kit
  - Power: 110 kW
- Auxiliary Jockey Pump:
  - Linear suction and impulsion
  - Material: Stainless steel /
  - Power: 4 kW
  - Protection: IP55
  - Shaft isolation with mechanical closure
  - 2 poles asynchronous motor
- Hydropneumatic tank (24/16):
  - Metallic bench
  - Cut valve and check valve in each pump
  - Impulsion manifold DN150

Basic Dimensional Sketch

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PERMANENT LIGHTING

Illustration	Basic Information
	LED technology lighting fixture. All components analysed to fulfil high quality standards in order to guarantee a long lifetime of the elements and a high system efficiency.

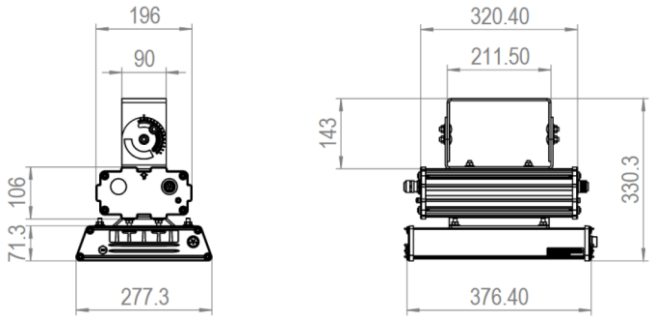
Technological Description

LED fixture made in aluminium (resistant to corrosion), with strong design and easy maintenance. Flexible solution for easy installation, overheat protection and long system lifetime (100,000 hrs).

Technical Data

Cover: anodize aluminium and injecting aluminium
Symmetry: asymmetric
Power: 95 W
Operating current: 600 mA
Flux: 10741 lm
Colour temperature: 4000 K
Efficiency: 113 lm/W
Protection: IP66
Operating temperature: -40ºC to 50ºC

Basic Dimensional Sketch



EMERGENCY LIGHTING

Illustration	Basic Information
	LED fixtures installed in both walls of the tube. They are normally placed every 10 m, at a height of 1 m. The housing of the modules are made of polycarbonate. Its operating mode is no permanent and it has a superficial installation.

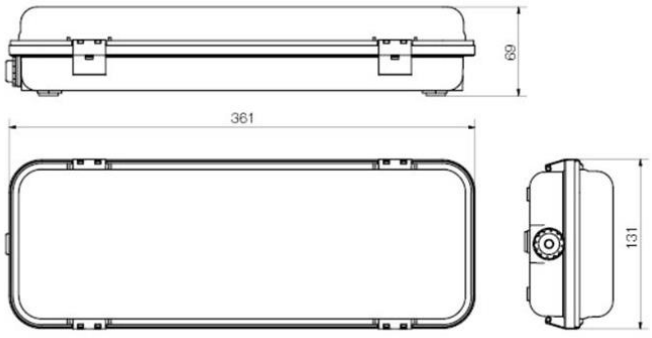
Technological Description

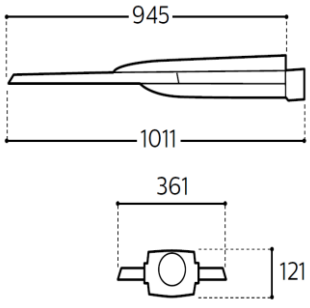
This optical sidewalk indication has been developed to mark the emergency way to exit the tunnel. It consists of a lighting system that will start operating in case there is an emergency in the tunnel. They will be connected to an Uninterruptible Power Supply.

Technical Data

Housing material: Polycarbonate
Dimensions: 360 x 131 x 69 mm
Flux: 110 - 200 lm
Autonomy: 1 hour
Supply: 230 V, 50 Hz
Protection: IP65
Ni-Cd battery, 3.6 V/750 mAh

Basic Dimensional Sketch



SELF-ILLUMINATING LIGHT MODULES (OUTDOOR LIGHTING_TC ACCESS ROADS)	
Illustration	**Basic Information**
	Optimized solution for outdoor lighting, saving up to 80% energy compared to conventional fixtures. It includes the identification of the fixture with Service tag for a faster and easier maintenance. Valid for any application due to its optimized optical distribution and the LEDGINE-0.21 optical platform. Its design is focused on future integrations, it is functional and it can easily be adapted to high lighting requirements projects.
Technological Description	
LED mast luminaire, aluminium cover, tempered glass closure, 12 meters high, reversible fixation, PMMA optics, symmetric light characteristic, overheat protection, long system lifetime (100,000 hrs).	
Technical Data	
Cover: high pressure aluminium injection Symmetry: symmetric distribution Flux: 29240 lm Colour temperature: 4000 K Overvoltage protection: 4 kV/6 kV, 10 kV Nominal voltage: 230 V, AC, 50Hz Area against wind: 0.0902 m^2 Approval Protection rating: IP66 Certification: CE, ENEC in preparation	
Basic Dimensional Sketch	
	

SELF-ILLUMINATING LIGHT MODULES (OUTDOOR LIGHTING_TC SURROUNDINGS)

Illustration	Basic Information
	Optimized solution for outdoor lighting, saving up to 80% energy compared to conventional fixtures. It includes the identification of the fixture with Service tag for a faster and easier maintenance. Valid for any application due to its optimized optical distribution and the LEDGINE-0.21 optical platform. Its design is focused on future integrations, it is functional and it can easily be adapted to high lighting requirements projects.

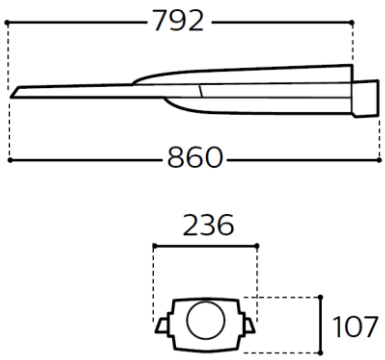
Technological Description

LED mast luminaire, aluminium cover, tempered glass closure, 6 meters high, reversible fixation, PMMA optics, symmetric light characteristic, overheat protection, long system lifetime (100,000 hrs).

Technical Data

Cover: high pressure aluminium injection
Symmetry: symmetric distribution
Flux: 9680 lm
Colour temperature: 4000 K
Overvoltage protection: 4 kV/6 kV, 10 kV
Nominal voltage: 230 V, AC, 50Hz
Area against wind: 0.0726 m^2
Approval Protection rating: IP66
Certification: CE, ENEC in preparation

Basic Dimensional Sketch



REFLECTIVE EVACUATION SIGN

Illustration	Basic Information
	Evacuation route signs show people in the tunnel the safe way to escape from the tunnel in the case of an emergency. Therefore, they show the distances to the closest exit in the left and right direction in metres.

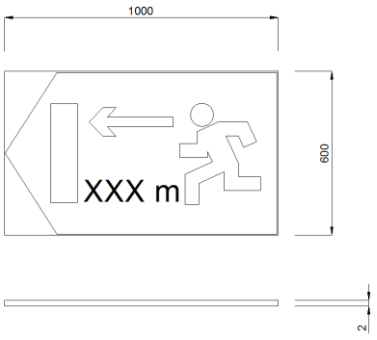
Technological Description

Reflective evacuation route signs are installed on the tunnel walls on both sides of the tunnel, in a height of about 1.0 m above the sidewalk. They are situated in distances of about 25 m to each other. They are made of aluminium to withstand the conditions in the tunnel, like corrosion, exhaust and moisture.

Technical Data

Material: Aluminium
Dimensions: 1000 x 600 mm
Thickness: 2 mm
High quality painting (UV rays resistant)
Luminance: 215 mcd/m^2 (10 min) / 30 mcd/m^2 (60min)
Certificate: AENOR, EN 71-3, etc.

Basic Dimensional Sketch



THREE COLOURED TRAFFIC LIGHTS

Illustration	Basic Information
	3-colured LED traffic light.

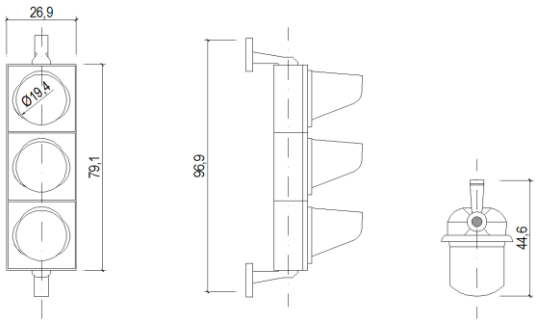
Technological Description

The optic ensures highest energy efficiency, optimized strength and stability, cannot be opened by unauthorized persons, available in different colours and colour combinations, can be mounted vertically as well as horizontally, available with integrated frame to fix backing boards, LED optic ensures highest energy efficiency.

Technical Data

Material: UV-stabilized polycarbonate
Diameters: 100, 200, 300 mm 1, 2, 3 as standard; more aspects on request
Optic: 100 / 210 / 300 mm
Mounting: Two point fixing
Backing Boards: fixation via basic frame or ALU/PC Composite
Housing colours: black (RAL 9005),light grey (RAL 7032),fir green (RAL 6009),orange (RAL 2000)
Impact resistance: acc. to EN60598-1; class IR 3 acc. to EN12368
Change of temperature: EN60068-2-14 passed

Basic Dimensional Sketch



TWO COLOURED TRAFFIC LIGHTS (A-A)

Illustration	Basic Information
	2-colured LED traffic light (amber-amber)

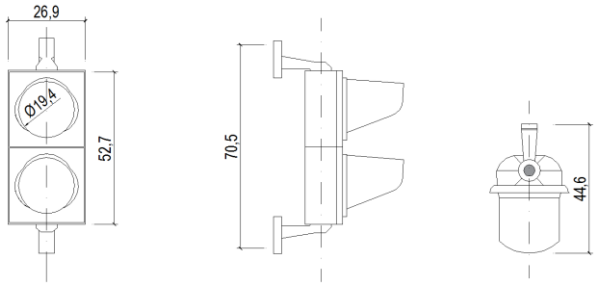
Technological Description

The optic ensures highest energy efficiency, 5 mm LEDs (high light intensity), LED optic ensures highest energy efficiency, long system lifetime (80,000 hrs), the lights can be seen from 300 m. It includes polycarbonate hooks to affix the traffic lights to any pole or wall.

Technical Data

Material: UV-stabilized polycarbonate
Diameters: 200 mm
Voltage range: 85-265 VCA
Mounting: Two point fixing
Power consumption: 7 W
Lamps: 61 LED in each lamp
Protection: IP54

Basic Dimensional Sketch



AUTOMATIC BARRIERS

Illustration	Basic Information
	Automatic barrier designed to operate under hardest and most unfavourable conditions.

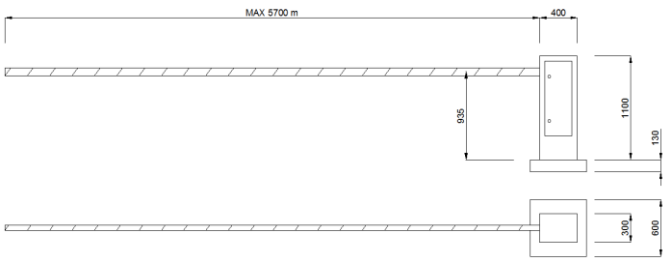
Technological Description

The automatic barriers have a three-phase synchronous motor, power 0.25 CV, and the internal control is conducted by means of relays. The mechanism is protected by an anti-corrosive treatment based on an electrolytic bath. The use of low maintenance materials and the simple and effective mechanical design, provide these barriers incomparable performance in terms of opening speed (1.5 sec), low maintenance, and long equipment life 5,000.000 cycles).

Technical Data

Supply voltage: three-phase 380 VAC / 220 VAC, 50-60 Hz
Motor velocity: 850 rpm
Operational temperature: -20ºC to 75ºC
Weight: 45 kg
Opening/closing speed: 1.5 s
Maximum length: 5.7 m
Protection: IP-44

Basic Dimensional Sketch



INDOOR CCTV CAMERA WITH AID SYSTEM	
Illustration	**Basic Information**
	Compact, rugged camera solution for automatic incident detection. Combines full HD visual imaging with advanced video analytics. Generates traffic data and incident detection information for tunnels, including alerts on stopped vehicles, wrong-way drivers, and lost cargo. High quality sensor 1/2.8" Sony CMOS, with high dynamic range to see in both, light and dark spaces. Bilinx communication for remote configuration and control. Easy to install
Technological Description	
Easy installing CCTV system camera with different colour options and a relation signal/noise higher than 54 dB.	
Technical Data	
Image sensor: 1/2.8" Sony CMOS sensor Nominal tension: 12 VCC / 24 VCA Nominal frequency: 50 / 60 Hz Power consumption: Max. 13W heater off Max. 23W heater on Total pixels: 1920 × 1080 Operating temperature: -30 ºC to 55ºC Housing: 316L stainless steel Protection: IP66 and 67 requirements against dust and water ingress/immersion Certificate: UL, FCC, CSA	
Basic Dimensional Sketch	
190 × 110 × 77mm	

REVOLVE CCTV CAMERA

Illustration	Basic Information
	Dynamic camera unit with universal qualities, high efficiency in low light conditions. High-quality video technology, the system is capable of detecting a person at a maximum distance of 180 m. Two available models, one suspended and another anchored to the ceiling.

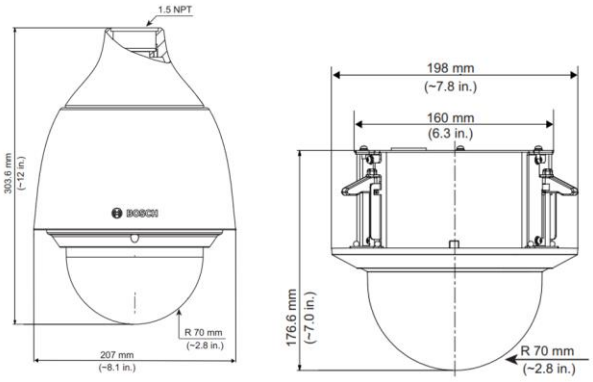
Technological Description

CCTV camera with a revolving range of 360º, aluminium cover, plastic exterior cover with IP51/IP66 protection. The camera has a shutter speed from 1/1 to 1/10000 s.

Technical Data

Certification: CE, FCC, cULus
Power Consumption: 14 W/24 W
Signal-to-Noise Ratio: >55 dB
Day/Night Mode: Colour, Mono, Auto
Dimensions (⌀ x H): 198 mm x 176.6 mm / 207 mm x 303.6 mm
Weight: approx. 2.1 kg / 3.25 kg
Temperature range extended: -40 up to +60 °C

Basic Dimensional Sketch



LOUDSPEAKER
(PA/VA SYSTEM)

Illustration	Basic Information
	The exponential loudspeaker has been designed for noisy zones, this is why it is optimal for indoor and outdoor areas in tunnels. It can resist in the outdoor. The speaker provides a high sound pressure level and a very low distortion.

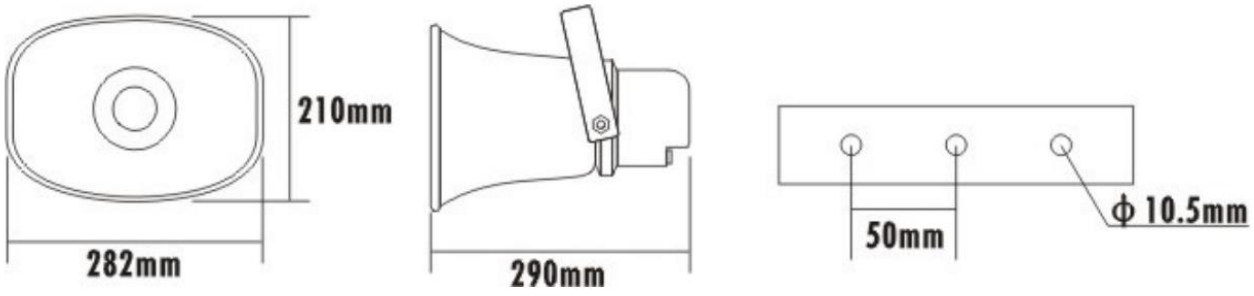
Technological Description

The loudspeaker has an integrated transformer (70 V/100 V), a huge scope and a metallic anchoring. It is outdoor resistant and it has a white ABS cover.

Technical Data

Power Consumption: 30 W (100 V)
Protection: IP66
Dimensions: 282 x 210 x 290 mm
Weight: 2.1 kg
SPL (1 W/1 m): 103 dB
SPL (nominal W/1 m): 118 dB
Frequency response (-10 dB): 300 Hz – 13 Hz

Basic Dimensional Sketch



COAXIAL CABLE	
Illustration	**Basic Information**
	Foam Coaxial Cable 1/2", corrugated copper, Low Smoke Halogen-free, Fire-retardant (Z).
Technological Description	
½'' foam coaxial cable with an attenuation from 3.22 dB/100 m (100 MHz) to 20.90 dB/100 m (3000 MHz)	
Technical Data	
Inner conductor material: Copper-Clad Aluminum Wire Dielectric material: Physical Foam Polyethylene Outer conductor material: Corrugated Copper Tube Jacket material: Black PE or Low Smoke Halogen-free Fire-retardant Minimum number of bends: 15 Tensile strength: 650 N Inner conductor diameter: 3.60 mm Dielectric diameter: 8.7 mm Outer conductor diameter: 12.00 mm Diameter over jacket: 13.30 mm Capacitance: 80.0 pF/m Impedance: 50 ± 1 Ω Velocity: 83% Peak power rating: 19 kW Insulation resistance: 5000 MΩ-km	
Basic Dimensional Sketch	
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SOS STATION

Illustration	Basic Information
	The IP SOS tunnel station is an assistance tunnel equipment, useful for help communication. This technological station has hands-free device and high power audio output. Besides, The SOS station presents different models, permitting the installation of extinguishers or hoses.

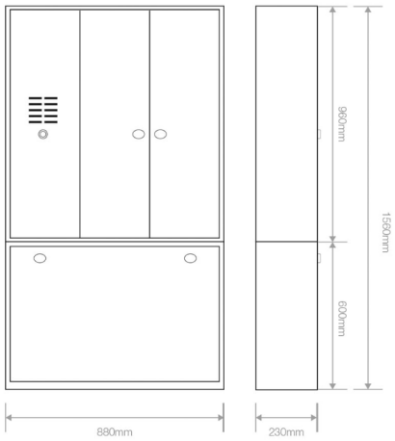
Technological Description

The SOS station offers the possibility of having one or two extinguishers. In addition, it is possible to install a camera unit with VGA, QVGA or QQVGA resolution and a SD card for audio recording. The box has security lock and hidden metallic hinges.

Technical Data

Housing material: Steel covered by corrosion resistant painting
Nominal power consumption: 1 W
Supply voltage: 5 V to 24 V
Industrial temperature range: -40ºC to 85ºC
Operating IP protocols: ARP, IP v4, ICMP, TCP, UDP, DHCP, DNS, SIP, SNMP, HTTP, Telnet, etc.
Body dimensions: 880 x 960 x 230 mm
Base dimensions: 880 x 600 x 230 mm

Basic Dimensional Sketch



TUNNEL VARIABLE LANE SIGN
(red cross / green arrow)

Illustration	Basic Information
	Luminous signal composed by a LED graphic zone showing the symbols: red cross (prohibition of lane) and green arrow (availability of lane). High availability of designs and configurations, adaptable to different projects and necessities. These signs have been designed in order to be easily installed in a metallic framework or fixed to the ceiling. The electronic panels have been developed with low consumption technology and they need very reduced maintenance.

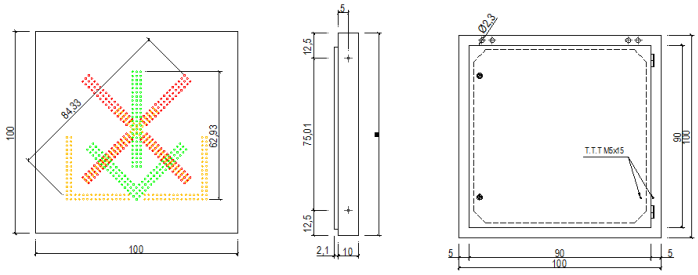
Technological Description

The tunnel variable lane sign is composed by permanently supervised LEDs, even if switched off; the status can be reported to the traffic center or local control. The brightness can be adjusted in both, automatic and manual way, and the long LED life cycle results in extended maintenance intervals.

Technical Data

Light source: High Power LEDs
Housing: Aluminium / Galvanised steel
Protection: IP65 / IP55
Beam width: B2 / B4
Luminance: L3
Interfaces: Ethernet IP, RS-232, RS-485, optical fiber, GPRS, WiFi
Distance between pixels: 14 mm, 20 mm…
Power supply: AC single-phase
Dimensions: 700 x 650 mm / 1000 x 1000 mm / 1200 x 1200 mm
Weight (Galvanised steel): 24 kg / 40 kg / 55 kg
Weight (Aluminium): 15 kg / 24 kg / 32 kg
Power (high power): 25 W / 40 W / 60 W
Power (low power): 7 W / 11 W / 15 W
Certification: CE, EN-12966-2005, 2002/95/CE

Basic Dimensional Sketch



TUNNEL VARIABLE SPEED LIMIT SIGN
(red cross / green arrow)

Illustration	Basic Information
	There are three basic models of the VSLS, each one with the capability to display two (2D) or three (3D) digits. The models' classification is based on the circle ring dimensions and the displaying digit heights. The model choice is based on the motorway typical speed limit and the required maximum reading distance that depends on the displaying digit heights. Every VSLS model can display all possible speed limits in increments of 10.

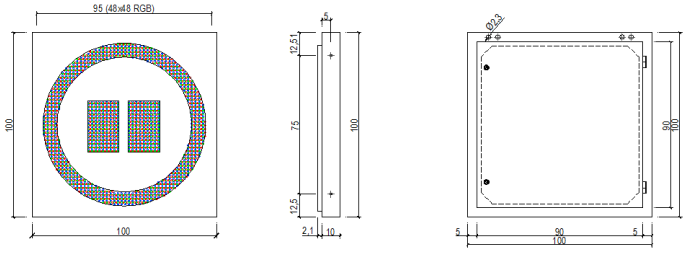
Technological Description

VSLS signs are usually integrated in a Traffic Management System (TMS SCADA), where all signs are controlled according to traffic scenarios and automations. Alternatively smaller scale integrations can be easily performed via the relay inputs. The communication method varies according to project network infrastructure and local communication interfaces.

Technical Data

In-Tunnel / Outdoor installation
SCADA integration
Automatic fault and error detection and
Automatic and manual brightness control in 16 discrete levels
Ability to increase LED gain
Minimal brightness reduction over lifetime due to strictly controlled LED driving conditions
Static 1:1 driving
Ability to display flashing speed limits
Contrast Enhancement Technology
Cover: Aluminium / Stainless steel
Communication interfaces: RS485, RS232, Ethernet, 4 digital inputs for PLC communication
Certification: CE, EN-12966
Protection: IP65
External luminance: 40.000 lux
Beam width: B4
Operational Temperature: -20ºC to +60ºC

Basic Dimensional Sketch



INDOOR VARIABLE MESSAGE PANEL

Illustration	Basic Information
	LED variable message sign designed with Low Power Technology. It has a mixed configuration formed by an alphanumeric zone and one or two graphic zones.

Technological Description

These panels have been designed in order to have minimum maintenance procedures and they can be installed in the ceiling or on metallic structures.

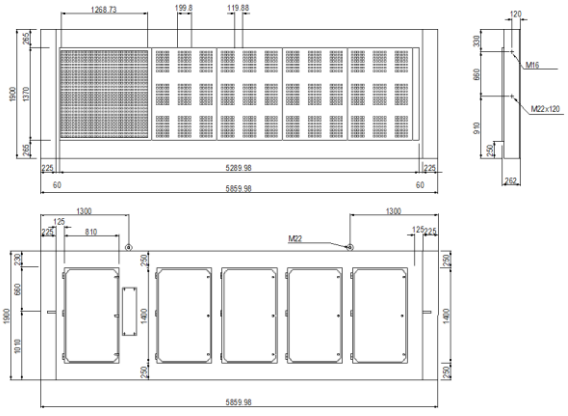
Technical Data

Usual configurations:

- 2 text lines of 12 characters each
- 1 graphic zone + 2 text lines of 12characters each (4580 mm x 1000 mm)
- 1 text line of 16 characters

Graphic area resolution: 32 x 32 pixels RGB / RGBY
Character height: 220 mm, 320 mm, 400 mm…
Housing: Aluminium / Galvanised steel
Protection: IP65 / IP55
Beam width: B2 / B4
Luminance: L3T
Interfaces: Ethernet IP, RS-232, RS-485, optical fiber, GPRS, WiFi
Distance between pixels: 20 mm, 25 mm, 40 mm…
Power supply: AC (single-phase / three-phase), DC

Basic Dimensional Sketch



OUTDOOR VARIABLE MESSAGE PANEL

Illustration	Basic Information
	LED variable message sign designed with Low Power Technology. It has a mixed configuration formed by an alphanumeric zone and one or two graphic zones. The graphic area allows the integration of text as an extended part of the alphanumeric area.

Technological Description

These variable message signs have a maximum consume of 350 W, its maintenance procedure is minimum and they can be installed anywhere in the world due to its adaptability to any communications protocol and to the different standards.

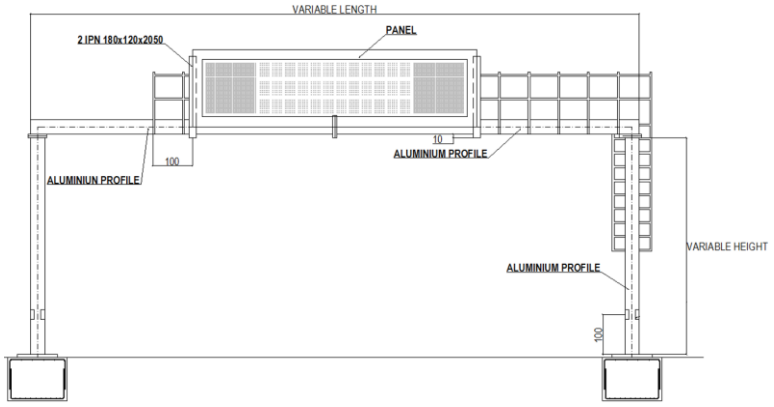
Technical Data

Usual configurations:

- 1 graphic zone + 3 text lines with 12/16/18 characters each (5800 mm x 1920 mm)
- 2 graphic zones + 3 text lines with 12/16 characters each (7140 mm x 1920 mm)

Character height: 220 mm, 320 mm, 400 mm…
Housing: Aluminium / Galvanised steel
Protection: IP65 / IP55
Beam width: B2 / B4
Luminance: L3
Interfaces: Ethernet IP, RS-232, RS-485, optical fiber, GPRS, WiFi
Distance between pixels: 20 mm, 25 mm, 40 mm…
Power supply: AC (single-phase / three-phase), DC
Certification: CE, EN-12966-2005, 2002/95/CE, EU 305/2001.E13

Basic Dimensional Sketch



TECHNICAL SPECIFICATION

Bridge

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

Sprayed Concrete

GUIDELINE

Österreichische Vereinigung
für Beton- und Bautechnik

Unter **www.concrete-austria.com** bzw. **www.ovbb.at**
finden Sie die neu gestaltete Web-Site der
Österreichischen Vereinigung für Beton- und Bautechnik (ÖVBB)

AKTUELLES
Unter diesem Punkt finden Sie aktuelle Termine und Informationen über neue Veröffentlichungen, Kongresse und sämtlichen Veranstaltungen der ÖVBB.

DIE VEREINIGUNG
Hier erfahren Sie alles über die Vereinigung für Beton- und Bautechnik (Organigramm, Geschichte, Mitglieder, Kontakt ...).

VERÖFFENTLICHUNGEN
Alle unsere Richtlinien, Merkblätter und Fortbildungsbände, aber auch unsere Mitteilungen sind hier aufgelistet und können online bestellt werden!

VERANSTALTUNGEN
Hier finden Sie unseren Veranstaltungskalender, in dem viele Seminare, Kongresse und Konferenzen auf dem Gebiet der Bautechnik aufgelistet sind. Im Falle von Eigenveranstaltungen der ÖVBB finden Sie dort auch die weiterführenden Informationsmaterialien.

GÜTEZEICHEN-DATENBANK
In der Datenbank sind alle Firmen und Produkte enthalten, die die Anforderungen laut der ÖVBB-Richtlinie "Qualitätssicherung für Instandsetzungsfachbetriebe und Instandsetzungsprodukte - Gütezeichen" erfüllen.

UND VIELES MEHR .....

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Österreichische Vereinigung
für Beton- und Bautechnik

Guideline

Sprayed Concrete

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PREFACE

The 2004 edition of the Sprayed Concrete Guideline is the second revision of the Sprayed Concrete Guideline first published by the Austrian Concrete Society in 1989 (Part I – Application) and 1992 (Part 2 – Testing).

The revision was necessary in order to define the new terms and requirements contained in the European Concrete Standard EN 206 also for sprayed concrete. At the same time, experience gained with the 1998 edition of the Sprayed Concrete Guideline as well as new developments in research and practice have been incorporated.

The 2004 edition of the Sprayed Concrete Guideline, continuing a fifteen-year tradition, is intended as a basis for the production of sprayed concrete of adequate quality under objective contractual conditions.

Vienna, July 2006 Baurat h.c. Dr. Helmut Huber

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Summary

GUIDELINE **0**

0. PRELIMINARY REMARKS **1**

1. SCOPE **1**

2. DEFINITIONS, ABBREVIATIONS **3**

2.1 DEFINITIONS 3
2.2 ABBREVIATIONS USED 6

3. ENVIRONMENTAL COMPATIBILITY OF SPRAYED CONCRETE **8**

4. CONSTITUENT MATERIALS FOR SPRAYED CONCRETE **11**

4.1 BINDERS 11
4.2 ADDITIONS 14
4.3 MINERAL AGGREGATES 14
4.4 WATER 16
4.5 ADMIXTURES 16
4.6 FIBRES 18

5. MIX **19**

5.1 MIX COMPOSITION AND PRODUCTION 19
5.2 MIX FOR PRESCRIBED SPRAYED CONCRETE (STANDARD SPRAYED CONCRETE) 22

6. SPRAYING PROCEDURES **23**

6.1 PLACING OF SPRAYED CONCRETE 23
6.2 DRY-MIX SHOTCRETING 24
6.3 WET-MIX SHOTCRETING 25

7. REQUIREMENTS TO BE MET BY SPRAYED CONCRETE **27**

7.1 SPRAYED CONCRETE CLASSES 27
7.2. CONSISTENCY 28
7.3. STRENGTH OF YOUNG SPRAYED CONCRETE (EARLY STRENGTH CLASSES) 28
7.4. STRENGTH CLASSES 30
7.5. SPRAYED CONCRETE WITH SPECIAL PROPERTIES (SPRAYED CONCRETE GRADES) 31
7.6. DESIGNATION OF SPRAYED CONCRETE GRADES 33

8. STRUCTURAL REQUIREMENTS **34**

8.1. FUNDAMENTAL REQUIREMENTS 34
8.2. REINFORCEMENT 34

9. SINGLE-SHELL CONSTRUCTION METHOD **35**

9.1 DEFINITION, PREREQUISITES, EXECUTION VARIANTS 35
9.2 SPRAYED CONCRETE GRADE, DESIGN 36
9.3 NOTES ON EXECUTION 36

10. SPECIAL PROCEDURES **37**

10.1. SPRAYED CONCRETE UNDER COMPRESSED AIR 37
10.2 FIBRE-REINFORCED SPRAYED CONCRETE 37

11. SPECIFICATIONS AND TESTING **39**

11.1. TESTING OF CONSTITUENT MATERIALS 39
11.2 TESTING OF THE MIX 39
11.3. TESTING OF SPRAYED CONCRETE 40
11.4. INSPECTION OF MIXING AND METERING EQUIPMENT 49

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

12. TESTING PROCEDURES 50
12.1 TESTING OF CONSTITUENT MATERIALS FOR CONCRETE PRODUCTION 50
12.2 MIX, BASE CONCRETE (WITHOUT ACCELERATOR) 58
12.3 TESTING OF YOUNG SPRAYED CONCRETE (EARLY STRENGTH CLASS) 60
12.4 TESTING OF SPRAYED CONCRETE 64
12.5 CHECKS TO BE PERFORMED DURING SPRAYED CONCRETE PRODUCTION 70
12.6 FIBRE CONTENT OF STEEL-FIBRE SPRAYED CONCRETE 72
12.7 DOCUMENTATION OF MIX PRODUCTION 73
13. QUALITY MANAGEMENT 73
14. RECOMMENDATIONS FOR TENDERING 74
14.1 GENERAL REQUIREMENTS 74
14.2 CONTRACTUAL PROVISIONS 74
15. STANDARDS, GUIDELINES, BIBLIOGRAPHY 75
15.1 STANDARDS REFERRED TO IN THE TEXT 75
15.2 GUIDELINES AND REGULATIONS 77
15.3 ADDITIONAL STANDARDS, GUIDELINES AND REPORTS TO BE TAKEN INTO CONSIDERATION 78
15.4. BIBLIOGRAPHY 80

Annex

Annex 1 Standard form "Designation of samples" 82
Annex 2 Penetration needle test – Test protocol 83
Annex 3/ Sheet 1 Bolt-driving method – Test protocol 84
Sheet 2 Bolt-driving method – Test protocol 85
Annex 4/ Sheet 1 Example – Evaluation of fine dust concentration 86
Sheet 2 Example – Evaluation of fine dust concentration 87
Sheet 3 Example – Evaluation of fine dust concentration 88
Annex 5 Conformity certificate – Calculation of design sprayed concrete thickness 89
Annex 6 Standard form „Early strength classes of fresh sprayed concrete“ 90

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

0. PRELIMINARY REMARKS

In order to eliminate barriers to trade within the European Economic Area, the following principles have to be observed:

- Products from member states of the European Union as well as goods originating from EFTA countries belonging to the European Economic Area (EEA), which are not in conformity with this Guideline, but have passed the tests and inspections performed and recognised in the member state concerned, are regarded as equivalent, including these tests and inspections, provided the level of protection required in Austria in terms of safety, health and fitness for use is reached and maintained on a permanent basis.
- The inspection bodies concerned must provide adequate and satisfactory guarantees of their technological and technical qualifications as well as their independence according to ÖVE/ÖNORM EN ISO/IEC 17025.
- The body inviting tenders may demand the submission of documents on the tests and inspections performed as well as standards, technical guidelines and regulations governing products and/or materials in German.

1. SCOPE

This Guideline applies to the production of structural components made of plain and reinforced concrete as well as close-textured reinforced concrete placed by the method of shotcreting.

Sprayed concrete is to be mixed from the constituent materials of concrete (cement, additions, spray cement, mineral aggregates, water and admixtures) in such a way as to permit proper placing under the conditions to be expected at the building site and to ensure achievement of the required properties.

Sprayed concrete is used in all fields of civil engineering and building construction. In particular, sprayed concrete is suited for use under special conditions, such as:

- absence of formwork
- application in thin layers
- early strength requirements
- special construction methods.

For the purposes of construction planning and execution, sprayed concrete can be classified as follows:

- Sprayed concrete without structural functions (**SpC I**), e.g. for surface improvement, short-term support during construction.
- Sprayed concrete with structural functions (**SpC II**), e.g. rock support in tunnelling, excavation support, open caisson foundations.
- Sprayed concrete with special structural functions (**SpC III**) e.g. for use in single-shell tunnel construction and for inner linings.

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Preference is given to sprayed concrete with non-alkaline acceleration (spray cement or non-alkaline acceleration), which offers special advantages in terms of occupational health and safety and is preferable for ecological and technological reasons. Sprayed concrete with non-alkaline accelerators does not experience a loss of strength or, if such loss occurs, it never exceeds 15%; it reaches a high level of final compressive strength and is dense-textured (less segregation in tunnel drainage systems).

Non-alkaline acceleration is to be used for sprayed concrete with structural functions (SpC II, SpC III). The use of alkaline accelerators is only permitted in sprayed concrete without structural functions (SpC I).

In dry-mix shotcreting, the use of mix with dry mineral aggregates (dry mix - TM) or spray cement mixed in situ with naturally moist mineral aggregates (moist mix - FM-S) enables building sites to be supplied with fresh mix at any time and thus ensures of a continuously high level of quality.

At present,

- the dry-mix sprayed concrete method uses spray cement or tunnel cement with powder or liquid accelerators;
- the wet-mix sprayed concrete method uses powder or liquid accelerators.

Sprayed concrete can be applied to the following types of substrate:

- rock and soil
- sprayed concrete
- formwork of different types
- structural components made of concrete, masonry and steel (casings)
- frozen rock or soil, ice.
- insulating layers, nap sheeting, geotextiles.

Further applications of sprayed concrete:

- sprayed concrete for repair, reinforcement and casings
- fibre-reinforced sprayed concrete
- sprayed concrete under compressed air
- sprayed concrete with light-weight mineral aggregates.

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2. DEFINITIONS, ABBREVIATIONS

2.1 Definitions

Accelerator (EB) Admixture in powder or liquid form to accelerate the reaction of cement in placed sprayed concrete.

Additives Finely dispersed substance used in concrete and added to the concrete during mixing in order to obtain or improve certain properties of the concrete.

Admixture Substance added during production of the concrete mix in small quantities, relative to the cement content, in order to modify the properties of fresh or hardened concrete.

Aerosols Multi-phase systems of air and other gases with finely dispersed solids or liquids.

Reference concrete Sprayed concrete without accelerator used for reference to evaluate changes in technological properties (e.g. loss of strength).

Binder Cement to which a hydraulically effective addition can be added and which meets the requirements of the application concerned.

Cement Finely ground inorganic substance; when mixed with water, it forms cement paste, which hardens and sets through hydration and retains its volume stability also under water.

Degree of utilisation Ratio of maximum stress level on the sprayed concrete and its strength at a given age.

Dense-stream concrete conveyance

A method of conveying the wet mix in which the concrete is pumped through the delivery line without compressed air.

Double-shell construction method

Tunnel lining consisting of two or several shell elements designed to meet different static and structural requirements (not forming a composite structure), placed in separate operations and by different methods (e.g. outer sprayed concrete shell, in-situ concrete arch).

Drop-off Mixture of sprayed concrete and substrate dropping off due to lack of adhesive strength of the substrate.

Dry mix (TM) Mix for dry-mix shotcreting consisting of dry mineral aggregates, binder, additions, water (process-related) and, possibly, fibres.

Dry-mix sprayed concrete Sprayed concrete made from dry mix or moist mix as base mixture.

Leachate Liquid enriched through elution.

Leaching Extraction of soluble components of a solid in contact with a liquid.

External inspection Periodic inspection of a building material and its production by an accredited inspection body.

Young sprayed concrete Sprayed concrete up to an age of 24 hours (J_1, J_2, J_3, depending on early strength class).

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Identity test Test performed to identify whether a batch or lot of concrete comes from a compliant total quantity of concrete.

Preconstruction test (qualification test)

Test or tests performed prior to the beginning of sprayed concrete production to establish the composition required for new sprayed concrete to meet the specifications in fresh and hardened condition.

Loss of strength Diminished strength of sprayed concrete with accelerator in comparison with reference concrete without accelerator.

Mix Mixture prepared for the respective shotcreting procedure.

Moist mix (FM-L, FM-S) Mix for dry-mix shotcreting with naturally moist mineral aggregates, binder, admixtures, water (process-related) and, possibly, fibres.

Multi-shell construction method

See double-shell construction method.

Non-alkaline acceleration of setting

The required strength of fresh sprayed concrete (J_1 - J_3) is achieved without addition of alkalis. For this purpose, spray cement with an alkali content not higher than that of normal cement or non-alkaline accelerator is used.

Non-alkaline accelerator Accelerator with a pH value within a certain range (3.0 - 8.0) and an alkali content below a certain limit (Na_2O equivalent $\leq$ 1.0 wt.%).

Ready-mix concrete plant Plant in accordance with the requirements of ÖNORM B 4710-1 with micro-processor control, in which the constituents required for concrete production are batched, as a rule, by weight (in case of liquids by weight or volume) and mixed into concrete ready for use.

Rebound Proportion of the mix rebounding from the substrate during placing of the sprayed concrete. Rebound consists mainly of mineral aggregate and, to a lesser extent - binder and water.

Single-shell construction method

All static and structural requirements to be met by the tunnel lining are fulfilled by a single-shell lining consisting of one or several layers forming a composite structure.

Spray cement (SBM) General term used to designate fast-setting binders which ensure the required rate of setting and fast strength development in young sprayed concrete without addition of admixtures (EB).

Overspray Proportion of fines in the sprayed concrete which deposit on the substrate and the reinforcing bars and diminish the adhesion of subsequent layers.

Sprayed concrete (SpC) Concrete projected into place at high velocity and compacted by its own momentum.

Sprayed concrete layer Two-dimensional structural component of a defined minimum thickness consisting of one or several spraying layers (e.g. sealing layer).

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Sprayed concrete shell Three-dimensional structural component consisting of one or several layers of sprayed concrete with a temporary or permanent supporting and/or load-bearing function (e.g. outer sprayed concrete shell, arch).

Spraying layer Sprayed concrete placed in a single operation without interruption.

Spraying mix The mixture discharged through the (spraying) nozzle.

(Spraying) nozzle A pipe with a mixing unit for the addition of liquid and/or air through which the mix is discharged from the delivery line. In dry-mix shotcreting, water and - if required - powder or liquid admixtures and additions are added; in wet-mix shotcreting by the dense-stream method, air and, possibly, admixtures are added.

Standard sprayed concrete (prescribed sprayed concrete)

Sprayed concrete without special properties (maximum strength class SpC 12/15) of predetermined composition, not subject to preconstruction testing (according to It. 5.2).

Substrate Surface onto which sprayed concrete is sprayed.

Thin-stream concrete conveyance

A method of pneumatic conveyance of the base mix to the location of placement; the loosened dry or wet mix is conveyed from the spraying machine to the nozzle by compressed air.

Water-binder ratio Mass ratio of effective water to cement content (eligible binder content) in fresh concrete.

Wet mix (NM) Mix for wet-mix shotcreting (usually pumped concrete) prepared from mineral aggregates, binders, water and, possibly, admixtures and fibres.

Wet-mix sprayed concrete Sprayed concrete made from wet mix (in dense-stream processes: usually pumped concrete) as base mixture.

Workability time Time between the first contact of naturally moist aggregate with cement and/or production of wet mix and application of sprayed concrete, or time between the first contact of naturally moist mineral aggregates with spray cement (SBM) and discharge from the nozzle.

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2.2 Abbreviations used

AAR	alkali-aggregate reaction
AHWZ	prepared hydraulically effective additions
AM	spread for determination of fresh concrete consistency
ASTM	American Society for Testing Materials
BV	plasticiser
CEM	cement type according to standard series EN 197-1
CEN	European Committee for Standardisation
D	density of accelerator
D_1	compressive strength of cement at the age of one day
DAfStb	German Reinforced Concrete Committee
DBV	German Concrete and Structural Engineering Association
DIN	German Industrial Standard
EB	accelerator
EB-AF	non-alkaline accelerator
EB-AH	alkaline accelerator
EFNARC	European Federation of National Associations of Specialist Contractors and Material Suppliers for the Construction Industry
EN	European Standard
F	category of resistance to frost and thaw cycles of mineral aggregates
f	category of fines content of mineral aggregates
FGSV	Road and Transport Research Society
FM	plasticiser
FM-L	moist mix, storable
FM-S	moist mix, for immediate application
FRSpC	fibre-reinforced sprayed concrete
GK	maximum grain size of the mineral aggregate
HK	frequency class
HZ	tensile adhesive strength
ISO	International Standards Organisation
J	young sprayed concrete strength class
K	factor for consideration of additive type II effect
LP	air-entraining agent
LPV	combined plasticiser and air-entraining agent
LV	bill of quantities
MAK	maximum permissible concentration at the workplace
MS	silica fume
NAD	national application document

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NM	wet mix
ON	Austrian Standard
PB	pumped concrete
ÖVBB	Austrian Association for Concrete and Structural Engineering
R	correlation coefficient
RVS	Guideline for Transport and Road Engineering
SBM	spray cement for sprayed concrete
SI	shape index, category of grain shape parameter
SIA	Swiss Association of Engineers and Architects
SN	Swiss Standard
SpC	sprayed concrete
SpC-XF4	sprayed concrete resistant to frost and thaw cycles
TM	dry mix
W	water content
WA	water segregation through bleeding of cement
XAL	exposure class: solvent chemical attack
XM	exposure class: wear and tear
XAT	exposure class: expansive chemical attack
XC 1 and XC 2	exposure classes: corrosion caused by carbonation
XC 3 and XC 4	exposure classes: water impermeability
XD	exposure class: corrosion caused by chlorides, except sea water
XF	exposure class: risk of frost attack, with or without thawing agent

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3. ENVIRONMENTAL COMPATIBILITY OF SPRAYED CONCRETE

To assess the environmental compatibility of sprayed concrete, its influence on ambient air, water and soil needs to be considered. Past experience with alkali accelerators suggests that the environmental impact is of minor importance. However, health effects on the building-site crew applying the sprayed concrete are possible.

A reduction of the environmental impact and improved occupational health and safety have been among the priority objectives in the further development of sprayed concrete technology. Sprayed concrete with non-alkaline acceleration has no negative influence on the environment and offers considerable advantages in terms of occupational health and safety.

The following environmental influences have to be considered:

- *Impact on air quality*

  In general, shotcreting operations do not have a negative impact on air quality. The presence of aerosols has to be assessed in terms of occupational health and safety.

- *Impact on soil*

  As a matter of principle, a reduction of the rebound ratio is desirable (to less than 25.0 wt.% in conventional traffic tunnels requiring large amounts of sprayed concrete).

  Experience available to date does not suggest that the use of non-alkaline acceleration in sprayed concrete has any negative influence on the leaching behaviour of excavated material, provided the rate of rebound in the excavated material is less than 5.0 wt.%.

- *Impact on water*

  When used in tunnelling, sprayed concrete may be exposed to rock and ground water. Increased leachability of sprayed concrete may therefore lead to segregation and a long-term impact on draining water [1, 2, 3].

  The leachability of concrete being very low even after a short period of hardening, a negative impact on water quality has not been observed. Thus, concrete qualifies as an environmentally safe construction material. The same applies to sprayed concrete with non-alkaline acceleration.

  Besides the use of non-alkaline accelerators, careful working and a low water-binder ratio (< 0.6) also contribute towards ensuring a leaching behaviour in sprayed concrete similar to that of in-situ concrete. The admixture of silica fume may also have a favourable influence on leaching. For sprayed concrete leachate, the limits according to Table 3/1 apply:

Table 3/1 Limits for leachate concentrations from sprayed concrete aged 28 days according to It. 12.4.12.

Parameter	**Unit**	**Limit**
pH		≤ 12
Electric conductivity	mS/m	≤ 100
Calcium	mg/l	≤ 25
Potassium	mg/l	≤ 40
Sodium	mg/l	≤ 10
Aluminium	mg/l	≤ 1.0

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- *Impact on occupational health and safety*

  During sprayed concrete production, the building-site crew is at risk due to dust formation and the alkalinity of suspended particles in the air. The amount of aerosols has to be minimised through suitable measures. Dust as well as smoke and mist are classified as aerosols.

Depending on the location and the time, the concentration of dust during the placing of sprayed concrete is subject to major fluctuations, which have to be considered in the interpretation of the results obtained. The fine dust concentration is assessed on the basis of the maximum permissible concentration of contaminants at the workplace measured according to It. 12.5.3 [4, 5]. Fine dust is defined as dust likely to penetrate into the alveoli of the lungs. Fine dust is deemed to be quartzitic, if its quartz content is 1.0 wt.% or more.

The maximum permissible contaminant concentration at the workplace according to Table 3/2 is equal to the maximum permissible concentration of dust which, in general, does not adversely affect the health of workers in the case of repeated and long-term exposure, usually for eight hours, but for no more than 40 hours a week, without use of personal protective equipment (fine-dust masks).

Table 3/2 Permissible dust concentration based on maximum permissible contaminant concentration at the workplace according to [4, 5]

C[mg/m³]	Type of dust	Assessment period	Pollutant load
15	total dust	annual average	inert
30	total dust	hourly average	inert
6	fine dust	annual average	inert
12	fine dust	hourly average	inert
4	quartzitic fine dust		silicogenic
0.15	fine quartz dust		silicogenic

Given the fact that a range of activities are performed during tunnelling which produce varying amounts of dust, the assessment has to be based on the entire working cycle. The hourly average may be reached twice per working day, but not consecutively, provided the daily average of 15 mg/m³ (total dust) and 6 mg/m³ (fine dust) is not exceeded. If personal protective equipment is used, higher limits are permissible, depending on the protective effect of the equipment (ÖNORM EN 149).

To diminish the dust load over the entire working cycle, the following measures are recommended:

- dry-mix shotcreting: use of moist mineral aggregates or pre-moistering of the dry mix, machine enclosure, favourable nozzle design, nozzle distance, water content
- wet-mix shotcreting with non-alkaline accelerators
- use of spraying arms (manipulators)
- sufficient ventilation.

The impact of spraying mist on the building-site crew has not yet been clearly established. In subjective terms, workers report that non-alkaline accelerators, compared with alkaline accelerators, are considerably less irritating.

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Health hazards for building-site personnel, above all the risk of skin and eye lesions, can be prevented through the elimination of highly alkaline and strongly irritating admixtures.

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4. CONSTITUENT MATERIALS FOR SPRAYED CONCRETE

The required strength of fresh sprayed concrete according to It. 7.3 is achieved without addition of alkalis (non-alkaline acceleration [6, 7]) either through spray cement according to It. 4.1.2 or cement according to It. 4.1.1. and non-alkaline accelerators (EB-AF) according to It. 4.5.1.1 (see Table 4/1) In special cases (e.g. strong ingress of water), the combined use of spray cement and non-alkaline accelerators is possible.

Alkaline accelerators (EB-AH) according to It. 4.5.1.2 are only permissible for SpC I. The use of water glass is not permitted.

Additions may be added according to It. 4.2.

4.1 Binders

4.1.1 Cement

Cement grades bearing a CE or ÜA mark and standard-compliant according to ÖNORM B 3327-1 and EN 197-1 are to be used. Cement grades not subject to external inspection according to ÖNORM B 3327-1 (e.g. CEM 152.5) have to meet the requirements of Table 4/2. Compliance with these requirements is to be demonstrated on the basis of samples taken at the construction site (mixing plant) at the frequency specified in ÖNORM B 3327-1[1), 2)]:

Table 4/1 Non-alkaline acceleration of setting

	Dry-mix shotcreting Wet-mix shotcreting	**Dry-mix shotcreting**
Acceleration	non-alkaline accelerators	spray cement (SBM)
Binders	cement grades meeting additional requirements according to ÖNORM B 3327-1, possibly with additions	SBM
Aggregates	dry or moist	dry[3)] or moist[4)]

[3)] Water content < 0.2 % or according to manufacturer's specifications

[4)] Water content as a rule between 2.0 wt.% and 4.0 wt.%

[1)] If necessary, the supply of information on test results has to be agreed upon.

[2)] To test compliance with these requirements, the values provided by a tesing body agreed upon before the beginning of delivery have to be used. Agreement between the results obtained by these testing bodies and those of the manufacturing plant has to be established by comparative testing before delivery is begun. The necessary samples have to be obtained from different consecutive deliveries and delivery days.

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Table 4/2 Permissible parameters of cement grades according to ÖNORM B 3327-1 for sprayed concrete

Requirement	Sprayed concrete	Sprayed concrete Sulfate attack
C_3A content	-	0 % according to Bogue
Initial setting	90 min [1)]	90 min [1)]
Compressive strength after 1 day	D_1 8 (D_1 11 for requirements of fresh SpC)	D_1 8 (D_1 11 for requirements of fresh SpC)
Fineness according to Blaine	Deviation < 5 %	Deviation < 5 %
Bleeding after 120 minutes	WA 20	WA 20
Cement temperature	max. 80 °C	max. 80 °C
Additional: alkali content (Na_2O equivalent)	< 1.5 wt.% for non-alkaline acceleration according to ÖNORM EN 196-21	< 1.5 wt.% for non-alkaline acceleration according to ÖNORM EN 196-21

[1)] If high early strength, e.g. J3, is required, this value may be lower.

4.1.2 Spray cement (SBM)

Use of spray cement permits the production of dry-mix sprayed concrete with specified fresh sprayed concrete characteristics without addition of an accelerator. Both dry and moist mineral aggregates can be used. Spray cement reacts very fast upon contact with water and has a permissible workability time of a few minutes. If moist mineral aggregates are used, the processing technology has to be adjusted accordingly on account of the limited workability time. The spray cement is mixed with the moist aggregate in a suitable in-situ plant for immediate placing.

Spray cement for the production of sprayed concrete according to prEN 14487-1 can be used as a constituent material primarily for dry-mix shotcreting, provided it meets the following requirements in addition to or other than those specified in ÖNORM EN 197-1:

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

Table 4/3 For spray cement the following parameters and/or requirements have to be established on the basis of the results of preconstruction testing [1]:

Requirement	Spray cement	Additional requirement in case of sulfate attack
Initial setting (Test see It 12.1.3)	≥ 60″	
Constancy of volume (ÖNORM EN 196-3)	passed	
SO_3 (ÖNORM EN 196-2)	≤ 4.5 wt.% ≤ 7.5 wt.% [3]	in the presence of water with SO_4^{-2} content above 600 mg/l ≤ 3.5 wt.%
Cl (ÖNORM EN 196-2)	max. 0.1 wt.%	
MgO in clinker (ÖNORM EN 196-2)	max. 5.0 wt.%	
C_3A		C_3A-free (C_3A content of clinker 0 wt.-%, C_3A content of cement ≤ 1.0 wt.%. If C_3A content is higher, test according to It. 12.4.7 required.)
Al_2O_3 (ÖNORM EN 196-2)	≤ 6.5 wt.% ≤ 9.0 wt.% [3]	≤ 5.0 wt.%
Strength [2]	1 h ≥ 0.5 N/mm² 6 h ≥ 1.5 N/mm² and ≥ 70 % of preconstr. test 24 h ≥ 12 N/mm² and ≥ 70 % of preconstr. test 28 d ≥ 32.5 N/mm² and ≥ 80 % of preconstr. test	
Specific surface according to Blaine	Coefficient of variation ≤ 5 %	
Alkali content (ÖNORM EN 196-2)	Na_2O equivalent ≤ 1.5 wt.%	
Spray cement temperature on discharge from plant	≤ 70 °C	

[1] Agreement between the test results of the inspection body and those reported by the manufacturer has to be established through comparative testing before the commencement of delivery.

[2] For method of determination, see It. 12.1.5. The water/binder ratio to be used for test purposes is determined on the basis of preconstruction testing (as a rule 0.35 – 0.45).

[3] Only applies to binder containing $C_{12}A_7$. Presence of $C_{12}A_7$ in the binder to be demonstrated by XRD.

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

A data sheet containing information on permissible reaction times, aggregate moisture, aggregate temperature, working temperature (air, mix) and the requirements regarding air humidity during pneumatic conveyance from the mill has to be provided for each spray cement grade.

Preconstruction testing and external inspection of the spray cement are to be performed by an accredited testing and inspection body on the basis of an inspection agreement. External inspection includes an audit of the contractor's system of self-inspection. Major changes in the nature of the spray cement, e.g. changes of the constituent materials, are to be notified to the inspection body and another preconstruction test, if necessary, is to be agreed upon.

4.2 Additions

The addition of hydraulically active substances serves to improve the properties of the sprayed concrete, such as workability, stickiness, dust formation, rebound, strength and density of the sprayed concrete texture, and to diminish heat build-up.

Prepared hydraulically active additions according to ÖNORM B 3309 have proved to be suited as additions, although other substances (e.g. silica dust, slag sand, hydraulic lime) can also be used. A qualification test has to be performed to establish the most favourable cement/additive ratio. The total amount of additions must not exceed 35 % (8% in case of silica dust) of the amount of binder used.

- Prepared hydraulically active additions must meet the requirements of ÖNORM B 3309.
- Silica dust must meet the requirements of ÖNORM EN 13263. Silica can be added as slurry or in powder form (but not as precompacted powder for dry-mix shotcreting) in dosages of between 2 wt.% and 8 wt.% of the solid components of the binder mass.

  Combinations of silica dust and plastifier, added to the sprayed concrete by means of suitable metering devices, have proved their value.

  In the case of dry-mix sprayed concrete, compatibility of the suspension with liquid accelerators has to be checked (preferably, the suspension should be added to the material flow at the spray nozzle). As regards storage of the suspension, the specifications for liquid accelerators apply.
- Stone dust (filler) according to ÖNORM EN 12620

In the case of cement grades with more than 20 % of additives (e.g. CEM II/B, CEM III), the use of additives is not to be recommended. In case of using spray cement specific compatibility tests have to be made.

The additions have to be metered as individual components and mixed homogeneously with the other constituent materials.

The k-value approach for additions is governed by ÖNORM B 4710-1, It. 5.2.5.2.

In case of sulfate attack, the additive used must have been tested for sulfate resistance according to ÖNORM B 3309.

4.3 Mineral aggregates

Following the withdrawal of ÖNORM B 3304, the mineral aggregates used must at least meet the national requirements (SI_{40}, F_2) of ÖNORM B 3131 according to ÖNORM EN 12620. Currently, the basic requirements are also laid down in ÖNORM B 4710-1, It. 5.2.3.

For sprayed concrete grades SpC II and SpC III, at least F_2 aggregates according to ÖNORM EN 12620, supplied in separate grain fractions from an on-site preparation plant or a plant conforming to the CE marking requirements, are used. For sprayed concrete of exposure classes XF2 or XF4, F_1 is required.

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

The grain size distribution has to be such as to ensure compliance with the standard range of the aggregate grading line according to Table 4/4 (with maximum deviations of grading line class SK2 from the value established in the preconstruction test) and/or the category required in ÖNORM B 3131. As a rule, segregation by grain size should be in 4 mm fractions.

Table 4/4 Favourable range of the aggregate grading line for grain sizes 0/8 and 0/11

Maximum grain size (mm)	Passing the screen in wt.%
11	95 – 100
8	85 – 95
4	65 – 75
2	45 – 55
1	30 – 40
0.5	18 – 25
0.25	8 – 15
0.063	2 – 6 (f_3 or f_{11})

Depending on the application, the maximum grain size should be between 4 mm and 16 mm. For SpC II and SpC III, a maximum grain size ≤ 11 mm is to be used. In the case of wet-mix sprayed concrete, pumpability of the concrete is an important consideration as far as the grading of the mineral aggregates is concerned.

In crushed mineral aggregates, the maximum permissible percentage of settleable solids or fines (grain size < 0.063 mm) may exceed the figure given in Table 4/4 by 5 wt.%, if the aggregate is purely carbonate and the fraction smaller than 0.02 mm (determined by sedimentation test) does not exceed 3.0 wt.%. (According to ÖNORM B 3131 category f3 or f11, if footnote 2 of ÖNORM B 3131 applies.)

If de-mixing during storage and transport is negligible, plant-mixed grain mixtures (prepared grain mixture) with a maximum grain size of up to 11 mm can also be used for the production of sprayed concrete mix. In pre-mixed dry mix, special attention has to be paid to the strong de-mixing tendency (special bin design, storage and transport units, limitation of maximum grain size).

An important factor to be considered in the selection of mineral aggregates is their ability (petrographic characteristics, grain adhesion, grain shape, grain mixture) to contribute towards compliance with the specified sprayed concrete strength requirements. If spray cement is used, the water content of the mineral aggregates should be between 2 wt.% and 4 wt.% so as to guarantee correct mixing and working of the dry mix.

In the case of unfavourable petrographic characteristics and, in particular, if alkali accelerators according to It. 4.5.1.2. are used, the contribution of the mineral aggregates to sprayed concrete strength has to be established in "reference concrete" (see It. 12.1.10.) or F2 according to ÖNORM EN 12620 must be demonstrated.

If experience from earlier use is insufficient, mineral aggregates may have to be tested for possible chemical reactions with cement, additions, admixtures and/or spray cement (e.g. alkali-aggregate reactions according to It. 12.1.13).

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

4.4 Water

As regards water, ÖNORM B 4710-1 applies. The characteristics of the water added must be within the limits of ÖNORM EN 1008.

4.5 Admixtures

Admixtures for sprayed concrete must comply with ÖNORM EN 934-2, ÖNORM EN 934-5 or an ÖVBB Guideline.

4.5.1 Accelerators (EB)

Accelerators (EB) are used in combination with suitable cements and, possibly, additions according to It. 4.1.1. and It. 4.2. At present, non-alkaline accelerators according to It. 4.5.1.1., or alkali accelerators according to It. 4.5.1.2. for applications of minor importance, are used. In special cases (e.g. strong ingress of water at the substrate) the addition of non-alkaline accelerator may be necessary even to spray cement. For accelerators an initial test certificate by an accredited testing body not older than three years has to be produced. The maximum permissible accelerator dose for the application in question has to be established in the preconstruction test.

In due time before the beginning of shotcreting, the admixtures used have to be specifically adjusted to the cement as regards acceleration, early setting, late development of strength and sulfate resistance (if necessary). Laboratory testing methods are to be employed for this purpose (see It. 12).

The values for the beginning and end of setting established in identity tests of accelerators must not deviate from the values established in the preconstruction test by more than ± 20 seconds and ± 60 seconds, respectively. The laboratory tests, although providing a good indication of building-site behaviour, are not able to consider all possible on-site influences and therefore are no substitute for preconstruction tests performed with the actual building-site equipment.

The manufacturer has to indicate the accelerator parameters, as established during preconstruction testing, for the purposes of identity testing according to It. 12.1.8.

4.5.1.1 Non-alkaline accelerators (EB-AF)

The requirements according to table 4/5 apply. For reasons of occupational health and safety, the pH value of the accelerator solution or suspension has to be within a range of 3.0 to 8.0. As a rule, the dosage should be between 4.0 and 8.0 wt.% (in liquid accelerators a solid content ≤ 5.0 % of the binder mass is recommended).

4.5.1.2 Alkali accelerators

The requirements of table 4/5 apply, except for the pH value (≤ 12.0), the loss of strength (≤ 30 %), and the Na_2O content (no limit).

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

Table 4/5 Requirements to be met by admixtures and accelerators according to ÖNORM EN 934-5 (Table 1) for sprayed concrete (including additional requirements)

Properties	**Test method**	**Requirements**
Homogeneity	Visual inspection	No segregation
Colour	Visual inspection	Uniform and according to manufacturer's description
Composition (active constituents)	ÖNORM EN 480-6	No difference found in comparison of infrared spectra with manufacturer's specifications
Relative density	ISO 758	D ± 0.03 at D > 1.10 D ± 0.02 at D < 1.10 D = density as indicated by manufacturer
Solid content	ÖNORM EN 480-8	0.95 T < X < 1.05 T, if T > 20 wt.% 0.90 T < X < 1.10 T, if T < 20 wt.% T = solid content according to manufacturer, X = test result
pH value	ISO 4316	Manufacturer's indication ± 0.2, additionally 3.0 < pH <8.0
Chloride	ISO 1158	< 0.1 wt.%
Water-soluble chloride	ÖNORM EN 480-10	< 0.1 wt.%
Na_2O equivalent	ÖNORM EN 480-12	< 1.0 wt.%
Corrosion behaviour	not yet regulated	No initiation of corrosion in reinforcement steel
Additional requirements to be met by accelerators:		
Setting times	according to It. 12.1.3 as reference procedure or based on ÖNORM EN 480-2	Initial setting < 10 min Completion of setting < 60 min
Loss of strength	based on ÖNORM EN 196-1 according to It. 12.1.5 (mix temperature 20±2°C)	≤ 15.0 %
Requirements to be met in addition to ÖNORM EN 934-5:		
Sulfate content as SO_3:	based on ÖNORM EN 196-2	≤ 4.8 wt.% as sum total of cement and accelerator
Al_2O_3 (water soluble) for sulfate-resistant sprayed concrete (water with SO_4^{2-} content of more than 600 mg/l):	According to It. 12.1.9 or proof of sulfate resistance in reference sprayed concrete or sprayed-concrete structure according to It. 12.4.7	Al_2O_3 in wt.% x accelerator dose in wt.% of binder ≤ 115

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

4.5.2 Other admixtures

The effectiveness of concrete admixtures and their mutual compatibility (if several admixtures are used) has to be established through preconstruction and conformity testing of the sprayed concrete.

For the admixtures listed in Table 4/6, approval documents, test reports and test certificates, as required in the technical regulations and not older than three years, must be available. For all other admixtures (retarders, stabilisers, etc.), the supplier has to provide evidence of the permissible chloride content of ≤ 0.1 wt.% at intervals of two years.

Long-term retarders prevent the hydration reaction of cement for a certain period of time, usually between a few hours and a maximum of three days. Thus, FM-L moist mix and NM wet mix (fresh concrete) can be stored without loss of quality and without change in consistence. The effect of long-term retarders has to be compensated for through the addition of a modified accelerator. Possible influences on the further setting process and the properties of the hardened concrete (e.g. loss of strength) have to be taken into consideration. The additional requirements specified in Table 4/7 have to be met.

Admixtures intended to diminish dust formation and rebound serve to improve working conditions on the building site, particularly in the case of dry mix. The quantities to be added have to be established through preconstruction testing. The other sprayed concrete properties must not be negatively affected. The method by which admixtures are added has to be adjusted to the shotcreting method used.

Table 4/6 Other admixtures

Admixture	Abbreviation	Standard
Plasticiser	BV	ÖNORM EN 934-2
Superplasticiser	FM	ÖNORM EN 934-2
Air entraining water reducer	LPV	Guidelines ÖVBB[1)]
Air entraining agent	LP	ÖNORM EN 934-2

[1)] ÖVBB Guideline "Herstellung und Prüfung von Beton mit LPV-Zusatzmittel"

Table 4/7 Additional requirements to be met by long-term retarders (consistence regulators) according to ÖNORM EN 934-5

Property	Reference concrete	Test method	Requirement
Maintenance of consistency	ÖNORM EN 934-5 Annex B	ÖNORM EN 12350-5	Spread after mixing 55-60 cm, after 6 hours 80 %
Compressive strength	ÖNORM EN 934-5 Annex B	ÖNORM EN 12390-3	After 28 days equal to or higher than reference mix

4.6 Fibres

Steel fibres have to meet the requirements of Table 10/1 and plastic fibres those of Table 10/2 of the ÖVBB Guideline on fibre-reinforced concrete. The production of fibres is subject to external inspection.

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

5. MIX

5.1 Mix composition and production

Based on current technology, mix as a base product for dry-mix sprayed concrete and wet-mix sprayed concrete is classified according to Table 5/1. For indicative values of mix composition, see Table 5/2.

Table 5/1: Mix classification

	Dry-mix sprayed concrete			**Wet-mix sprayed concrete**
Water content of mineral aggregates	W < 0.2 wt.%	Standard W = 2.0 - 4.0 wt.% Scatter W = 1.5 - 5.0 wt.%		W ≤ 8.0 wt.%
Designation	dry mix	moist mix storable	moist mix for immediate placing	wet mix
Designation	TM	FM-L	FM-S	NM
Binder	Cement and additions or SBM	Cement and additions	SBM	Cement and additions
Addition of EB	in mixing plant, if necessary	during working	during working, if necessary	during working
Production	plant or site mixing	plant or site mixing	continuous mixing during working	plant or site mixing
Storage	closed (e.g. bin, bag)	sheltered	-	sheltered
Availability	unlimited	limited	unlimited	limited
Storage time (without long-term retarder)	storage according to requirements	Produced in advance, to be used within storage time (max. 1.5 h)	Produced for immediate use	Produced in advance, to be used within storage time (max. 1.5 h)

Table 5/2: Indicative values for mix composition for SpC II and SpC III

	Dry-mix sprayed concrete	**Wet-mix sprayed concrete**
Cement, SBM additions (e.g. fly ash)	310 - 360 kg/m³ 30 - 50 kg/m³	360 - 420 kg/m³ 0 - 70 kg/m³
Binder dose (cement, SMB and additions)	340 - 380 kg/m³ [1)]	400 - 450 kg/m³
Water-binder ratio	≤ 0.50 for strength requirements J_2 and/or J_3	
Consistency (spread)	-	Favourable range: Dense stream: 55 – 60 cm [2)] Thin stream: 65 ± 5 cm [2)]
Mineral aggregates: standard ranges see Tab. 4/4	GK 8, GK 11	GK 8, max. GK 11

[1)] With binder doses of less than 340 kg/m³ adhesion of the sprayed concrete to the substrate is noticeably diminished.

[2)] See It. 7.2.

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

5.1.1 Dry mix - TM (dry-aggregate mix)

- *Production*

  Dry mix can be plant-mixed or site-mixed from dry mineral aggregates with cement, with a combination of cement and accelerators, if necessary either with additions or with spray cement (SBM).

  The mixing plant has to meet the following requirements:

  - Facilities for dry storage of cement or spray cement and additions as well as facilities for clean storage of mineral aggregates of the required grain sizes.
  - Weighing equipment for all concrete constituent materials with a weighing accuracy of ± 3.0 wt.%.
  - Metering equipment with a batching accuracy (target-actual deviations) for the concrete constituent materials according to ÖNORM B 4710-1 Table NAD 15.
  - Mixing plant of sufficient mixing efficiency to guarantee a homogeneous mix. Mixing plant with microprocessor control meeting the requirements of ÖNORM B 4710-1, It. 9.6.2.3.1. Extent of documentation according to It. 12.7 of this Guideline.

- *Working temperature*

  The temperatures indicated in Table 5/3 have to be observed.

Table 5/3: Temperature of dry and moist mix during working

	TM	**FM-L FM-S**	**TM**	**FM-L FM-S**
Working temperature	max. °C		min. °C	
Spray cement	+ 60	+ 50	no requirement	
Mineral aggregate	+ 40		+ 5	+ 10
Water	+ 60		no requirement	
Mix	+ 40	+ 30	+ 5	+ 10

The most favourable temperature range for the mix is between 13 °C and 25 °C. Temperatures below 13 °C impair early strength, whereas temperatures above 25 °C shorten the workability time. Frozen mineral aggregates must not be used.

- *Natural moisture*

  Maximum natural moisture: 0.2 wt.% or according to specifications of spray cement manufacturer.

- *Storage and transport*

  Dry mix has to be stored under cover and must not deteriorate during transport. Measures have to be taken to avoid segregation (e.g. central pipe in the bin, bin never completely empty, discharge by means of vibrating floor). Air humidity in the conveyor line may lead to early setting reactions in spray cement.

  Mix spilled during handling or ejected from the spraying machine must not be re-used without prior treatment.

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

- *Storability of the mix*

  Dry mix can be stored for a period of up to several months according to the manufacturer's specifications.

5.1.2 Moist mix (moist-aggregate mix) FM-L, FM-S

- *Production*

  FM-L moist mix can be ready-mixed or site-mixed from moist mineral aggregates, cement and additions and transported to the placing site. The accuracy of constituent material metering and the mixing plant have to be in accordance with It. 5.1.1. The mixing plant is to be set up in the vicinity of the placing site, so that the maximum permissible workability time of 1.5 hours is not exceeded without additional measures.

  If SMB is used, the short reaction time of a few minutes necessitates continuous (steady) mixing of the FM-S moist mix in a special mixing plant set up next to the sprayed concrete delivery machine. Use of a mixing plant for continuous mixing is permitted. Batching and mixing of the constituent materials has to be such as to guarantee the placing of homogeneous sprayed concrete on the substrate. Metering may be performed by rotary vane batchers on a volumetric basis or, preferably, by weighing conveyors. The batching process (metering) has to be adjusted so as to achieve the required mixing ratio according to Table NAD 15 ÖNORM B 4710-1 (calibration according to It. 12.5.1), which has to be documented accordingly. For dry-mix shotcreting a tolerance range of ±5% for all constituent materials is permissible, since the final composition of the mix is obtained during placing.

- *Working temperature*

  The temperatures according to Table 5/3 have to be observed.

  Measures to reach a favourable working temperature:

  - at low ambient temperatures: heating (direct steaming is to be avoided), covered and/or enclosed storage of mineral aggregates, heating of water added for mixing;
  - at high ambient temperatures: sprinkling of grain size fractions 4/8 and/or 4/11, covered and/or enclosed storage of mineral aggregates, cooling of constituent materials in special cases.

- *Natural moisture of mineral aggregates*

  The natural moisture of the total quantity of mineral aggregates has to be between 1.5 wt.% and 5 wt.% (standard range; 2 wt.% - 4 wt.%).

  If SBM is used, a moisture content within the standard range is essential to ensure correct mixing and working of the mix. As a rule, the mix has to be covered for protection against climatic influences during both transport and storage. If the natural moisture is insufficient, the mix has to be moistened immediately before further use.

- *Storage and transport*

  Prior to placing, the FM-L mix has to be protected against external influences during transport and storage. Any mix spilled during handling or ejected from the spraying machine must not be re-used without prior treatment.

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

- *Workability time*

  The length of time for which FM-L mix remains workable depends largely on external influences, the type and dosage of the binder, the water content of the mineral aggregate and the temperatures.

  To guarantee first-rate quality of the sprayed concrete, the time taken to spray a mix made from cement according to It. 4.1.1 must not exceed 1.5 hours. Long-term retarders can be used to keep the mix workable for a longer time.

  If SBM is used, the workability time of the FM-S mix is product-specific (workability time of a few minutes).

5.1.3 Wet mix - NM

- *Production of pumped concrete and wet mix for thin-stream conveying*

  The mixing equipment has to be in accordance with ÖNORM B 4710-1 It. 9.6.2.3. The use of microprocessor-controlled equipment is required. Ready-mixed concrete may be used.

- *Working temperature*

  Mineral aggregates and fresh concrete should have a temperature of more than 15° C.

  If the fresh concrete temperature is above 20 °C, pre-hydration of the binder may lead to excessive stiffening of the pumped concrete, which results in an unfavourable setting behaviour.

- *Workability time*

  As a rule, working must not take more than 1.5 hours. The workability time can be prolonged through the addition of retarders or long-term retarders.

5.2 Mix for prescribed sprayed concrete (standard sprayed concrete)

Sprayed concrete without special requirements up to strength class SpC 12/15 and for exposure classes X0 and XC1 can be produced without preconstruction testing according to Table 5/4 with the following mix composition:

Table 5/4: Prescribed sprayed concrete (standard sprayed concrete)

FM-L	Mineral aggregates GK 8 to GK 16 Grading line range AC	5 parts by weight
	Cement CEM I, CEM II Strength class 42.5 (350 kg corresponding to 1 m³ of sprayed concrete)	1 part by weight
NM	C 15/20/XC1/PB/GK 8 and/or GK 11/F66, site-mixed	

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

6. SPRAYING PROCEDURES

6.1 Placing of sprayed concrete

When placing the sprayed concrete, care has to be taken to produce a homogeneous, dense sprayed concrete texture and a closed, even surface.

For thick sprayed concrete linings, sprayed concrete is to be applied in two or more layers to prevent separation. This applies, in particular, to sprayed concrete placed overhead. Rebound has to removed and not incorporated into the lining.

If the individual layers required to achieve the ultimate sprayed concrete thickness are placed at longer intervals, the previous sprayed concrete layer has be to cleaned and/or wetted by means of a mixture of compressed air and water.

The distance between the nozzle and the substrate should be adjusted to the rate of delivery and the speed at which sprayed concrete is placed. Depending on the operating air volume, it is between 0.5 m and 2.0 m. The spraying angle, i.e. the angle between the nozzle and the wall to be shotcreted, should be as close to 90° as possible. Nozzle distances and angles other than those recommended diminish the sprayed concrete quality and result in increased rebound.

The reference spray cement and/or accelerator dose determined during preconstruction testing may be modified slightly according to local conditions. Such modifications may be required due to the location and condition of the substrate, seasonal temperature fluctuations, moisture, water ingress and geological conditions.

If conditions turn out to be particularly unfavourable for a limited period of time, i.e. strong water ingress, the admixture of additional accelerator, adjusted to the overall system, or an increase of the spray cement dose may be necessary.

The amount of rebound is strongly influenced not only by the nozzle angle, but also by the composition of the mix, the amount of water, the spraying velocity, as well as the thickness of the sprayed concrete layer and the surface of the wall. Rebound and sprayed concrete residues must not be reused for shotcreting without prior treatment [8].

Reinforcements and steel components have to be adequately secured. Loose rock behind the reinforcement (wire mesh) have to be removed before shotcreting. In the presence of steel components, such as steel arches, steel girders, laggings, pipes, etc., small cavities in the lining cannot be excluded, but the effect can be diminished through proper positioning and control of the nozzle. Core samples should not be taken from such places. If a two-layer reinforcement is provided for, the second layer wire mesh (facing the tunnel clearance) should not be placed before the first one (facing the rock) is covered with sprayed concrete.

If sprayed concrete is to be placed consecutively on sections of the substrate and/or joined to existing sprayed concrete structures or protruding steel reinforcements, proper jointing to the existing sprayed concrete surface is essential. Tapering sprayed concrete edges and dirty jointing surfaces in the case of overlapping reinforcements are to be avoided.

If the substrate temperature is low, particularly in the case of frozen rock and soil or ice, the thickness of the sprayed concrete layer has to be increased by 2 – 3 cm.

If sprayed concrete is to be worked at air and underground temperatures of less than +5 °C, additional measures have to be taken. A minimum mix temperature of +13 °C is recommended.

After-treatment of sprayed concrete in tunnels is only required if special properties are to be guaranteed (e.g. SpC III) or under special circumstances (e.g. excessive drying or cooling). In such cases, the sprayed concrete surfaces are to be kept moist for seven days or sprayed with sufficient quantities of post-treatment agent according to RVS 11.064, Part II. For other applications

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

ÖNORM B 4710-1, NAD 17, applies. Thin layers of sprayed mortar for the rehabilitation of concrete structures require twice the time indicated in Table NAD 17.

6.2 Dry-mix shotcreting

6.2.1 Delivery of the dry mix

The mix is delivered to the nozzle in a pressurized airstream by means of compressed air, wetted with water in the nozzle ring and sprayed onto the substrate.

- *Mix*

  For dry-mix sprayed concrete, dry mix (TM) or moist mix (FM-L, FM-S) according to It. 5 can be used.

- *Mix conveyor, shotcrete gun, shotcreting machine*

  Mix for dry-mix sprayed concrete is delivered into the air stream by means of a rotary spraying machine, a double-chamber spraying machine or other equipment (batching screw). The mix conveyor has to ensure a uniform flow of material at the nozzle. The mechanical equipment has to be absolutely tight (dust formation, sprayed concrete quality).

  Unused mix residues and deposits have to be removed continuously.

- *Conveyor pipework, material delivery hoses*

  The conveyor hoses or pipelines should be installed in straight lines or wide bends. Couplings have to be absolutely tight.

- *Spraying nozzle*

  The spraying nozzle has to be designed in such a way as to ensure thorough mixing of the mix, water and, if necessary, the accelerator and the additions (e.g. micro-silica slurry).

- *Addition of water*

  Water has to be conveyed to the nozzle under sufficient pressure through hoses or pipelines. The temperatures indicated in table 5/3 should be observed.

  If sprayed concrete is delivered at a constant rate, the amount of water required for optimum workability of the sprayed concrete varies within narrow limits. Observance of these limits ensures a water-binder ratio of the sprayed concrete of ≤ 0.5. As a rule, measurements are not required.

6.2.2 Metering of the accelerator

The metering device has to ensure constant batching of the accelerator at a quantity specified relative to the cement mass and/or proportional to the conveyor output. The amount of accelerator to be added to the stream can be adjusted at the metering device. The set values have to be recorded in a calibration certificate (calibration curves, with due consideration given to water pressure in the case of liquid accelerator). To ensure delivery of a constant dose throughout the period of operation at the building site, the metering device has to be maintained, cleaned and calibrated at regular intervals. The accelerator has to be kept at a temperature of above 10° C.

The accelerator dose has to be accurate to less than 1.0 % of the binder dose (e.g. 6.0 % ± 1 % of binder).

- *Metering devices for liquid accelerators*

  As a rule, liquid accelerator is added continuously to the water by means of metering pumps. Addition to and mixing with water in batches in large containers is also possible.

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During aspiration of the accelerator from the storage tank, care has to be taken to avoid air bubbles and contamination. During storage, the liquid accelerator has to be stirred and maintained in stable condition (no flocculation or changes in viscosity, e.g. under extreme weather conditions).

- *Metering devices for powder accelerators*

  During dry-mix shotcreting, accelerator in powder form is usually added by means of metering devices immediately upstream of the shotcreting machine.

  - Manual metering into the spraying hopper is permitted in special cases only.
  - Batching screws and rotary vane batchers have to be installed above the conveyor belt according to the supplier's instructions. The accelerator quantity to be added has to be accurately adjusted to the conveyor belt rate in a pre-operational test.

6.3 Wet-mix shotcreting

6.3.1 Delivery of the wet mix

- *Wet-mix shotcreting equipment*

  Piston pumps are used to convey wet mix in a dense stream (piston pumps are suited for use in concrete repair work only). To minimise the interruption of delivery during switching, a long stroke, fast switch control and an accelerated piston speed in the unfilled piston range are recommended.

  Modified dry-mix shotcreting machines or pressure vessels with screw discharge are used for thin-stream conveying.

- *Delivery pipework*

  The delivery pipework is similar to that used for normal pumped concrete. The lines should be as straight as possible. The number of couplings is to be minimised.

- *Spray nozzle*

  In thin-stream conveying, the nozzle only has a guiding function and therefore consists of a single steel pipe, possibly cone-shaped.

  In dense-stream conveying, the dense stream has to be loosened and accelerated through the injection of air.

  Special care must be taken to allow the continuous addition of accelerator to the concrete stream.

6.3.2 Metering of the accelerator

The accelerator has to be added continuously to the concrete stream. Positioning of the batching device a few metres before the end of the pipe and subdivision of the total accelerator dose into smaller quantities have proved successful.

- *Metering device for liquid accelerators*

  The provisions for dry-mix sprayed concrete apply (see It. 6.2.2.). For slurry accelerators, valveless pumps (e.g. squeezecrete pumps) are to be preferred. Pumps integrated into the hydraulic stream of the concrete pump also proved to be useful. During switch-over of the concrete pump, the metering pump must also be stopped.

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- *Metering device for powder accelerators*

  Powder accelerators are batched via a compressed-air flow.

  - *Rotary batchers*

    Rotary batchers are based on the principle of the dry-mix shotcreting machine, which delivers the powder accelerator via a rotor into the thin stream in the sprayed concrete hose. The accelerator dose can be adjusted to the shotcreting machine by selection of rotor speed or rotor size.

  - *Pressure pot or pressure silo*

    Instead of a rotor, a pressure pot or pressure silo can also be used to deliver the required accelerator dose. The air pressure required for delivery of the accelerator has to be adjusted to the air pressure for sprayed concrete delivery to prevent the formation of residues. The accelerator dose can be adjusted through selection of the nozzle geometry and control of the air flow. Addition to the sprayed concrete stream is based on the same principle as with rotary batchers.

Powder accelerators can be blown into the dense stream via special nozzles at 3 – 5 m from the end of the hose, which also serve to convert the sprayed concrete stream from dense flow to thin flow. Sufficient mixing of the accelerator with the pumped concrete can also be achieved by simpler means, if the accelerator is batched directly into the thin stream. The design details always depend on the shotcreting system used. The accelerator has to be kept at temperatures of more than 10 °C.

6.3.3. Placing of wet-mix sprayed concrete

As a rule, wet-mix sprayed concrete is placed by remote-controlled spraying arms (spraying robots), manual handling of the nozzle being impossible on account of the weight of the dense stream of fresh concrete and the spraying equipment. If large-diameter pipes and high-rated machines are used, mechanical spraying arms ensure a higher placing output, provided sprayed concrete is applied continuously on large areas of substrate.

The nozzle distance, the nozzle orientation and the delivery rate can be optimised by the nozzle man according to individual requirements. The nozzle man is positioned at a certain distance from the substrate outside the direct rebound and dust range. Depending on the type of equipment, he may be positioned in a control booth on the lower part of the spraying arm, a control booth on the base machine, or on the ground with a remote-control module. Thus, better visibility and greater occupational health and safety can be ensured for the nozzle man.

However, owing to the distance from the substrate and the high delivery rate, production of a sprayed concrete layer of uniform surface and thickness is difficult. At any rate, shotcreting under hazardous conditions is facilitated through low-risk manipulation of the nozzle close to the substrate.

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7. REQUIREMENTS TO BE MET BY SPRAYED CONCRETE

The properties of sprayed concrete - sprayed concrete classes, early strength classes, strength classes and exposure classes – are defined in terms of sprayed concrete grades according to It. 7.5.

The properties have to be indicated in the schedule of specifications and/or implementation schedules through reference to the corresponding short designations (sprayed concrete grades according to It. 7.5).

7.1 Sprayed concrete classes

Sprayed concrete is classified according to its application and the structural functions to be fulfilled. The individual sprayed concrete classes have different requirements in terms of early strength, density of the sprayed concrete structure, (e.g. XC4, XAT), uniformity and leaching behaviour; the test requirements to be met differ accordingly.

To reduce the alkalinity of sprayed concrete and, thus, ensure a higher level of occupational health and safety, an improved leaching behaviour and less segregation, the use of non-alkaline accelerators is recommended for sprayed concrete class SpC I; use of non-alkaline accelerators is obligatory for SpC II and SpC III.

If no particular test frequency class (sprayed concrete inspection class) is specified, the sprayed concrete classes correspond to the test frequency classes indicated in Tables 11/1 and 11/2.

7.1.1 Sprayed concrete without structural functions (sprayed concrete class SpC I)

As a rule, the level of quality required (strength class, durability) is relatively low.

7.1.2 Sprayed concrete with structural functions (sprayed concrete class SpC II)

In general, SpC II sprayed concrete is used to fulfil "securing and supporting functions". It is used, inter alia, for outer linings, to support the working face during tunnelling, and for slope, shoulder and trench support. Care should be taken to obtain a close texture.

Special requirements have to be specified as regards the development of early strength according to It. 7.3. When determining the range of strength required ($\mathbf{J_1}$, $\mathbf{J_2}$ or $\mathbf{J_3}$), the degree of utilisation at the respective age has to be considered. The addition of accelerator is not required for certain applications.

7.1.3 Sprayed concrete with special structural functions (sprayed concrete class SpC III)

This class of sprayed concrete is suited for all structural functions according to ÖNORM B 4700, e.g. for outer linings of excavations under built-up areas and a low overburden, single-shell tunnel linings, support elements for slopes and excavated surfaces, and sprayed concrete walls for water tanks.

Sprayed concrete for the repair of structures made of concrete, reinforced concrete and masonry is also understood to fulfil special structural functions. Special care has to be taken to obtain a homogenous and dense texture. Therefore, exposure class XC 4 is generally required for SpC III. Moreover, SpC III is required for applications subject to sulfate attack with $SO^{2-}_4 > 600$ mg/l.

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

As in the case of SpC II sprayed concrete, special requirements have to be specified with regard to early strength according to It. 7.3. When determining the range of strength required ($\mathbf{J_1}$ or $\mathbf{J_2}$, $\mathbf{J_3}$ in special cases only), the degree of utilisation at the respective age has to be considered. The strength requirements have to be adjusted to the development of loading over time.

SpC III sprayed concrete should not be placed directly on surfaces with a strong water ingress without prior precautionary measures (e.g. pre-spraying, drainage).

7.2. Consistency

Maintaining the required consistency is essential to ensure the pumpability of wet-mix sprayed concrete and to guarantee correct metering of the accelerator. Any change in consistency must be taken into account when determining the accelerator dose.

The consistency classes according to ÖNORM B 4710-1 do not apply.

When placing wet-mix sprayed concrete in a dense stream, a spread of AM = 550 mm to 600 mm is favourable. As a rule, an allowance of 80 mm should be made for a workability time of 2 hours. A minimum slump of 500 mm is required.

When placing wet-mix concrete in a thin stream, a spread of AM = 650 ± 50 mm is desirable. As a rule, an allowance of 8 cm should be made for a workability time of 2 hours.

If a longer workability time (VV) is agreed according to ÖNORM B 4710-1, It. 4.2.6 and It. 5.4.9., maintenance of the required consistency is checked 15 minutes before the end of placing.

Consistency classes are of no relevance for dry-mix sprayed concrete.

7.3. Strength of young sprayed concrete (early strength classes)

Fresh sprayed concrete is defined as sprayed concrete not older than 24 hours.

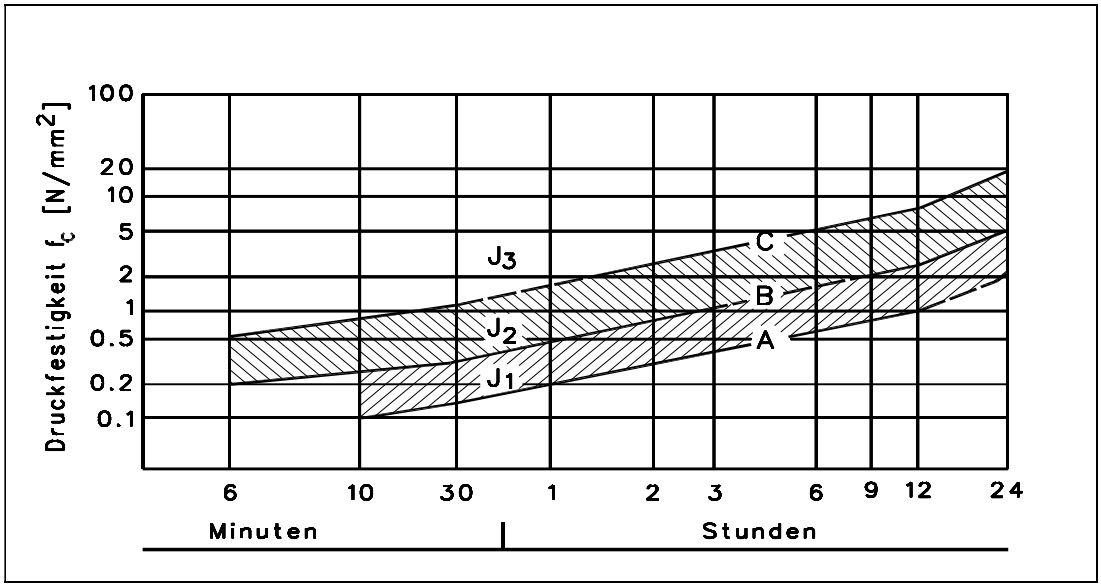
If the fresh concrete has to meet certain requirements in terms of strength development, these are specified according to early strength classes $\mathbf{J_1}$, $\mathbf{J_2}$, $\mathbf{J_3}$ (see Fig. 7/1).

An adequate development of strength during the first few minutes is a precondition for overhead placing (strength after 2 minutes 0.1 – 0.2 MPa). Test according to It. 12.3.1.

The development of strength during the first few minutes also has a major influence on the extent of dust formation and rebound. If strength builds up too fast, the sprayed concrete will harden instantly after being jetted onto the application wall, which prevents proper embedding of the coarse-grained particles of the subsequent shot. Hence, to keep dust formation and rebound within acceptable limits, the strength measured after 2 minutes under normal conditions should not exceed 0.2 MPa.

In the presence of strong water ingress or on a unfavourable substrate, a higher strength should be reached after a few minutes, which, however, implies a greater amount of dust and rebound.

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012



between A and B class J_1
between B and C class J_2
above C class J_3

Fig. 7/1: Early strength requirements to be met by fresh sprayed concrete

The development of strength in fresh sprayed concrete is determined by the test method specified under It. 12.3. Testing and measuring have to be timed in accordance with the build-up of strength in the sprayed concrete so as to obtain as continuous a picture of strength development as possible (the timing shown in the diagram serving as a guideline). It should be noted, though, that strength values of between 1.0 and 2.0 N/mm² cannot be measured on account of the test methods required according to Fig. 12/3. In all cases the development of sprayed concrete strength has to be demonstrated over the period from 6 minutes to 3 hours; moreover, at least one strength value has to be obtained for the period between 5 and 9 hours (in the measuring range of Procedure B) and 24 hours after placing.

Evidence of strength development after 9 and 12 hours is required in special cases only (e.g. low overburden, built-up areas), but may be specified in greater detail within the strength class (e.g. J_2 and after 12 h: 5.0 n/mm², after 24 h: 10.0 N/mm²).

J_1 sprayed concrete is suited for the placing of thin layers on a dry base without special load-bearing requirements and offers the advantage of low dust formation and rebound.

If sprayed concrete is to be placed in thick layers (including overhead) at a high delivery rate, strength development according to **J_2** is required. The same applies to locations with water seepage and applications involving immediate loading due to subsequent operations (e.g. drilling of anchor holes, driving of steel lagging, vibrations due to blasting).

J_2 requirements also have to be met in the case of rapid load build-up due to rock pressure, earth pressure or gravity loads. The specification of the range required also depends on the degree of utilisation of the fresh sprayed concrete. Examinations have shown that a linear creep behaviour is to be expected in fresh sprayed concrete with a degree of utilisation of up to 40 %, whereas a strongly progressive creep behaviour with a disruptive effect on the concrete texture is to be expected at a degree of utilisation of more than 80 % [9].

For reasons of increased dust formation and rebound, **J_3** sprayed concrete should only be specified under special circumstances (e.g. strong ingress of water, load-bearing requirements, fast rate of advance).

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

7.4. Strength classes

Compressive strength is specified according to ÖNORM B 4710-1. Strength testing is performed after not more than 28 days (or later at an agreed point in time, e.g. after 56 or 90 days, to be indicated in brackets after the strength class) on drilled cores from load-bearing sprayed concrete structures according to ÖNORM EN 12504-1 or, subject to special agreement and for preconstruction testing, from test panels according to prEN 14488-1.

Table 7/1: Sprayed concrete strength classes – Test age according to specifications

Sprayed concrete strength classes	Characteristic minimum compressive strength of cores with h/d = 1 in MPa
SpC 8/10	10
SpC 12/15	15
SpC 16/20	20
SpC 20/25	25
SpC 25/30	30
SpC 30/37	40
SpC 35/40	45

Preferably, strength testing is performed in cores with a height-to-diameter ratio of 1, if the result is to be compared with cube compressive strength (cores with a height-to-diameter ratio of 2 are used for comparison of the result with cylinder compressive strength). Cores have to be obtained according to ÖNORM B 3303, It. 5.2., and stored according to Table 12/2.

Equivalence of the compressive strength of sprayed concrete is determined according to Table 7/2 for:

- groups of n consecutive test results x_n (criterion 1)
- each individual test result x_i (criterion 2)

Table 7/2 Equivalence criteria for results of compressive strength testing in cores from load-bearing structures or test panels

	Criterion 1	Criterion 2
Number „n“ results in group	Mean value „n“ results x_n in MPa	each individual test result x_i in MPa
at least 15	$\geq f_{ck} + 1{,}48\ \sigma$	$\geq f_{ck} - 4$
3	$\geq f_{ck} + 4$	$\geq f_{ck} - 4$

with: f_{ck} ..... being the characteristic compressive strength
σ ..... being the standard deviation of at least six samples

In addition to the strength class according to Table 7/1, strength requirements may be specified for certain points in time, e.g. strength after 24 hours or after 3 days.

Instead of conformity testing of core samples according to It. 12.4.2., conformity testing of sprayed concrete by the bolt-driving method according to It. 12.3.2 may be contractually agreed upon in the case of large strength allowances (+ 10 N(mm² in Table 7/2). However, calibration of the method in the course of preconstruction testing is indispensable.

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

7.5. Sprayed concrete with special properties (sprayed concrete grades)

The special requirements refer to the material properties of the concrete, but not to the properties of the structure. The special properties only have to be demonstrated in the sprayed concrete texture.

For sprayed concrete with special properties, only F2 mineral aggregates according to ÖNORM 12620 may be used. To ensure the required density of the concrete texture, the use of alkaline accelerators is not permitted. The sprayed concrete must correspond at least to strength class SpC 20/25.

As regards the permissible limits for the constituent materials of sprayed concrete according to Table NAD 10 of ÖNORM B 4710-1, the following exceptions apply:

- conformity and identity tests for exposure classes XC3, XC4, XF3, XF4, XD3, XAL and XAT are to be performed in hardened concrete,
- a W/B value of 0.50 is assumed for dry shotcrete without testing,
- use of binders specified under It. 4.1 of this Guideline is permitted,
- the composition is determined in the mix delivered to the construction site, the air content normally assumed to be 3%.

7.5.1. Water-impermeable sprayed concrete (XC 3/XC 4)

Classification as exposure class XC3 with a penetration depth of < 50 mm or XC4 with a penetration depth of < 30 mm has to be performed in hardened concrete (drilled core) according to It. 12.4.4. of ÖNORM B 3303.

7.5.2 Frost-resistant sprayed concrete (frost attack without de-icing salts – XF 3)

Testing for frost resistance is performed in hardened concrete (drilled cores) according to It. 12.4.5. Contrary to the provisions of ÖNORM B 3303, frost resistance is to be demonstrated on the basis of the reduction of the static modulus of elasticity, which must nor exceed 25% after 56 frost-thaw cycles.

7.5.3 Sprayed concrete resistant to frost and thaw cycles (frost attack in combination with de-icing salts – XF 2 and XF 4)

As a rule, this type of sprayed concrete can only be produced by wet-mix or by dry-mix processes from ready-made products filled in bags. The requirements of the ÖVBB Guideline “Maintenance and Repair of Concrete and Reinforced-Concrete structures”. In the case of thawing agents other than salt, the possibility of a sulfate attack may have to be taken into consideration.

7.5.4 Sprayed concrete with high resistance against expansive chemical attack (XAT)

Given the fact that sprayed concrete placed in contact with the substrate cannot be protected against expansive attack from mountain water through subsequent measures, preventive measures must be taken if such attack is suspected. As the sulfate concentration in mountain water may vary strongly, the risk of sulfate attack must be assessed in at least three samples obtained at different points in time.

Sprayed concrete for applications subject to sulfate attack must have a durable and dense texture, i.e. meeting the requirements of SpC III and XC4 (penetration depth < 30 mm). In the case of sulfate contents of SO_4^{2-} > 600 mg/l, suitable constituent materials according to It. 4, in particular a C_3A-free binder, must be used. Testing for sulfate resistance is performed according to It. 12.4.7. Testing on the basis of the W/B value is not permitted.

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7.5.5. Sprayed concrete with high resistance against solvent chemical attack (XAL)

For applications subject to mild solvent attack (XA1L), a durable and dense texture must be ensured through class XC 4 (penetration depth < 30 mm).

For applications subject to moderate solvent attack (XA2L), non-carbonated mineral aggregates with a CO_2 content < 15% must be used for the grain size fraction $\leq$ 4 mm (except in cases of solvent attack in which renewal of the attacking liquid is insignificant to nil; mineral aggregates containing limestone or dolomite have to be used in such cases to neutralise the attacking liquid). Testing for class XA2L is to be performed according to ÖNORM B 3303. Sprayed concrete is to be produced according to SpC III.

Applications subject to strong solvent attack (XA3L) require special measures. As a rule, sprayed concrete must not be used as a permanent support measure for such applications.

7.5.6 Sprayed concrete to be tested for bond strength (HZ)

For special procedures, a tensile adhesive strength value, e.g. HZ 1.5 (tolerance in initial testing: 0.5 N/mm²) has to be specified by the design engineer on a project-specific basis. For concrete repair measures and/or the placing of sprayed concrete layers of up to 80 mm, the ÖVBB Guideline "Maintenance and Repair of Concrete and Reinforced-Concrete structures". Testing is to be performed on drilled cores or on the structure (in case of thin layers) according to It. 12.4.11.

As a rule, preparation of the substrate is required. To demonstrate the sufficiency of substrate preparation, the adhesive strength and the surface roughness of the substrate are established.

7.5.7 Fibre-reinforced sprayed concrete

The assessment of fibre-reinforced sprayed concrete (FRSpC) is performed in accordance with the ÖVBB Guideline on fibre-reinforced concrete. Fibre-reinforced concrete is classified according to its specific properties.

For sprayed concrete used for tunnel support, classification is based on the indicative toughness values established in the panel loading test, i.e. E1 (500-700J); E2 (700-1000J) and E3 (800-1200J). In Table 9/1 of the Guideline on fibre-reinforced concrete these classes are allocated to different tunnelling conditions.

For applications subject to bending forces (e.g. normal force), fibre-reinforced concrete is classified T1–T5, TS in terms of ultimate strength or TG1-TG5, TGS in terms of service state. The classes are based on the mean equivalent flexural tensile strength measured at the bending test beam. Fibre-reinforced concrete classes higher than T3 or TG5 can only be obtained through special measures.

Fibre-reinforced concrete classes BB 1 and BB 2 are required for applications demanding increased fire resistance through reduced spalling near the surface of the structure; concrete classes BB 1G and BB 2G are required for arches.

Fibre-reinforced concrete classes FS 1 and FS 2 are used to characterise the reduction of early shrinkage cracking through the addition of fibres.

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

7.6. Designation of sprayed concrete grades

The properties required in sprayed concrete, to be demonstrated through testing, are specified by reference to sprayed concrete grades according to Table 7/3. To indicate the sprayed concrete grades, the abbreviations given in It. 7.1 are to be used. The concrete grades to be used must be indicated in the construction specifications and/or planning and tender documents (for examples of sprayed concrete grades, see Table 7/3).

Table 7/3 Examples of sprayed concrete grades

Application and requirements	**Concrete grade**
Sprayed concrete for outer lining of traffic tunnel	SpC20/25(56)/II/J_2/XC1/GK8
Water-impermeable sprayed concrete for outer lining of traffic tunnel (moderate water pressure)	SpC20/25(56)/II/J_2/XC3/GK8
Fibre-reinforced sprayed concrete for initial support	FRSpC20/25/II/J_2/XC1/E3/GK8
Sprayed concrete for permanent penstock lining	SpC20/25(56)/III/J_1/XC4/GK8
Fibre-reinforced concrete for permanent lining of cross passages in traffic tunnels	FRSpC25/30/III/J_1/XC4/T3/BB2/ GK8
Sprayed concrete for outer lining exposed to sulfate attack	SpC25/30(56)/III/J_2/XC4/XAT/ GK8
Sprayed concrete as base layer for sealing material	SpC 12/15/I/GK 8
Sprayed concrete for bridge repair work, reprofiling mortar according to ÖVBB Guideline [1)]	SpC25/30/III/XC4/XF4/HZ1.5/ GK4
Sprayed concrete for temporary slope support	SpC20/25/II/J_1/XF3/GK8

1) ÖVBB Guideline "Maintenance and Repair of Concrete and Reinforced-Concrete Structures"

Additional properties established through quality testing as properties of fresh sprayed concrete and hardened sprayed concrete are not defined in this Guideline, but may be of relevance under special conditions, e.g. compressive strength of sprayed concrete between 1 and 28 days after placing, tensile splitting strength, shear strength, creep behaviour, modulus of elasticity (development over time), and adhesion of sprayed concrete to the substrate as well as the procedures indicated in the Guideline “Maintenance and Repair of Concrete and Reinforced-Concrete structures".

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

8. STRUCTURAL REQUIREMENTS

Given the method by which sprayed concrete is worked and placed, special requirements have to be met in terms of structural design to ensure the required quality of execution.

8.1. Fundamental requirements

- In terms of structural design, preference should be given - as far as possible - to increased sprayed concrete thickness instead of additional reinforcement.
- Joints in the sprayed concrete lining should be reduced to the absolute minimum and, if possible, located outside areas of flexural loading.
- Sprayed concrete with structural functions should be designed to a minimum thickness of 10 cm (except for structural reinforcement and repair works).
- In the case of longitudinal construction joints, the use of formwork is recommended, with due consideration given to the possible transmission of shear forces.
- In the case of double-layer reinforcements, the second layer (facing the tunnel clearance) must not be placed before the first layer (facing the rock) has been embedded with sprayed concrete.

8.2. Reinforcement

- Reinforcing steel mesh with a mesh width of ≥ 100 mm and a diameter of no more than 10 mm is to be used.
- Secondary reinforcing bars required for static reasons are to be placed, if possible, in every other field of the steel mesh only (e.g. mesh width 150/150 mm - min. distance = 30 cm).
- As a rule, the diameter of secondary reinforcing bars should not exceed 14 mm.
- Concrete cover: the minimum thickness of the concrete cover is to be observed throughout the structure. For planning purposes, the minimum design thickness is to be increased by the tolerance (see RVS 9.35); in the case of exposure to frost and thawing agents and/or a requirement for increased fire protection, the corresponding values have to be specified for each individual case.

Table 8/1 Concrete covers required

	Minimum thickness	Tolerance	Minimum design thickness
SpC I	15 mm	15 mm	30 mm
SpC II	20 mm	15 mm	35 mm
SpC III	30 mm	15 mm	45 mm

- Cross-shaped joints of reinforcing steel mesh are to be avoided, if possible (longitudinal and transverse direction). Overlap of additional reinforcing bars should also be avoided. If reinforcement overlaps circumferentially, no longitudinal overlap is required.
- Lap reinforcements to be bent backwards on site must not be more than 12 mm in diameter. The total cross-sectional area of the steel reinforcement may be utilised up to 80 % in the finished structure.

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

9. SINGLE-SHELL CONSTRUCTION METHOD

9.1 Definition, prerequisites, execution variants

The single-shell construction method is characterised by the fact that all static and structural requirements are fulfilled by a single shell structure. This shell can be produced in one or several operations.

The shell structure has to be designed not only to meet the need for support during tunnel driving, but also to fulfil the requirements of the finished structure. If the sprayed concrete shell fulfils a support function during tunnel driving and is to be subsequently strengthened by another sprayed concrete layer or shuttered in-situ concrete, the structural effectiveness of the composite structure has to be guaranteed through shear bonding.

If single-shell structures are made exclusively from sprayed concrete, local water penetration due to cracks, construction joints and defects cannot be excluded; hence, this method is preferably used in areas with little or no water ingress and the possibility of sufficient drainage.

If there is an ingress of water, the amount of water leakage permissible should be established before deciding in favour of or against a single-shell structure. Possible measures of water drainage and, if necessary, subsequent sealing, should also be considered.

In order to minimise crack formation and to keep the amount of reinforcement low throughout the structure, the bending stress on the tunnel shell should be as low as possible. Under appropriate geological conditions, this can be achieved through an adequate geometry of the tunnel cross section and in case of structurally favourable loading behaviour (symmetrical loading).

Form of execution

Basically , there are two variants based on the exclusive use of sprayed concrete.

- Single-layer sprayed concrete

  The sprayed concrete tunnel shell is placed in the course of tunnel driving, its thickness and reinforcement being sufficient to meet the requirements of both tunnelling and the finished state of the structure.

  Example: *25 cm sprayed concrete shell applied in the course of tunnel driving, with an outer (facing the rock) and inner (facing the tunnel clearance) layer of reinforcement.*

- Sprayed concrete shell formed by a composite multi-layered structure

  The outer sprayed concrete layer is applied during tunnel driving as a support for tunnelling. In a subsequent operation, one or several additional sprayed concrete layers are applied to achieve the shell thickness required for the finished state in static and structural terms, with shear bonding between the sprayed concrete layers being ensured by adequate measures (see It. 9.3).

  The use of fibre-reinforced sprayed concrete is preferable for the inner layer, as the higher density of the concrete eliminates the need for reinforcement by steel mesh or re-bars.

  Application of a sprayable sealing coat, capable of bridging cracks to a limited extent, is also possible.

  Example: *Outer layer of sprayed concrete shell, min. 15 cm, applied on a reinforcement mesh, with due consideration given to rock support by means of anchors, arches, etc., in the course of tunnel driving. After tunnelling, the second sprayed concrete layer is applied to and bonded with the existing outer layer with as few construction joints as possible, 15 cm thick, either with another reinforcement mesh or made from fibre-reinforced sprayed concrete.*

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

9.2 Sprayed concrete grade, design

Sprayed concrete grade

Considering the requirements to be met by fresh sprayed concrete, the minimum strength class required is SpC 25/30. As special properties, water permeability and a sufficient resistance against chemical attacks are essential.

Example of outer shell: *SpC 25/30(56)/III/XC4/GK8/J_1 or J_2.*

Example of inner shell: *SpC 25/30(56)/III/XC4/XF3/HZ1.0/GK8 .*

Design, structural considerations

In addition to Item 8 of this Guideline, the following applies:

The stability of the sprayed concrete shell under all load conditions during construction is established for single-shell structures in the same manner as for double-shell structures.

In the case of multi-layer execution, the stability of the structure in its final state is established for the composite structure, with due consideration given to load transfers. Testing for stability of the structure under construction, in its final state and in borderline cases (in soil or soft ground) can be performed, for instance, in analogy to the Guidelines for Traffic and Road Engineering, RVS 9.32, Items 3.4 and 3.5.

Bonding (shear bonding) between the sprayed concrete layers, if properly executed, is ensured by their surface roughness. Shear strength and bond strength at joints have to be established through preconstruction testing.

In view of the desired avoidance of inhomogeneities and/or defects in the sprayed concrete, the amount of reinforcement used it to be kept at its minimum; the reinforcement should be easy to place and evenly distributed.

In order to avoid additional inhomogeneities in the inner sprayed concrete layer, shear reinforcement should not be used. Reinforcement bars (mandrels, etc.) must not be allowed to penetrate the sprayed concrete shell to avoid the entrance of water.

9.3 Notes on execution

To ensure bonding of the sprayed concrete layers, the outer sprayed concrete layer has to be cleaned with a mixture of compressed air and water, or preferably by means of a high-pressure water jet, before the inner sprayed concrete layer is placed.

The reinforcement is to be kept in the required position through adequate measures, with overlaps of reinforcing mats being arranged in such a way as to avoid the superposition of four mat layers.

Breaking of construction joints in the individual sprayed concrete layers is essential.

After completion of the sprayed concrete shell, a thin levelling layer may be required in view of the use of the tunnel and/or as an additional seal against the ingress of water.

Single-layer sprayed concrete shells have to be executed with special care. Hence, appropriate instruction of the building-site staff and intensive construction supervision and quality control are essential.

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10. SPECIAL PROCEDURES

10.1. Sprayed concrete under compressed air

Sprayed concrete under compressed air [10] differs from sprayed concrete under atmospheric conditions for a number of reasons:

- *Increased air humidity*

  Owing to increased air humidity and - in most cases - higher air temperature, the sprayed concrete is permeated by air immediately after placing as a result of above-atmospheric pressure.

- *Impact on quality*

  The equipment set-up and the organisation of mix delivery under compressed air from the lock to the nozzle has to be such as to keep the exposure of the dry mix to compressed air as short as possible, since the high humidity under compressed air leads to a fast reaction of the binder.

  The more permeable the subjacent rock and the higher the pressure above atmospheric, the more easily will the sprayed concrete be permeated by compressed air.

  As a result of air permeation, the sprayed concrete loses moisture immediately after placing, which in turn leads to rapid drying and early shrinkage. Therefore, if sprayed concrete is to be placed on highly air-permeable soil or soft ground, the quality of the sprayed concrete (e.g. strength) will presumably be lower than that of sprayed concrete placed under atmospheric conditions as a result of fast drying and removal of fines. This is true, above all, of fresh sprayed concrete.

  If the substrate is largely impermeable, compressed air has a favourable influence on sprayed concrete quality.

- *Additional measures*
  - Repeated moistening of the fresh sprayed concrete (spraying with water from a nozzle).
  - Use of suitable additions to increase the density of the sprayed concrete texture.
  - Application of a sealing coat (sealing mortar) on the sprayed concrete surface as soon as possible after placing.

  The latter measures also help to diminish the total loss of air in the pressurised section.

- *Air pressure fluctuations*

  Air pressure fluctuations (due to normal tunnel driving or special incidents) have no particular influence on the build-up of strength in fresh sprayed concrete and subsequent strength development, provided the pressure does not drop below 0.6 bar.

10.2 Fibre-reinforced sprayed concrete

Besides steel fibres, glass, polymer, textile and carbon fibres can be used for the production of fibre sprayed concrete according to It. 7.5.7. It is important to note, however, that use of such fibres requires a different working method.

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Steel-fibre reinforced sprayed concrete

- *Applications and functions*

  Steel-fibre reinforced sprayed concrete contains at least 30 kg of steel fibres per m³ of placed sprayed concrete; fibres are added to obtain special properties in both fresh and hardened concrete. The fibre component in the rebound has to be taken into consideration. The maximum grain size of the mineral aggregate should not exceed 8 mm.

  The following sprayed concrete properties can be influenced through the addition of steel fibres:

  - increased toughness, particularly under flexural loading
  - limitation of crack width
  - no need for reinforcement for thin and/or irregular sprayed concrete layers
  - improved homogeneity through the avoidance of voids due to the ommitance of reinforcement (e.g. single-shell construction).

  The amount of fibres contained in the placed sprayed concrete is lower than in the base mix. Therefore, the fibre content has to be checked at regular intervals (see It. 12.6).

- *Working procedure*

  Steady addition of the steel fibres is essential for the quality of the placed steel-fibre concrete. The steel fibres need to be straightened out before being added to the mix. Collated fibres require contact with moisture to dissolve the bonding.

  Steel fibres can be added to the moist mix in the mixing plant, the truck mixer or on the conveyor belt upstream of the shotcreting gun. By means of a suitable batching device, steels fibres can be fed into the shotcreting machine or directly into the delivery stream in a well-targeted and controlled manner.

- *Requirements to be met by steel-fibre reinforced sprayed concrete*

  To ensure the necessary bonding of the fibres to the matrix, the strength class must not be less than SpC 20/25. A water-binder ratio of under 0.5 is desirable.

  An essential property of steel-fibre reinforced sprayed concrete is its increased toughness. Toughness is determined through classification according to flexural tensile strength and post-cracking behaviour into the levels T1 to T5, TS and/or TG1 – TG5, TGS (service state), tested on the bending test beam, or according to stress and strain performance levels E1 to E3 of the energy absorption equivalent, tested by loading plate-specimens.

Structural considerations

An "overlap" of fibres at construction joints is not possible. It is therefore necessary to determine the location of construction joints already in the planning stage and to provide for additional overlapping reinforcement.

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

11. SPECIFICATIONS AND TESTING

The specifications for sprayed concrete production refer either to concrete properties (specification of properties by the author, e.g. design engineer, as a rule), to concrete composition (inspection class I only), or to standard concrete (prescribed concrete, in exceptional cases only).

The specifications and tests applicable to sprayed concrete include the following:

- Specification of properties and inspection classes
- Preconstruction test
- Production control, including conformity tests (constituent materials, mix)
- Additional conformity tests of the mix to be performed by the sprayed concrete user, if not identical with concrete manufacturer
- Identity test
- „Certification“ of production control
- Measures to be taken in the event of non-compliance with criteria

For the purposes of production control, the constituent materials, the mix, the sprayed concrete, and the equipment for the production and intermediate storage of the mix and/or the sprayed concrete have to be tested. The constituent materials have to be subjected to both self-inspection and external inspection. Conformity testing of the mix and the shotcrete comprises preconstruction testing and continuous self inspection.

The frequency of conformity testing depends on the frequency classes to be specified in the tender documents. As a rule, frequency classes I - III correspond to sprayed concrete classes SpC I - III according to It. 7.1.

The identity test is performed on behalf of the owner/client by an accredited inspection body; testing for sprayed concrete thickness and early strength is performed by an experienced representative of the owner/client.

The scope of testing according to Tables 11 is to be observed. The manufacturer and the user have to agree in unmistakable terms on who is to perform which tests. If the manufacturer and the user are identical, double testing is not required.

Sprayed concrete properties and tests to be performed "according to requirements" and/or for special procedures, e.g. steel-fibre reinforced sprayed concrete, are to be specified in the tender documents.

11.1. Testing of constituent materials

The constituent materials for sprayed concrete production (cement, spray cement, additions, mineral aggregates, admixtures) have to be tested according to Table 11/1/1 and Table 11/1/2. As a rule, products subject to external inspection have to be used. In special cases, i.e. if no external inspection is performed, regular submission of evidence of performance of the tests required according to It. 4 by other means may be agreed upon.

11.2 Testing of the mix

The mix is to be subjected to conformity testing in the course of application at the building site. The frequency of testing depends on the type of mix, the frequency class and the presence or absence of certification of mix production, see Table 11/2/1 to Table 11/2/5.

With regard to mix production, the composition of the mix is to be recorded and submitted to the inspection body upon request.

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11.3. Testing of sprayed concrete

11.3.1 Preconstruction testing

The composition of the sprayed concrete is to be determined through preconstruction testing, which serves to demonstrate that both fresh sprayed concrete and hardened sprayed concrete meet the requirements specified for the structure in question (Table 11/2). The preconstruction test is to be performed under construction-site conditions, using the concrete components intended for execution of the construction job. The evaluation is made on a step by step basis as the individual test results become available.

If accelerators are used, at least two mixtures with different binder percentages and the corresponding admixture doses are to be tested to establish the required sprayed concrete composition (binder and accelerator doses required)[1)]. To establish the loss of strength, concrete made from the same constituents but without accelerator (base concrete) is to be tested. Base concrete should also be used to test the mix under building-site conditions.

In the event of significant changes regarding the constituent materials used for sprayed concrete production (change of manufacturer, binder, admixtures, additions, binder quantity of more than + 20 kg/m³, etc.), repeat preconstruction testing is required.

For sprayed concrete of a specified strength class, a sufficient allowance has to be made (indicative value: 25 % of characteristic strength of the corresponding strength class, but not less than 6 N/mm²). The allowance is higher than provided for in ÖNORM B 4710-1, which is due to the unavoidable scatter of quality. As regards the allowances for the other test parameters, Annex A of ÖNORM B 4710-1 applies. If new admixture-binder combinations are used, preconstruction testing according to It. 12.1.12 is recommended. For prescribed sprayed concrete up to strength class SpC 12/15, preconstruction testing is not obligatory.

11.3.2. Conformity testing

Conformity testing in the course of execution of the structure serves to demonstrate that the sprayed concrete composition is such as to guarantee the required properties at the specified age of 28 (56 or 90) days, assuming proper production, post-treatment and storage according to It. 12.4.1. The specified testing age may be exceeded by a maximum of 10 %. If wet mix is delivered by a ready-mix plant, the properties of hardened concrete also have to be demonstrated within the framework of conformity testing. The testing frequency is specified in Tables 11/2/1 to 11/2/5.

If the results of conformity testing are inadequate, performance of a second test on twice the original number of samples from the same test batch and/or a theoretical calculation according to Annex 5 is permissible. The conformity criteria for compressive strength are summarised in Table 7/2, and for other properties in Table 11/3.

[1)] If cement according to It. 4.1.1 and non-alkaline accelerator and/or spray cement are used, preconstruction testing with a single binder dose (min. 340 kg/m²) is sufficient.

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Tab. 11/1/1 Testing of base materials in the course of conformity testing

Base material and requirements to be met	Base material testing to be performed by the manufacturer	User of base materials				
		Preconstr. test	Conformity test			
			Frequency class (HK)			
				HK I	HK II	HK III
CEMENT						
Delivery note checked and reference samples taken	Plant inspection according to ÖNORM EN 197-1 and ÖNORM B 3327-1 incl. items listed in Tab. 4/2	x	x	every consignment, weekly testing of reference samples		
Delivery temperature	according to Tab. 4/2	x	x			
SPRAY CEMENT SBM						
Delivery note checked and reference samples taken	Plant inspection according to Tab. 4/3 twice a year	x	x	every consignment, weekly testing of reference samples		
Delivery temperature		x	x	every consignment		

ADDITIVES TYPE II ACCORDING TO ÖN B 4710-1				
Fly ash, slag sand	Inspection according to ÖNORM B 3309 or EN 450			
Silica dust	Inspection according to ÖNORM EN 13263			
Delivery note checked and reference samples taken		x	x	every consignment

WATER				
Chemical composition		x		Check according to ÖNORM B 4710-1

x to be tested
(x) to be tested, if necessary

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

Tab. 11/1/2 Testing of Base Materials in the Course of Conformity Testing

Base material and requirements to be met	Base material testing to be performed by the manufacturer	User of base materials				
		Preconstr. test	Conformity test Frequency class (HK)			
				HK I	HK II	HK III
MINERAL AGGREGATES						
Delivery note checked, visual inspection, reference sample	Preconstruction test and plant inspection according to ÖNORM B 3131/ ÖNORM EN 12620	x	x	every consignment, reference samples to be tested weekly		
Grain size distribution (grading line)		x	x	1 x month	2 x month	4 x month
Water content		x	x	1 x week	2 x week	
Fines and/or settleable solids		(x)	-	-	-	-
chem. reaction (e.g.: alkali-silica reaction)		(x)	-	-	-	-
ACCELERATOR						
Delivery note checked, visual inspection, reference sample taken	Preconstruction test and plant inspection according to ÖNORM EN 934-5 and Tab. 4/5 Preconstruction test by accredited inspection body	x	x	every consignment		
Density, solid content		x	x	every 2 months	every 2 months	monthly
pH value		x	x			
Setting behaviour		x	x	every EB consignment		
OTHER ADMIXTURES						
Delivery note checked, visual inspection, reference sample taken	Preconstruction test and plant inspection according to ÖNORM EN 934-2 and Tab. 4/5 Preconstr. test by accredited inspection body	x	x	every consignment		
FIBRES						
Delivery note checked, visual inspection, reference sample taken	Preconstruction test and plant inspection according to Guideline on fibre-reinforced concrete	x	x	every consignment		
Fibre dimensions		x	x			
Fibre-reinforced concrete class BB and/or BBG	(x)	-	-			
Fibre-reinforced concrete class FS	(x)	-	-			

x to be tested
(x) to be tested, if necessary

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

Tab. 11/2/1 Testing of Mix and Sprayed Concrete

Performance of test		**Manufacturer of mix**				**User of sprayed concrete**					**Identity test**	
		Preconstr. test	Self-inspection		External inspection	Preconstruction test	Conformity test					
							Frequency class (HK)					
								HK I	HK II	HK III		
SPRAYED CONCRETE MADE FROM DRY MIX (TM) SUBJECT TO EXTERNAL INSPECTION[1)]												
Temperature	Mix	x	x	continuously upon delivery	Plant inspection twice a year	no test required	x	continuously (min. once daily)			(x)	for sur-faces over 100 m² every 20,000 m²
Uniformity (de-mixing)		x	x				x				x	
Moisture		x	x	2 x monthly			x	every 4 months and/or every 10,000 m²	every 2 months and/or every 5,000 m²	monthly and or every 2,500 m²		
Apparent density		x	x				x				(x)	
Grain size distribution		x	x			x	x				x	
Binder content		x	x	continuously		-	-				(x)	
Early strength class	Sprayed concrete	x	x	every 1,000 to, max. once a month[2)]		x	x				x	
Compressive strength 7 d, 28 d		x	x			no test required	x				x	
Sprayed concrete thickness		-	-				x	every 500 m²			x	
Water impermeability XC3/XC4		x	x	once a year[2)]			(x)	1 x	12 months		(x)	
Frost resistance XF3		(x)	(x)				(x)				(x)	
Resistance to frost and thaw cycles XF4		(x)	(x)				(x)				(x)	
Modulus of elasticity 28 d		(x)	(x)				(x)					
Elution behaviour		(x)	(x)				(x)	-				
Tensile adhesive strength		(x)	(x)				(x)	-	every 500 m³		(x)	
Sulfate resistance XAT		(x)	(x)	every 2 years								
Solvent attack XAL		(x)	(x)									

1) For sprayed concrete for repair works an agreement has to be made with the external inspection body in accordance with the ÖVBB Guideline on "Maintenance and Inspection of Concrete and Reinforced Concrete Structures".
2) May be included in the conformity test to be performed by the user
x to be tested
(x) to be tested, if necessary
If the user is also the manufacturer of the mix, double testing (manufacturer – user) is not required
Tests for XF1 and XF2 are to be performed in fresh concrete according to ÖNORM B 4710-1

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

Tab. 11/2/2 Testing of Mix and Sprayed Concrete

Performance of test			**Manufacturer of mix**					**User of sprayed concrete**					**Identity test**
			Preconstr. test	Self-inspection		External inspection	Preconstruction test	Conformity test					
								Frequency class (HK)					
								HK I		HK II		HK III	
SPRAYED CONCRETE MADE FROM DRY MIX (TM) NOT SUBJECT TO EXTERNAL INSPECTION													
Temperature	Mix		x	x	continuously upon delivery		x	x		continuously (min. 1 x daily)			(x)
Uniformity (de-mixing)			x	x			x	x					x
Grain size distribution			x	x	1x weekly		x	x		1 x weekly			x
Apparent density			x	x	1x monthly		x	x	every 2 months and/or every 5,000 m²	monthly and/or every 2,500 m²	2 x monthly and/or every 1,250 m²		(x)
Moisture			x	x	1x monthly		x	x					x
Binder content			x	x	continuously		x	x					(x)
Early strength class	Sprayed concrete	Mixing plant according to It. 5.1.1 or ready-mix plant according to ÖNORM B 4710-1 with microprocessor control					x	x	1x	every 500 m²			x
Compressive strength 7 d, 28 d							x	x					x
Sprayed concrete thickness							-	x					x
Water impermeability XC3 / XC4							x	(x)		every 6 months			(x)
Frost resistance XF3							(x)	(x)					(x)
Modulus of elasticity 28 d							(x)	(x)					
Elution behaviour							(x)	(x)	-	every 12 months			
Tensile adhesive strength							(x)	(x)		every 500 m²			(x)
Sulfate resistance XAT							(x)						
Solvent attack XAL							(x)						

for sur-faces over 100 m² every 20,000 m²
(x)
x
x
(x)
x
x
(x)
x
x
x
(x)
(x)
(x)

x to be tested
(x) to be test, if necessary
If the user is also the manufacturer of the mix, double testing (manufacturer – user) is not required
Tests for XF1 and XF2 are to be performed in fresh concrete according to ÖNORM B 4710-1

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Tab. 11/2/3 Testing of Mix and Sprayed Concrete

Performance of test		**Manufacturer of mix**				**User of sprayed concrete**					**Identity test**	
		Preconstr. test	Self-inspection		External inspection	Preconstr. test	Conformity test					
							Frequency class (HK)					
								HK I	HK II	HK III		
SPRAYED CONCRETE MADE FROM MOIST MIX FM-L AND FM-S												
Temperature	Mix	x	x	continuously		x	x	continuously (min. 1 x daily)			(x)	for sur-faces over 100 m² every 20,000 m²
Uniformity (de-mixing)		x	x	continuously		x	x				x	
Mix ratio, batch protocols		x	x	daily							x	
Moisture of mineral aggregates		x	x	daily							(x)	
Grain size distribution		x	x	weekly		x	x	every 2 months and/or every 5,000m²	monthly and/or every 2,500m²	monthly and/or every 1,250m²	x	
Workability time (FM-L only)		x	x	2 x monthly		X (FM-L only)	x				(x)	
Base concrete (FM-L only)		x	-	-		x (FM-L only)	x					
Early strength class	Sprayed concrete	Mixing plant according to It.5.1.2 or ready-mix plant according to ÖNORM B 4710-1 with microprocessor control				x	x				x	
Compressive strength 7 d, 28 d						x	x				x	
Sprayed concrete thickness						-	x	every 500 m²			x	
Accelerator dosage						x	x	2x weekly			x	
Water impermeability XC3/XC4						x	(x)	1 x	every 6 months		(x)	
Frost resistance XF3						(x)	(x)				(x)	
Modulus of elasticity 28 d						(x)	(x)					
Elution behaviour						(x)	(x)	-	every 12 months			
Tensile adhesive strength						(x)	(x)		every 500 m²		(x)	
Sulfate resistance XAT						(x)						
Solvent attack XAL						(x)						

x to be tested
(x) to be tested, if necessary
If the user is also the manufacturer of the mix, double testing (manufacturer – user) is not required
Tests for XF1 and XF2 are to be performed in fresh concrete according to ÖNORM B 4710-1

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Tab. 11/2/4 Testing of Mix and Sprayed Concrete

Performance of test		**Manufacturer of mix**				**User of sprayed concrete**					**Identity test**	
		Preco nstr. test	Self-inspection		External inspection	Preconstr. test	Conformity test					
							Frequency class (HK)					
								HK I	HK II	HK III		
SPRAYED CONCRETE MADE FROM WET MIX (WET-MIX SPRAYED CONCRETE, DENSE STREAM OR THIN STREAM)												
Fresh concrete temperature	Mix	x	x	continuously		x	x	continuously (min.1 x daily)			x	for sur-faces of more than 100 m² every 20,000 m²
Moisture of mineral aggregates		x	x	according to B 4710-1		-	-				-	
Slump		x	x			x	x				x	
Workability time		x	x			(x)						
LP		x	x			(x)	(x)				x	
Mix ratio, batch protocols		x	x			x	x				x	
Compressive strength 28 d Base concrete not sprayed		x	x	every 400 m³		x	-	if user is not identical with manufacturer			x	
Accelerator dosage	Spayed concrete	Mixing plant according to It. 5.1.3 or ready-mix plant according to ÖNORM B 4710-1 with microprocessor control				x	x	2 x weekly			x	
W/B ratio						x	x	every 2 months and/or every 5,000 m²	monthly and/or every 2,500 m²	monthly and/or every 1,250 m²	x	
Base concrete sprayed						x	x				(x)	
Early strength class						x	x				x	
Compressive strength 7 d, 28 d						x	x				x	
Sprayed concrete thickness						-	x	every 500 m²			x	
Water impermeability XC3/XC 4						x	(x)	1 x	every 6 months		(x)	
Frost resistance XF 3						(x)	(x)				(x)	
Frost resistance XF 4						(x)	(x)				(x)	
Modulus of elasticity 28 d						(x)	(x)					
Elution behaviour						(x)	(x)	-	every 12 months			
Tensile adhesive strength						(x)	(x)		every 500 m²		(x)	
Sulfate resistance XAT						(x)						
Solvent attack XAL						(x)						

x to be tested
(x) to be tested, if necessary
If the user is also the manufacturer of the mix, double testing (manufacturer – user) is not required
Tests for XF1 and XF2 are to be performed in fresh concrete according to ÖNORM B 4710-1

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

Tab. 11/2/5 Additional Tests for Fibre-Reinforced Sprayed Concrete

Performance of test		Manufacturer of mix			Manufacturer of mix and user of sprayed concrete						Identity test
		Preconstr. test	Conformity test	External inspection	Preconstr. test	Conformity test					
						Frequency class (HK)					
						HK I	HK II	HK III			
Fibre content	Mix	x	x	x	x	x	if necessary	1 x every 200 to 1,000 m^3	1 x every 100 to 500 m^3	for sur-faces of more than 100m^2 every 20,000 m^2	
Fibre-reinforced concrete class BZ	Sprayed concrete				(x)	(x)	every 6 months			(x)	
Fibre-reinforced concrete class T					(x)	(x)	-	every 6 months		(x)	
Fibre-reinforced concrete class TG					(x)	(x)	-			(x)	
Fibre-reinforced concrete class E					(x)	(x)	-			(x)	
Fibre content					x	x	-			x	

x to be tested
(x) to be tested, if necessary
If the user is also the manufacturer of the mix, double testing (manufacturer – user) is not required

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Table 11/3 Conformity and identity criteria for other properties

Property	Test method	Maximum permissible deviation of individual test results from limits or tolerances
Moisture of mineral aggregates	Weighing and drying test or equivalent method	± 20 %
Bleeding	ÖNORM B 3303	according to ÖNORM B 4710-1: < 1 kg/m^3
Spread	ÖNORM B 3303	according to It. 7.2: -30 mm/+30 mm upon delivery, after working time –30 mm
Density	ÖNORM B 3303	according to ÖNORM B 4710-1: -30 kg/m^3
W/B ratio	according to ÖNORM B 4710-1, It. 5.4.2	± 0.02 for wet mix
Fresh concrete temperature	ÖNORM B 3303	< +1°
Binder content	according to ÖNORM B 4710-1, It. 5.4.2	-10 kg/m^3
Bulk density	ÖNORM EN 459-2	± 0.05 kg/dm^3
Early strength class	It. 12.3	Compliance with required J class over entire period
XC3/XC4	It. 12.4.4 according to ÖNORM B 3303	according to ÖNORM B 4710-1: < 5 mm
XF 3	It. 12.4.5 according to ÖNORM B 3303	Drop of static modulus of elasticity < 25 % after 56 frost-thaw cycles
Leaching?? behaviour	It. 12.4.12	Compliance with values of Table Tab. 3/1
Modulus of elasticity	It. 12.4.6	± 15 %
Bond strength	It. 12.4.11	according to ÖNORM B 4710-1: < -0.3 N/mm^2
Thickness of sprayed concrete layer	It. 12.5.4	± 1 cm or Annex 5
Fibre dosage	ÖVBB Guideline „Fibre-Reinforced Concrete“	-15 %, mean -5 %
Fibre-reinforced concrete class BZ	ÖVBB Guideline „Fibre-Reinforced Concrete“	-10 %
Fibre-reinforced concrete class T	ÖVBB Guideline „Fibre-Reinforced Concrete“	-10 %
Fibre-reinforced concrete class TG	ÖVBB Guideline „Fibre-Reinforced Concrete“	-10 %
Fibre-reinforced concrete class E	ÖVBB Guideline „Fibre-Reinforced Concrete“	-10 %
Sulfate resistance	It. 12.4.7.2	to be specified by expert

The minimum number of samples is specified in Table 11/2.

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11.3.3 Identity testing

The identity test serves to verify compliance of a lot or batch with a compliant total population. Sprayed concrete of a given strength class is deemed to originate from a compliant total population, if it meets the two criteria of Table 11/4 for "n" results of strength testing of samples obtained from the defined concrete volume. Sprayed concrete is deemed to originate from a compliant total population, if the properties specified are met within the permissible maximum deviations of Table 11/3.

Table 11/4 Identity criteria for the results of compressive strength testing on the load-bearing structure or, if specifically agreed, in test panels

	Criterion 1	**Criterion 2**
Number „n" results for compressive strength of defined concrete volume	Mean value of „n" results f_{cm} in MPa	Each of the individual test results f_{ci} in MPa
5 - 6	$\geq f_{ck} + 2$	$\geq f_{ck} - 4$
2 - 4	$\geq f_{ck} + 1$	$\geq f_{ck} - 4$
1	not applicable	$\geq f_{ck} - 4$

in which: f_{ck} …. characteristic compressive strength

11.3.4. Hardening/structural test

The hardening test serves to establish the structural strength and the special properties of the sprayed concrete in the finished structure at a specified point in time. Hardening tests (except for tests of the young sprayed concrete) are performed to establish matters of principle only and do not form part of the normal conformity testing procedure. For this purpose, tests are to be performed on young sprayed concrete (see It. 7.3) or on core samples (It. 12.4.1).

11.4. Inspection of mixing and metering equipment

In the course of commissioning, mixing plants have to be inspected by an accredited inspection body to establish compliance with the requirements according to It. 5 of this Guideline at the frequency indicated in Table 11/5. The same applies to metering equipment for liquid and powder accelerators. The results have to be recorded in an inspection protocol.

Table 11/5: Inspection of mixing and metering equipment

	Mix	**Type of test**	**Preconstruction test**	**Self-inspection**
Mixing equipment	Dry mix TM with external inspection[1)]	Inspection of weighing equipment	x	monthly during the first three months of operation, subsequently every three months
	without external inspection Moist mix FM-L and FM-S[2)]	Batching accuracy of metering devices	x	
		Mixing efficiency	x	
	Wet mix NM	Bin[3)] (segregation)	x	
Metering device for accelerator (powder, liquid)	-	Batching accuracy	x	Maintenance and inspection at least once a month

[1)] Inspections as part of external inspection
[2)] Inspection of other equipment, if any
[3)] for dry mix (TM) only

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12. TESTING PROCEDURES

The testing methods outlined below are laboratory and building-site tests which provide an indication of the behaviour of spray cement and the interaction of binders and accelerators in sprayed concrete production. To ensure due consideration of building-site influences, adjustments have to be made to local conditions (e.g. temperature, effectiveness of mixing, material flow, type and condition of substrate). The use of special testing methods, optimised for certain procedures or products, may be agreed upon between the parties concerned.

12.1 Testing of constituent materials for concrete production

The constituent materials to be used for concrete production have to be subjected to a preconstruction test to establish the properties essential for sprayed concrete production, such as acceleration of setting, early strength development, strength development, durability and leaching behaviour, well before the beginning of building-site operation. This applies, in particular, to binders (cement, spray cement) and materials to be added (additions, admixtures), possibly also to mineral aggregates and water.

12.1.1. Sampling of constituent materials and dry mix (TM)

Samples of constituent materials and dry mix (TM) are taken for the verification of material properties. Depending on individual arrangements, these tests are either carried out continuously for identification or at a later point in time on the basis of retained samples.

Availability of samples in sufficient quantities and of a quality as delivered and/or used for working has to be ensured. To meet this requirement, extreme care has to be taken during sampling and storage of samples.

Sample quantities:	Cement or spray cement: at least 5 kg Additions (fly ash, silica materials, etc.) and/or admixtures (accelerator): 1 kg or 1 litre Mineral aggregates 10 kg Dry mix: at least 10 kg
Sampling:	The equipment used for sampling and storage of samples must be clean and dry and, if possible, should serve for no other purpose. In the case of silo deliveries, representative samples are to be taken either through the lid of the silo truck or from newly filled containers. Samples must under no circumstances be taken from concrete residues left in the filling hose or the filling flange.
Filling and packaging:	Liquid products and powders have to be filled into clean, dry, and tight-shutting containers. Powders are first filled into PE bags, which then have to be closed tight without air cushions (shrink-wrapped, if possible) and stored in sheet-metal or plastic boxes.
Labelling:	All samples have to be labelled as follows (see enclosed specimen sheet "Sample Labelling"): - type and designation of the product - manufacturer (and/or supplier) - delivery day and, if possible, day of manufacturing - quantity delivered - mode of delivery (silo, bag, barrel, etc.) - place and date of sampling

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- name of person taking the sample

Storage: Samples to be retained for later testing are to be stored in a cool and dry place. Samples for subsequent testing on the building site are to be stored until the required sprayed concrete properties have been demonstrated.

In addition, ÖNORM EN 932-1 applies to mineral aggregates and dry mix; ÖNORM EN 196-7 applies to cement, binders and additions.

12.1.2. Bleeding of cement and/or binder pastes

Test to be performed according to ÖNORM B 3303, It. 9.4.

12.1.3. Laboratory testing of binder/accelerator combinations and spray cement (SBM) for acceleration of setting

The testing methods used to assess the acceleration of setting are based on the principle of penetration. The Vicat needle apparatus (test performed on binder paste) or the Proctor penetrometer (test performed on reference sprayed concrete) can be used for this purpose. The manual Vicat needle method described below basically serves to test and assess the suitability of spray cement and binder/accelerator combinations as regards the acceleration of setting. The Proctor penetrometer is used primarily to assess the effect of binder/accelerator combinations on the acceleration of setting and the development of early strength in wet-mix sprayed concrete.

- *Manual testing by means of the Vicat needle apparatus*

  This method of establishing the setting time of the binder/accelerator combination or the spray cement is modelled on the test provided for in ÖNORM EN 196-3. At a given water-binder ratio, the beginning and end of setting are established for a given binder/accelerator combination or spray cement.

- *Instructions for testing*

  a. Temperature of binder (spray cement) and water: +20 °C ± 2 °C, in special cases +8 °C ± 1 °C.

  b. Prepare 250 g binder (spray cement) and water according to preconstruction test[1)].

  c. Add liquid accelerator to water (dry-mix shotcreting), normally at a rate of 3 – 5 wt.% of binder. The moisture content of the accelerator is counted to the water quantity.

     When testing for wet-mix shotcreting, first prepare the binder paste and add the liquid accelerator quickly after 15 minutes (see e,f,g).

  d. When using powder accelerators, pre-mix thoroughly with binder.

  e. Fill the dry components into a conical hard-rubber ring (h = 40 mm, d_{ui} = 65 mm, d_{oi} = 74 mm) placed on a glass or plastic plate and topped with a cylindrical structure (ring) (h = 62 mm). A cylindrical vessel according to It. 12.1.4.1., h = 60 mm, can also be used.

  f. Form a dent in the binder.

  g. Quickly add the liquid components and mix the binder/accelerator paste or spray cement paste thoroughly within 15 seconds by means of a spatula or, preferably, an automatic stirring device (see Fig. 12/1) adapted to the shape of the vessel. After mixing, compact the paste by repeated jolting. Remove the ring and level the paste by means of the spatula. These operations have to be completed within 25 seconds after the initial addition of water or - in the case of wet-mix shotcreting - the addition of accelerator. If the binder paste is not easily workable, repeat the trial with a lower dose.

[1)] Water/binder ratio normally between 0.35 and 0.45.

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h. Use Vicat needle apparatus to determine the beginning and end of setting. Calculate the times from the first addition of water or - in the case of wet-mix shotcreting - the completed addition of accelerator. The beginning of setting is defined as the point in time when the needle remains stuck in the paste at 3 to 5 mm above the plate (glass or plastic plate); the end of setting is defined as the point in time when the needle penetrates no more than 1 mm into the paste.

   Alternatively, the needle method according to ÖNORM EN 934-5 (modelled on EN 480-1 with W/B < 0.5 and Vicat needle apparatus 300 g) can be used.

12.1.4. Preparation of samples for the testing of binder/accelerator combinations and spray cement

12.1.4.1 Preparation of cylindrical samples from binder paste

The method is suited for spray cement or binder/accelerator combinations with a setting time $\geq$ 15 seconds for tests of early strength and volume stability (soundness test). The samples are prepared according to the following instructions:

- *Materials and equipment required:*
  - metal cylinder with an inner diameter of 60 ± 1 mm, 60 ± mm high (cut up longitudinally). For volume stability and sulfate resistance testing, a suitable insert for the required height of 10 mm has to be used.
  - ring top
  - base and cover plate
  - basket stirrer (see Fig. 12/1)
  - hand-drill (1200 rev/min)
  - water tank
  - stop watch
  - weighing device, 0.1 g accuracy
  - amount of binder used: 320 g
  - amount of water - depending on the water-cement ratio established for setting between 15 seconds and 3 minutes (water-cement ratio 0.35 - 0.45)

The temperature of the water and the binder must be 20 °C ± 2 °C.

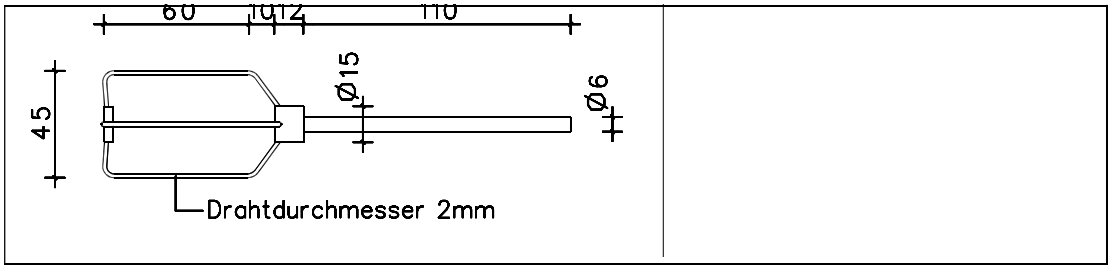


Fig. 12/1: Suitable basket stirrers (dimensions in mm)

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- *Sample preparation:*
  - Place the cut cylinder (with top) on the base plate.
  - Pour the binder into the cylinder.
  - Pour water quickly into the cylinder and start the stop watch.
  - Use hand-drill with attached basket stirrer to mix the binder with water for 10 seconds by circular and vertical movements.
  - Remove the cylinder top and press the cover plate onto the cylinder.

    Operations 4 to 5 have to be completed within 15 seconds after the start of the stop watch. The glass plate may have to be turned to remove the binder paste from between the plate and the cylinder rim.
  - Remove the cover and base plates after approx. 10 minutes.
  - Insert a screwdriver into the longitudinal gap of the mould and turn it to strip the sample.
  - If the surface of the sample is not smooth, use fine-grained sand (e.g. standard sand, fine) and water to rework it on a glass plate.
  - Keep the sample moist for one day after stripping, then store it in a water bath at 20 °C ± 2 °C until testing.

12.1.4.2 Preparation of samples 4 cm x 4 cm – 16 cm, in analogy to ÖNORM EN 196 – 1, at water-binder ratio = 0.75[1)], for tests of compressive strength and loss of strength

Preferably, a water-binder ratio of 0.75 is to be observed. Test mortar (with accelerator) and reference mortar (without accelerator) must have the same water-binder ratio. If the loss of strength due to the addition of accelerator can be determined in the sprayed concrete (e.g. during building-site operation), the test according to It. 12.2.4. is to be preferred.

Test method based on the use of cylinders is being investigated – MVA Strass.

- *Mortar consisting of binder/accelerator combinations (M) and mortar without accelerator (0)*
  - Temperature (cement, standard sand and water): +20 °C ± 2 °C.
  - Mix cement and admixtures thoroughly before removal from container.
  - Mix 450 g cement with the dose of powder accelerator established in the setting-time test in dry state by hand with a spoon for two minutes in a dish. Liquid accelerators are added to the mixing water, the rest of the procedure being the same.
  - Pour 315 ml water into the dry mortar mixing dish (in analogy to ÖNORM B 3310).
  - Pour 1350 g ISO standard sand into the mixing dish of the slow-moving mixer.
  - Transfer the binder/accelerator mixture into the mixing dish within five seconds and immediately, i.e. without interruption, switch the mortar mixer to high speed for 15 seconds.
  - Place the mortar in the 4 cm x 4 cm x 16 cm prism moulds as quickly as possible and compact well.
  - Level the mortar in the mould immediately after compacting. This operation has to be completed before stiffening begins.
  - Determine the bulk density of the mortar to verify proper compacting (maximum permissible deviation of prisms prepared with and without additions: ± 5 %.

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1) A water-binder ratio of 0.75, higher than that provided for in ÖNORM EN 196 - 1, is due to practical conditions. Comparative tests have shown that the loss of strength in this laboratory test largely corresponds to that of sprayed concrete in practice. If sample preparation is not possible, the test can be performed on sprayed concrete.

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- After storage in a moist atmosphere for one day, the prisms are stripped and subsequently stored in a water bath at 20 °C ± 2 °C until testing.

- *Mortar made from spray cement*
  - The water-binder ratio depends on the product and has to be specified during preconstruction testing. The samples are produced in analogy to the above procedure, with the quantities being modified in accordance with the water-binder ratio.

12.1.4.3 Preparation of samples from reference sprayed concrete

Samples from reference sprayed concrete are used to test spray cement or binder/accelerator combinations for strength development, frost resistance, modulus of elasticity, water impermeability, sulfate resistance and leaching.

Table 12/1: Composition of reference sprayed concrete

	Dry-mix sprayed concrete	**Wet-mix sprayed concrete**
Mineral aggregates	calcite-dolomite aggregate	
Maximum grain size	8 mm	8 mm
Grain size distribution	grading line according to Table 4/4	
Spray cement[1)], binder	380 kg/m³	430 kg/m³
Plastifier	-	according to requirements
Mean water-binder ratio	0.45 ± 0.03	0.50 ± 0.03
Accelerator[2)]	corresponding to J_2	
Consistency	-	dense-stream process: a = 55 – 60 cm thin-stream process: a = 65 ± 5 cm

1) Minimum requirements to be met by fresh sprayed concrete J_2

2) Tests for sulfate resistance and elution are to be performed with the maximum permissible accelerator dose (according to manufacturer's specification).

- The following information has to be provided for reference sprayed concrete:
  - binder (designation, plant, place and date of delivery) and mineral aggregates (grading line)
  - mix composition
  - water-cement ratio (in case of dry-mix sprayed concrete through flow measurement)
  - consistency (wet-mix sprayed concrete)
  - spraying method
  - spraying machine and machine parameters, diameter and length of delivery hose, nozzle, water pressure, air pressure at the shotcreting machine or at the nozzle (wet-mix sprayed concrete)
  - spraying output
  - device for dosage and dosage level
  - ambient, fresh-concrete, water and storage temperatures
- Reference sprayed concrete is sprayed into sampling boxes according to It. 12.4.1. and stored.

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

- Testing of fresh sprayed concrete is performed according to It. 12.3. For all other tests, cores are drilled in the dimensions specified in the individual test procedures.

12.1.5. Laboratory testing of binder/accelerator combinations and spray cement for strength development and loss of strength

The addition of accelerator (above all of alkaline accelerator) may result in a diminished build-up of strength in older sprayed concrete and, thus, lead to a loss of strength relative to accelerator-free sprayed concrete (base sprayed concrete).

Strength development and the loss of strength (binder/accelerator combinations) can be established by means of the test methods described below. The most suitable method has to be chosen on the basis of the spray cement characteristics and/or the binder/accelerator combination used. A combination of different methods is possible.

- *Laboratory testing for compressive strength development on cylindrical samples according to It. 12.1.4.1.*

  The strength development of spray cement as well as binder/accelerator combinations is established through tests performed on cylindrical samples, 60 mm in diameter, 60 mm high, prepared and stored in accordance with It. 12.1.4.1.

  At least class II test presses according to DIN 51302 are permissible for compressive strength testing. Class III presses are permissible for the measuring range from 1 to 4 kN (determination of one-hour strength).

  Compressive strength testing is performed on 3 samples each after 1, 6 and 24 hours (evaluation of spray cement with regard to early strength) and after 28 days. Compressive strength is expressed as a mean value to an accuracy of 0.1 N/mm². Individual values deviating from the mean by more than 15 % are not considered for averaging. At least two useful samples are required for averaging. At least 2 useful samples are required for averaging.

- *Laboratory testing for compressive strength development and loss of strength in 4 x 4 x 16 cm test samples according to It. 12.1.4.2.*

  Testing for compressive strength is performed after 7 days and/or 28 days, or earlier.

- *Laboratory testing for compressive strength development in samples obtained from reference sprayed concrete according to It. 12.1.4.3.*

  Fresh sprayed concrete is evaluated according to It. 12.3.

  Testing for compressive strength after 7 days and/or 28 days is performed on 3 cores, 50 mm in diameter and 50 mm high.

  The loss of strength is calculated on the basis of the mean compressive strength of samples aged 28 days without accelerator (0) and with accelerator (M) according to the following equation:

$$\text{Loss of strength (\%)} \quad \frac{EB(0) - EB(M)}{EB(0)} \times 100$$

12.1.6. Volume stability testing of spray cement

The test is performed according to the Le Chatelier procedure in analogy to ÖNORM EN 196 – 3.

12.1.7 Determination of alkali content (Na2O equivalent) of spray cement and accelerators

12.1.7.1 Determination of alkali content (Na_2O equivalent) in spray cement

Test according to ÖNORM EN 196-21

12.1.7. Determination of alkali content (Na_2O equivalent) in accelerators

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Test according to ÖNORM EN 480-12

12.1.8 Identity testing of accelerators

Identity testing of accelerators according to ÖNORM EN 934-5 serves to establish the uniformity of accelerators selected through preconstruction testing and delivered to the building site. A plant certificate has to be produced by the admixture manufacturer at the time of preconstruction testing and at least every other month as long as building-site deliveries are made:

- pH value (ISO 4316)
- density (bulk density, if required, proof of homogeneity, ISO 758)
- infrared analysis (ÖNORM EN 480-6)
- solids content (infrared drying or hot cabinet, 105°C)
- Al_2O_3 content according to It. 12.1.9.2
- SO_3 content (by analogy to ÖNORM EN 196-2)
- content of alkalis (Na_2O equivalent according to It. 12.1.7.2)
- Cl content (according to ÖNORM EN 480-10)
- acceleration of setting with a cement grade agreed upon before delivery (according to It. 12.1.3.)
- loss of strength (with accelerators) according to It. 12.1.5.
- proof of sulfate resistance (to be produced upon preconstruction testing, if required) according to It. 12.4.7.1

12.1.9 Determination of the Al2O3 content of accelerators (EB) and spray cement (SBM)

12.1.9.1 Total Al_2O_3 content of spray cement

Test according to ÖNORM EN 196-2

12.1.9.2 Content of water-soluble Al_2O_3 of accelerator

As a rule, this is determined by complexometric titration by means of Titriplex III and xylene orange as an indicator.

Instructions for testing

Use twice distilled water to dilute a 1 ml sample[1] to 100 ml. Boil up briefly with 50 ml 0.1 m (molar) Titriplex III solution and 2 ml 1 n (normal) hydrochloric acid and keep it on the boiling water bath for 10 minutes. After cooling, adjust to a pH value of 5 to 6 with sodium acetate, and after addition of triturated xylene orange indicator use 0.1 m zinc sulfate solution to titrate until the colour changes abruptly from yellow to red.

Triturated xylene orange indicator: 1 g xylene orange
99 g potassium nitrate

To control the titrating solution, titrate a reference sample in the same manner.

[1]) Powder accelerator has to be dissolved (1:1).

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Calculation:

1. (50 - V) x 5.098 = mg [Al_2O_3]

   V = consumption in ml 0.1 zinc sulfate solution

2. $\frac{\text{mg } [Al_2O_3]}{\rho \times 10} = \%\ [Al_2O_3]$

   ρ = density at + 20 °C in g/cm²

12.1.10 Testing of mineral aggregate contribution to sprayed concrete strength

If mineral aggregates other than those corresponding to class I according to ÖNORM B 3304 and/or F2 according to ÖNORM EN 12620 are used, the following concrete without accelerator has to be tested at the age of 7 days:

- Specified mineral aggregates for sprayed concrete

  (aggregate grading line - according to Table 4/4, maximum grain size - depending on application - between 8 mm and 16 mm, for structural tasks 11 mm).
- CEM I 42.5 R/WT 38/C_3A-free, dose 400 kg/m³
- Water-binder ratio 0.50 ± 0.05:

  The water-binder ratio is to be chosen within the range specified for C2 concrete consistency. If this is not the case or if another consistency is more appropriate for the working method in question (wet-mix shotcreting), this has to be indicated separately.
- Sample preparation and testing according to ÖNORM B 3303. Compressive strength is to be indicated as the mean value of 3 cube tests.

  The compressive strength to be reached by this concrete has to be at least 1.3 times the strength of the required sprayed concrete strength class with non-alkaline accelerator and at least 1.6 times the strength of the required sprayed concrete strength class with alkaline accelerator.

12.1.11 Testing of grain size distribution of mineral aggregates

Test according to ÖNORM EN 933-1

12.1.12 Advance qualification testing

In view of the fact that sprayed concrete can only be produced and subjected to preconstruction testing under practical conditions by means of the actual building-site equipment when construction work has begun, a quality forecast should be made in time on the basis of the following tests:

- Testing of cement or spray cement according to It. 4.1.1. and/or 4.1.2
- Testing of the cement/accelerator combination according to It. 12.1.3 and 12.1.5. (for spray cement the results of self-inspection and external inspection are available).
- Testing of mineral aggregates: grain size distribution according to It. 12.1.11

  evaluation of strength contribution according to It. 12.1.10 (not obligatory if the same mineral aggregates have been used before)

On the basis of these tests, an evaluation of the sprayed concrete composition with regard to the binder/accelerator combination and the development of strength can be anticipated before the results of preconstruction testing are available. Ready-mix concrete plants, which only supply a sub-product for the dry-mix shotcreting procedure, should also use these tests for advance assessment. Tests of this type are of particular importance for minor construction projects, where they may fulfil the function of preconstruction testing.

Example: Reference concrete f_{cm} with sprayed concrete formula 42.0 MPa

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- Loss of strength due to accelerator, e.g. 15%	- 6.3 MPa
	35.7 MPa
- Influence of compacting 10 %	- 3.6 MPa
- Allowance (6 N/mm³)	- 6.0 MPa
	26.1 MPa
required f_{ck} for SpC 2725	25

12.1.13 Testing for possible alkali - aggregate reaction (AAR) with spray cement or binder/accelerator combination

If the mineral aggregate contains alkali-sensitive constituents, an expansive reaction likely to damage the sprayed concrete may occur under certain circumstances.

In case of doubt, the reactive potential can be established through instant testing according to ASTM C 289-97. If the test results indicate a possible risk, the extent of the potential reaction has to be established in analogy to ASTM C 227-81. Risk assessment can also be based on the Alkali Guideline of the DAfStb.

12.1.14 Testing for extended workability time through use of long-term retarder for wet mix

Test of long-term retardation under ÖNORM EN 934-5 according to ÖNORM EN 12350-5

12.2 Mix, base concrete (without accelerator)

12.2.1 Testing of fresh concrete parameters of wet mix

The fresh concrete parameters (slump, void content, water-binder ratio and fresh-concrete temperature) are tested according to ÖNORM B 3303, sampling is performed according to prEN 14488-1.

12.2.2 Assessment of workability time of moist mix (FM)

The workability time of moist mix depends on the cement grade, the temperature and the natural moisture of the mineral aggregates. To assess the workability time, the temperature development of a cement-sand mixture is measured in analogy to ÖNORM B 3303, It. 9.3..

Evaluation

The time elapsed between the preparation of the cement-sand mix and the point in time by which the temperature has risen by +2 °C over the initial temperature provides the basis for the assessment of workability time. At any rate, the permissible workability time is limited to a maximum of 3 hours. Building-site influences (temperature, natural moisture of mineral aggregates, cement temperature) have to considered when assessing the actual workability time.

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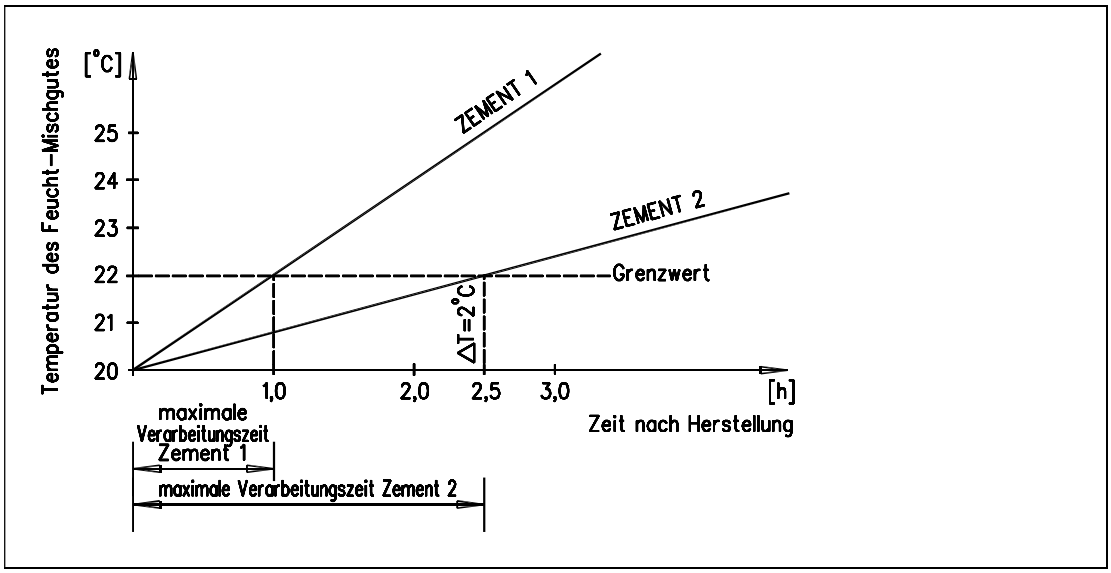


Fig. 12/2: Assessment of workability time of moist mix

12.2.3. Testing of extended workability time of wet mix

The extended workability time (VV) of wet mix is to be determined in terms of maintenance of consistency 15 minutes before the end of working according to ÖNORM B 3303 on the basis of spread table test.

12.2.4. Testing of base concrete (sprayed concrete without accelerator)

The base mix without accelerator is sprayed into test panels by means of the installed shotcreting equipment with the amount of water used for sprayed concrete production. Production of test panels, sampling and compressive strength testing according to It. 12.4.1 and 12.4.2.

The compressive strength determined after 28 days serves as:

- baseline value for the determination of the loss of strength due to the use of accelerators:

$$\text{Loss of strength (\%)} \quad : \quad \frac{EB(0) - EB(M)}{EB(0)} \times 100$$

EB (0) = compressive strength of concrete without accelerator

EB (M) = compressive strength of sprayed concrete with accelerator

- evidence of the correct mix design of the concrete without accelerator.

If the user and the manufacturer are not identical, testing of the base concrete is obligatory.

To simplify subsequent conformity testing of wet mix, the compressive strength of sprayed concrete without accelerator tested on drilled cores can be compared with the cube compressive strength of the wet mix. The cubes are to be produced according to ÖNORM B 3303, It. 5.

This test is recommended, in particular, if moist mix is supplied from a ready-mix plant. In addition, the overall amount of water needs to be determined, e.g. through kiln-drying.

The strength of accelerator-free concrete established in the conformity test must at least be equal to the required strength class plus the accelerator-related loss of strength.

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To assess the loss of strength due to the use accelerator, base concrete is also sprayed with the amount of water required for sprayed concrete production. If complete compacting is not possible, a suitable concrete plasticiser has to be used.

A comparison of sprayed concrete made with spray cement or plant-mixed dry mix with base concrete is not possible.

12.2.5 Testing for early shrinkage cracking

Fibre-reinforced concrete is tested according to the ÖVBB Guideline on fibre-reinforced concrete, It. 10.4.

12.2.6 Testing of dry mix (TM)

To assess the uniformity of the dry mix (e.g. ready-mixed products), the following parameters can be used:

- bulk density (ÖNORM EN 1097-3)
- grain size distribution up to 0.25 mm
- binder content in dry mix

The method used to determine these parameters needs to be specified (e.g. chemical determination through tracers).

The binder content can, at best, be determined to an accuracy of ± 10 kg/tonne of dry mix.

12.3 Testing of young sprayed concrete (early strength class)

Depending on the measuring range, procedures (see Fig. 12/3) according to It. 12.3.1 and 12.3.2 can be used for strength testing [12].

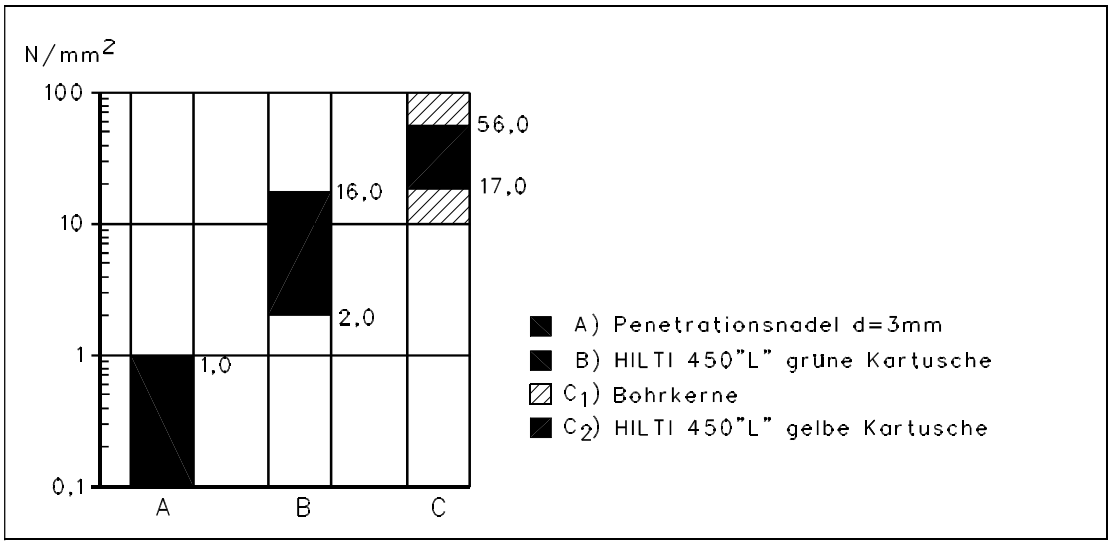


Fig. 12/3: Measuring procedures for the testing of fresh sprayed concrete

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12.3.1 Penetration needle method (measuring range 0 to 1.0 MPa)

This method is used to measure the force required for a needle of specified dimensions to penetrate into sprayed concrete to a depth of 1.5 cm. A Proctor penetrometer[1)] according to ASTM C 403-95 is used for this purpose. The device indicates the resisting force through compression of a calibrated spring [12].

Description of equipment and test procedure:

a) Needle with a diameter of 3 mm and a tip with a taper angle of 60° for compressive strength determination up to 1.0 N/mm².

The procedure has been calibrated for commonly used sprayed concrete grades according to this Guideline (see Fig. 12/4).

In case of deviations, special calibration curves have to be established as follows:

20 cm x 20 cm x 20 cm test specimens and 30 cm x 30 cm x 10 cm plates are produced for calibration. Simultaneous strength measurements have to be performed on the test specimens and the plates. The evaluation is made according to the rules of regression analysis.

b) *Instructions for testing and evaluation (Annex 3, Sheets 1 and 2):*

- Apply device and impress to a depth of 15 mm in one go.
- Read scale and record resisting force.
- Perform at least 10 individual tests for each test sequence - take care not to impress the needle on a large aggregate grain.
- Record testing time and location.

Use the average of the measurements performed according to b) to derive the cube compressive strength from the calibration curve (Fig. 12/4). Extrapolations are not permissible.

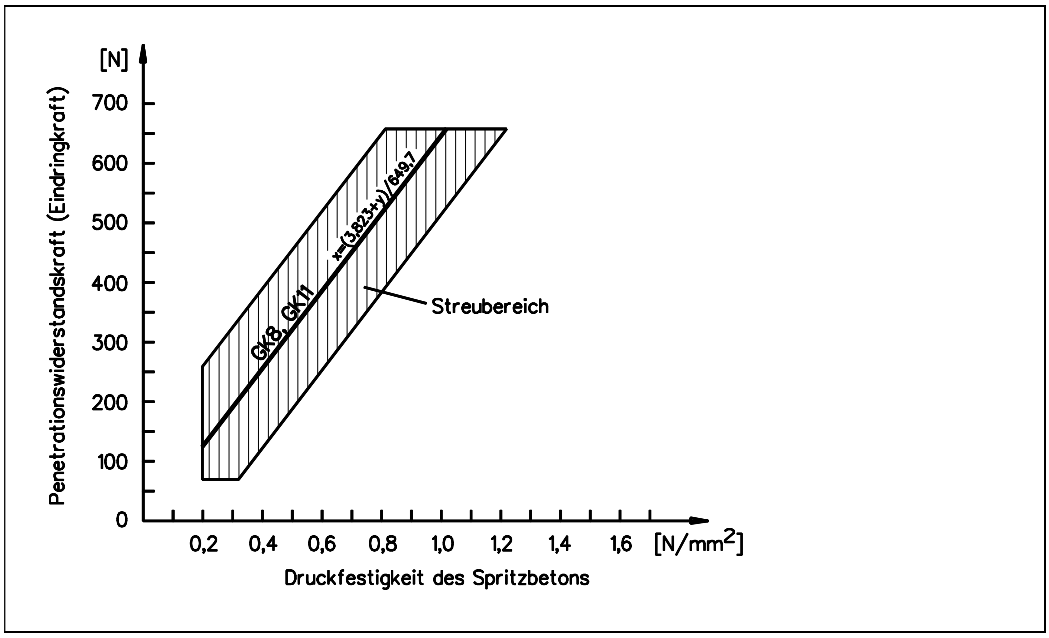


Fig. 12/4: Calibration curve for penetration needle device (needle diameter 3 mm)

[1)] List of suppliers available from ÖVBB

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12.3.2 Bolt-driving method

12.3.2.1 Measuring range 2 to 16 N/mm² [13]

Stud-bolts are driven into the concrete and the depth of penetration is determined. Then the bolt screws are removed and the pull-out force is measured. The ratio of pull-out force to penetration depth is the parameter used to determine the compressive strength. A HILTI DX 450 L piston tool equipment unit with green cartridges is used to shoot the stud-bolts into the concrete (see Annex 3, Sheets 1 and 2).

The pull-out force is determined by means of a pull-out device (e.g. HILTI or ETIRIP). The procedure has been calibrated for commonly used sprayed concrete grades (Fig. 12/5a and 12/5b). In case of deviations - particularly as regards Mohs' hardness of aggregates - calibration has to be performed according to It. 12.3.1.

Instructions for testing and evaluation

- Load bolt screw and set the unit to power-setting position 1, Annex 3, Sheet 1.
- Apply the unit and shoot the bolts into the concrete, 10 individual tests for each test sequence.
- Measure and record the length of stud-bolts that did not penetrate into concrete.
- Determine penetration depth.
- Fasten nut and pull out the stud-bolts in the same order as shot.
- Record pull-out force, time and place of testing, correct force by means of calibration curve.
- Determine the ratio of pull-out force (P) to penetration depth (L).
- Establish individual P/L values.
- Establish cube compressive strength on the basis of the mean derived from the calibration curve according to Fig. 12/5a or 12/5b. Extrapolations are not permissible.

The procedure can be used for measurements at any location without advance preparations. Hence, the method is well suited for quality control measurements. With measuring points distributed over larger surfaces, fluctuations in concrete strength can be detected.

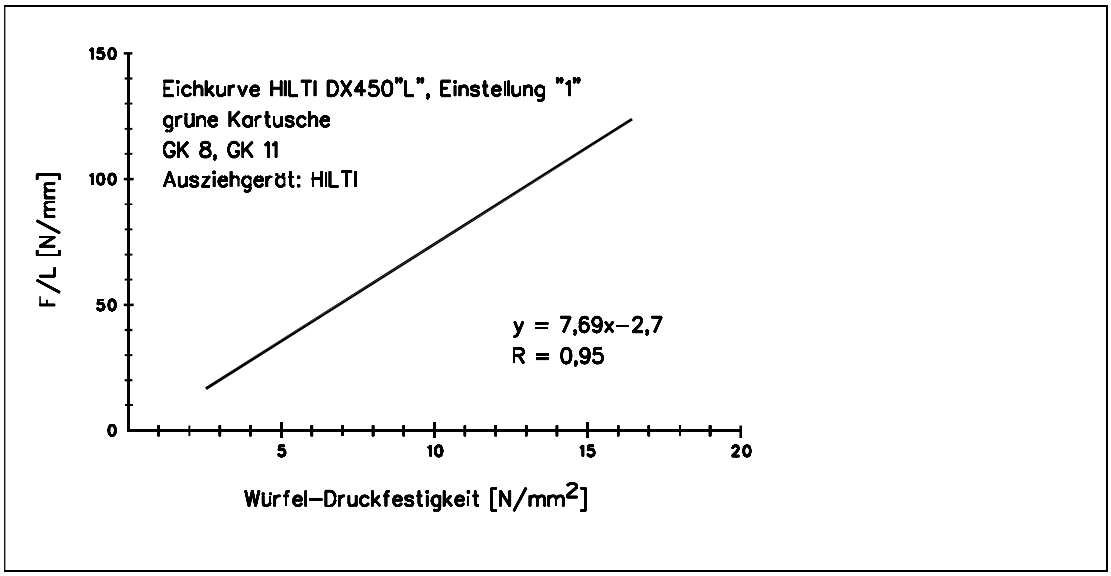


Fig. 12/5a: Calibration curve for bolt-driving method – measuring range 2 N/mm² to 16 N/mm², HILTI unit

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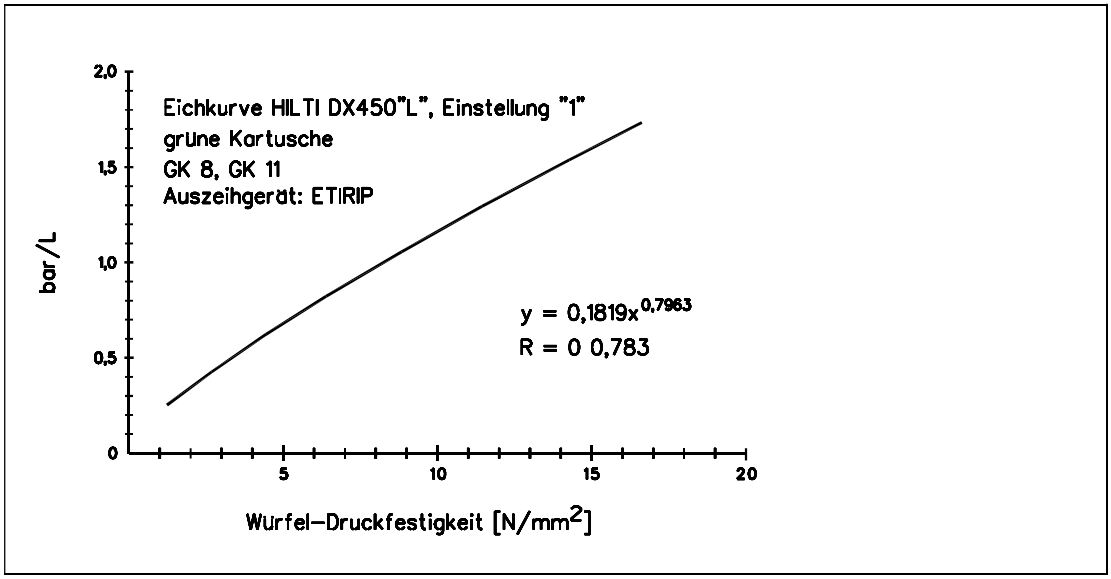


Fig. 12/5b: Calibration curve for bolt-driving method – measuring range 2 N/mm² - 16 N/mm², ETIRIP unit

12.3.2.2 Measuring range 17 to 56 N/mm² [14]

HILTI stud-bolts, type M6-8-52 D12 (60 mm) are shot into the concrete and the depth of penetration is determined. Then the stud-bolts are removed and the pull-out force is measured.

The ratio of pull-out force to penetration depth is the parameter used to determine the compressive strength. A HILTI DX 450 L piston tool equipment unit, set to position 2, with yellow cartridges is used to drive the bolt screws into the concrete (see Annex 3, Sheets 1 and 2). The pull-out force is determined by means of a pull-out tester (e.g. HILTI Tester 4). The procedure has been calibrated for commonly used sprayed concrete grades (Fig. 12/6); a multi-variant evaluation y = 44.297 + 0.057 x F/L – 1.546 x L improves the correlation to R = 8.24. In case of major deviations - particularly as regards Mohs' hardness of aggregates – a new reference line according to It. 12.3.1 has to be determined.

During preconstruction testing of the sprayed concrete, a reference test by means of the bolt-driving method is to be performed simultaneously with core testing (7, 28 or 56 days – at least two measurements). The ratio of mean compressive strength of core samples to the mean value of 10 F/L measurements is to be entered into the diagram with the reference line. The reference line is to be displaced in parallel until the relation between core compressive strength and the measured F/L values is established (calibration curve). In case of major deviations between the reference line and the averaging line, recalibration is necessary.

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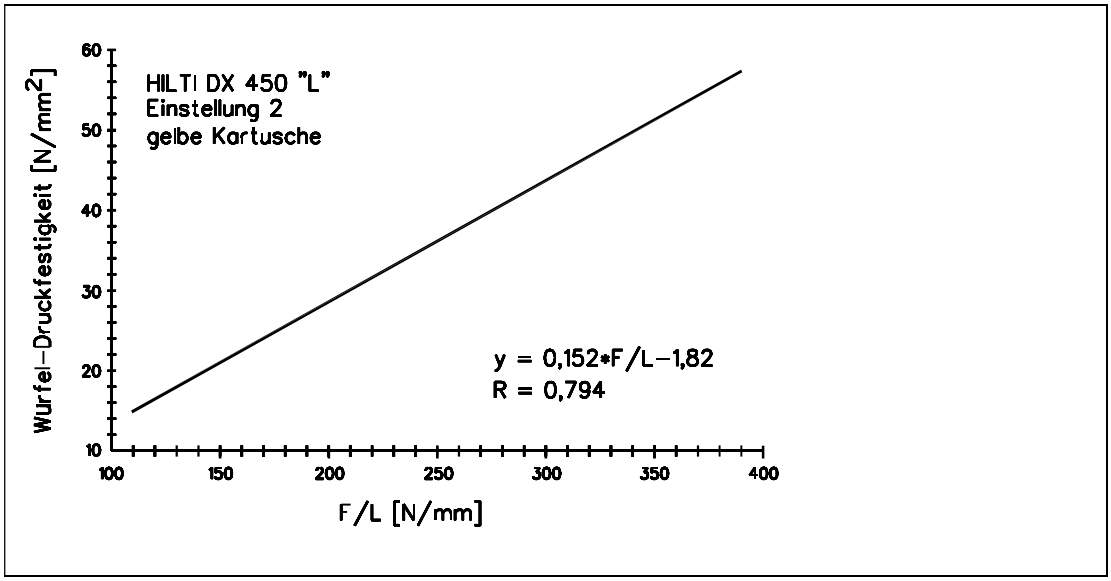


Fig. 12/6: Reference line for bolt-driving method, measuring range 17 N/mm² - 56 N/mm²

Instructions for testing and evaluation

- Load stud-bolts and set the unit to position 2, yellow cartridges.
- Apply the unit and place stud-bolts into the concrete, 10 individual tests for each test sequence.
- Measure and record the length of stud-bolts that did not penetrate into concrete and determine penetration depth.
- Fasten nut and pull out stud-bolts in the same order.
- Record pull-out force.
- Determine the ratio of pull-out force (F) to penetration depth (L).
- Establish averages and read core compressive strength from averaging line (instead of reference line).

12.4 Testing of sprayed concrete

12.4.1 Dimensions of test specimens and storage conditions

Cores of suitable dimensions (see Table 12/2) obtained either from placed sprayed concrete (sampling areas, structure) or from test panels are used as test specimens for sprayed concrete testing. Preference should be given to samples from placed sprayed concrete.

The tolerances must in accordance with ÖNORM B 3303, It. 5.2.

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

Table 12/2: Sample dimensions and storage conditions

	Core samples		Storage conditions see ÖNORM B 3303 It. 5.1.3
	Diameter	Height	
Compressive strength up to 20 days	100 mm	100 mm	Storage in water, air drying for 24 hours before testing
Compressive strength from 21 days onwards	100 mm	100 mm	Storage in water for 7 days, air drying until testing
Tensile splitting strength	100 mm	50 mm	Storage in water after drilling until testing
Water impermeability	150 mm	min. 120 mm	
Frost resistance	100 mm	250 mm	
Modulus of elasticity	100 mm	250 mm	
Adhesive tensile strength	50 mm	100 mm	
Leaching	50 mm	100 mm	Dry storage after drilling until testing
	Prisms		
Sulfate resistance	20 x 20 x 160 mm prisms		Storage in water after cutting until testing
Fibre-reinforced concrete class T or TG	150 x 150 x 500 mm prisms		
Fibre-reinforced concrete class E	600 x 600 x 100 mm plate		

Depending on the method of preparation and storage, the cores can be used for preconstruction, conformity, identity or hardening tests.

Samples taken from placed sprayed concrete with steel reinforcements may be unsuitable for testing (e.g. too high a percentage of reinforcing mesh, shading). Therefore, samples should be taken from different locations in the testing lot.

For sprayed concrete testing, sprayed concrete is produced in firmly secured panels in analogy to prEN 144888-1 (ca. 40 cm x 60 cm, 15 - 20 cm deep, open at the side facing downward). Cores can be taken from these boxes, though not from near the bottom edge (rebound), provided the strength of the concrete is sufficient for core drilling (at least 10 N/mm²). Prior to sampling, the boxes should remain undisturbed in a humid atmosphere at a temperature of between +5°C and +25°C.

Test cores for preconstruction and conformity testing have to be drilled not later than 5 days after shotcreting. Cores have to be drilled in time and as close to the intended time of testing as possible. As a rule, the direction of drilling is the same as the direction of spraying.

Testing for water impermeability (XC3/XC4) and frost resistance (XF3) is performed after 56 days.

12.4.2 Testing for compressive strength

Compressive strength testing is performed according to ÖNORM B 3303, It. 7.2. Contrary to the provisions of the standard, five samples have to be tested and aggregated. For sprayed concrete testing, individual values deviating from the mean by more than 20 % are not considered for averaging. At least three useful samples are required for averaging.

In the case of sprayed concrete made from ready-mix mortar with a maximum grain size of ≤ 4 mm, cores with a diameter of 50 mm can also be used.

12.4.3 Testing for tensile splitting strength

Testing for tensile splitting strength is performed on 5 cores according to ÖNORM B 3303, It. 7.2.

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12.4.4 Testing for water impermeability

Testing for water impermeability is performed according to ÖNORM B 3303, It. 7.8. Five core samples have to be taken. Samples with obvious spraying defects have to be excluded. At least three samples must be subjected to testing.

12.4.5 Testing for frost resistance

Three cores, stored under the conditions specified in ÖNORM B 3303, It. 7.10, are tested for frost resistance. Prior to frost storage and after 25 and 56 frost-thaw cycles, the modulus of elasticity is determined according to ÖNORM B 3303, It. 7.7, under the following conditions other than those specified in the standard: $\sigma_u = 0.5$ MPa, σ_o at 0.2 ± 0.03 ‰ compressive strain.

12.4.6 Testing for modulus of elasticity

Modulus of elasticity testing is performed on 3 cores according to ÖNORM B 3303, It. 7.7.

12.4.7 Testing for sulfate resistance

12.4.7.1 Determination of sulfate resistance based on the constituent materials

Sprayed concrete may be considered sulfate-resistant, if it is produced according to class III as XC4 (maximum depth of penetration 30 mm) and if the constituent materials meet the following conditions:

Spray cement	C_3A of SBM (ÖNORM EN 196-2) < 1 wt.% according to Bogue SO_3 (ÖNORM EN 196-2) ≤ 4.8 wt.% Al_2O_3 (ÖNORM EN 196-21) < 4 wt.%
Cement	C_3A of clinker (ÖNORM EN 196-2) 0 wt.% according to Bogue C_3A of cement (ÖNORM EN 196-2) < 1 wt.% according to Bogue
Accelerator	Sulfate content as SO_3 in analogy to ÖNORM EN 196-2 ≤ 4.8 wt.% in total together with the cement and/or SBM used Al_2O_3 (water-soluble) according to It. 12.1.9 in wt.% x accelerator dose in wt.% of binder ≤ 115

12.4.7.2 Sulfate resistance testing of prisms

Spray cement, binder-accelerator combinations and sprayed concrete are tested for sulfate resistance in analogy to ÖNORM B 3309 according to the Graf-Kaufmann method through measurements of changes in length and through visual inspection of sprayed concrete samples stored in saturated gypsum solution.

Resistance to sea water is assessed through storage in synthetic sea water.

- *Preparation of samples*

  Samples can be taken from sprayed concrete test panels produced for this purpose or from structures. Prism-shaped test specimens, 20 mm x 20 mm x 160 mm, are to be cut from the samples obtained. A total of five samples are required.

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- *Preparations for measurement*

  At sprayed concrete age 25 days:

  - Drill dia. 6 mm holes, centrally located in front faces of the prism.
  - Insert measuring cones and fasten them by means of suitable bonding agent.
  - Optionally, bonding of measuring cones to the surface is possible.
  - Store samples with measuring cones until age 28 days in water at 20 ± 2 °C.

- *Measurement*

  Principle: Measurement of change in length of prisms due to sulfate or sea-water attack according to Graf-Kaufmann.

  Depending on requirements, the change in length is determined after storage in:

  - saturated gypsum solution (Ca SO_4 x 2 H_2O) with sediment
  - synthetic sea water

  The zero-reading measurement of the prisms is performed after appropriate preparation of samples and storage in water for at least 24 hours.

  During sulfate attack, measurements are made after 4, 8, 12, 16, 20, 28, 40 and 52 weeks of storage. A preliminary assessment can be made after 12 weeks of storage. An interim result can be obtained after 28 weeks of storage.

  Changes in length are measured; moreover, the prisms are inspected for cracks, spalling, warping, segregation of aggregate, etc.

- *Storage in testing media*

  Storage at 20 ± 2°C

  Volumetric ratio of storage medium to test specimen ≥ 4/1.

  Three or five prisms are stored in each medium.

  Change of medium: once a month.

- *Preparation of testing media*

  a) Saturated gypsum solution:

  - Dissolve 2 g/l powdered $CaSO_4$. 2 H_2O through stirring in tap water at +30°C to +40 °C.
  - Allow to cool to +20° C.
  - Add 20g/l CaSO4 . 2 H_2O as sediment.
  - Place prisms in the medium after sedimentation.

  b) Synthetic sea water:

  Composition: solution in 1000 g water

NACl	30.0 g
$MgCl_2 . 6H_2O$	6.0 g
$MgSO_4 . H_2O$	5.0 g
$CaSO_4 . 2H_2O$	1.5 g
$KHCO_3$	0.2 g

- *Evaluation*

  Sulfate resistance is evaluated through visual inspection of the changes in surface quality of the specimen. Cracks, spalling, warping, segregation of aggregates, etc. must not be present. Currently, the change in length is determined for information only, but does not serve as a criterion for evaluation.

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12.4.8 Determination of equivalent flexural strength and toughness

The special properties of fibre-reinforced sprayed concrete - high impact resistance, increased energy absorption capacity - are characterised through their performance in the bending test, in particular after the maximum flexural strength has been exceeded.

The test is performed in accordance with the ÖVBB Guideline on fibre-reinforced concrete, It. 10.5.

12.4.9 Panel test

- *Purpose*

  The "plate-bending" test serves to determine the energy absorption capacity, i.e. a function of ductility and concrete quality, of steel-fibre reinforced sprayed concrete. As a comparative test, it does not permit an accurate determination of material parameters, but adequately considers the three-dimensional effect of fibre-reinforcement.

- *Instructions for testing*

  - Preparation of test specimens and dimensions

    Prepare a sprayed concrete sample in a test panel, 60 cm x 70 cm x 10 cm, with side walls open at the bottom allowing the rebound to fall down.

    Number of test specimens required for each test: 3

  - Storage

    Store the test specimens according to It. 12.4.1 of this Guideline in the same manner as specimens for determination of the modulus of elasticity.

  - Preparation of test specimens for testing

    The test specimens are cut plane-parallel to the rough sprayed concrete face to a size of 60 cm x 60 cm x 10 cm and subsequently polished.

  - Performance of the test

    The test specimens are fully supported on a metal frame (UPB 140) and loaded at the centre on an area of 10 cm x 10 cm (see Fig. 12/7). The load is applied to the face which was originally rough from shotcreting.

  As a rule, the test is performed on test specimens aged 28 days.

  The load is applied by a deformation-controlled testing press at a deformation rate of 1.5 mm/min to a deflection of 25 mm.

  The force required for deformation is recorded continuously as a function of deflection with a measuring accuracy of ± 0.01 mm and/or ± 0.01 KN. The data are represented as a load-deformation curve. On the basis of this diagram, the energy-deformation curve is calculated and represented as the area between the X axis and the load-deformation curve (see Fig. 12/8).

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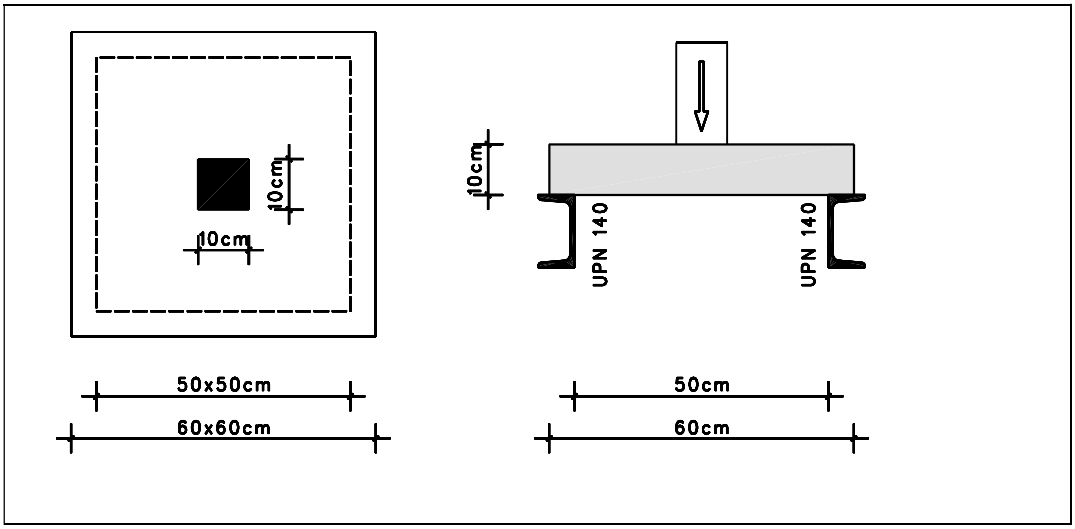


Fig. 12/7: Test specimens and test set-up for panel test

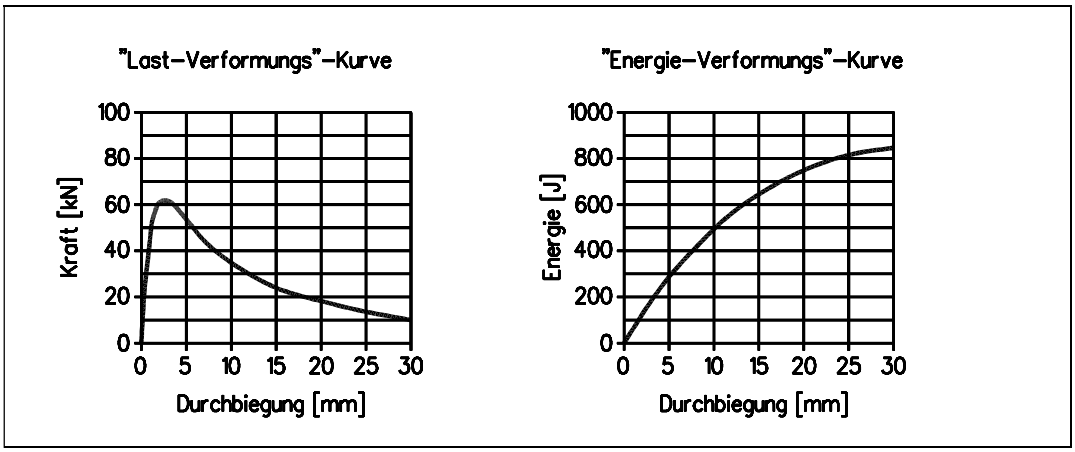


Fig. 12/8: Diagram of load-deformation and energy-deformation curves

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12.4.10 Testing for increased fire resistance

Testing is performed according to the ÖVBB Guideline on sprayed concrete for inner linings, Annex 5. Sprayed concrete is placed on the substrate panel, aged 1 month, in the area to be exposed to fire. Further storage of one plate in wet condition and the second plate in dry condition for another month. In the contact layer 3 additional sensors are to be distributed over the surface exposed to fire.

12.4.11 Testing for tensile adhesive strength

Testing for tensile adhesive strength is performed according to ÖNORM EN 1542 for layers of newly placed sprayed concrete of up to 50 mm in thickness, and according to prEN 14488-4 for layers more of than 50 mm in thickness. The quality of the substrate prior to placing of sprayed concrete can be assessed on the basis of its adhesive strength according to ÖNORM B 3303, It. 7.5.

12.4.12 Leaching of sprayed concrete

Elution of sprayed concrete is to be performed on cores aged 28 days, 50 mm in diameter and 100 mm high [1, 2, 3]. The cores have to be obtained from sprayed concrete aged 7 to 14 days through wet drilling. The cores thus obtained are to be stored dry and at room temperature until testing.

The test specimen is to be placed in a leaching vessel and eluted in a leaching agent, which is continuously agitated by a magnetic stirrer (rate of agitation = 200 to 300 rev/min), for 24 hours. The eluant used is de-ionised water, the mass ratio of test specimen to eluant being 1 : 10, with the test specimen completely wetted. The leachate is to be examined for the following parameters: pH value, electric conductivity, calcium, potassium, sodium and aluminium.

12.5 Checks to be performed during sprayed concrete production

12.5.1 Verification of dosages of powder and liquid accelerator and spray cement

The dosage of the accelerator and/or the spray cement has a decisive influence on the early and final strength of the sprayed concrete. Compliance with the dosages determined through preconstruction testing has to be verified continuously during shotcreting. Regular maintenance of the metering equipment has to be performed and recorded in a protocol. In addition, the spraying output has to be determined according to It. 12.5.2.

- *Inspection of the metering equipment for powder accelerators*

  Basically, the correct dosages are verified through weighing. Attention has to be paid to continuous, steady conveyance and, possibly, wear and tear of the metering equipment. Bridge formation in the storage bin and strong fluctuations of filling levels are to be avoided. The calibration intervals according to Table 11/5 have to be observed.

- *Inspection of metering equipment for liquid accelerators*

  Dosage accuracy is checked through weighing of the accelerator bin before and after shotcreting. If a flow meter is connected, accelerator consumption can be recorded continuously over time. The values set at the metering pump have to be checked each time before shotcreting is begun. The calibration intervals according to Table 11/5 have to be observed.

- *Inspection of metering equipment for spray cement SBM-FT (continuous mixing)*

  Calibration of dosages is performed through back-weighing over defined time intervals. Speed and/or weighing protocols are kept to supplement the calibration test. The calibration intervals according to Table 11/5 have to be observed.

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- *Inspection of metering equipment for mineral aggregates (continuous mixing)*

  A high degree of measuring accuracy is also required for moist mineral aggregates. Metering can be gravity-based or volume-based. In the case of volume-based metering, possible changes in bulk volume due to different degrees of aggregate moisture should be taken into consideration. Hence, calibration is absolutely necessary. Any change of conditions requires renewed determination of the moisture content. Back-weighing at regular intervals is to be performed according to Table 11/5.

12.5.2 Determination of spraying output and rebound

Before the test is carried out, the spraying output needs to be accurately established, as it affects the accuracy of rebound determination. The quantity of rebound is to be determined separately.

- *Determination of spraying output*

  The total amount of sprayed concrete discharged from the nozzle during a certain period of time (spraying time) is determined through weighing.

  $$\text{Spraying output (kg/h)} = \frac{\text{mass}_{\text{shotcrete}}\ [\text{kg}]}{\text{spraying time}\ [\text{h}]}$$

  It is also possible to spray a weighed amount of mix and to record the time taken for spraying. The amount of water consumed at the nozzle has to be added to the mass of the mix.

- *Determination of rebound*

  A time-consuming, but accurate method consists in collecting the rebound on a tarp spread out before shotcreting, storing it in a suitable container and weighing it. If the spraying time and the rebound mass (converted into kg/h) are known, the percentage of rebound relative to the initial mass can be calculated as follows:

  $$\text{Rebound [\%]} = \frac{\text{Mass}_{\text{rebound}}\ [\text{kg/h}]}{\text{sprayingoutput}\ [\text{kg/h}]}$$

  For rebound measurements to be performed on a laboratory scale, sprayed concrete is applied to wooden formwork prepared with a layer of sealing sprayed concrete (size of formwork depending on weighing unit); the rebound is collected on a tarp and weighed. The concrete mass is calculated by deducting the formwork mass from the (sprayed concrete + formwork) mass. The rebound is obtained as

  $$\text{Rebound [\%]} = \frac{\text{Mass}_{\text{rebound}}[\text{kg}]}{\text{Mass}_{\text{shotcrete}}[\text{kg}] + \text{mass}_{\text{rebound}}\ [\text{kg}]} \times 100$$

- *Process parameters*

  The following factors have to be considered for rebound determination:

  - spraying output
  - process technology
  - conveying pressure
  - spraying angle and distance from substrate
  - sprayed concrete thickness
  - fresh concrete temperature
  - spraying time
  - fluctuations of water flow and pressure at the nozzle
  - water-binder ratio
  - spraying nozzle cross section
  - location of substrate (benches, roof, entire round)
  - building-site or laboratory measurement

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12.5.3 Measurement of fine dust concentration

Gravity-based dust measuring devices as well as light-scattering instruments are best suited to determine the concentration of fine dust. For practical purposes, a simple and safe method (preferably with direct display of results without time lag) is recommended. Light-scattering instruments[1)] meet these requirements. Conversion of the values displayed into fine-dust concentrations obtained by gravity-based methods (e.g. PM 4F, VC 25, PAS, etc.) is possible by approximation through $c/l_{reading\ TM} = 1.1$ for sprayed concrete and 1.5 for other activities (especially in the case of a diesel-fuelled vehicle fleet). (Accurate measurements by the Austrian Dust Control Body [4, 5], see Annex 5, sheet 1 and 2).

12.5.4 Sprayed concrete thickness

The sprayed concrete thickness is defined by the average thickness to be obtained (mean value of five measurements) and a minimum thickness for each structural component.

The average thickness derived from five drillings has to be reached. Sprayed concrete thickness must not be below the minimum thickness at any place.

The sprayed concrete thickness has to be determined five times each over 500 m² (at defined randomly distributed points) either during shotcreting on defined structural components or through drilling.

12.6 Fibre content of steel-fibre sprayed concrete

The fibre content in sprayed concrete can be determined immediately after placing or through core sampling according to the ÖVBB Guideline on fibre-reinforced concrete, It. 10.3.

- *Sampling immediately after placing:*
  - Quick drying of sample (minimum sample quantity 10 kg) by means of spirit method
  - Crushing of coherent sprayed concrete particles
  - Removal of fibres by means of hand magnet
  - Weighing
- *Core drilling*
- Drilling of 5 cores, dia. 100 mm, height ca. 100 mm
- Weighing of cores
  - "Crushing" of sample by means of test machine
  - Further manual and mechanical comminution
  - Removal of fibres by means of hand magnet
  - Weighing (errors due to "cut-off" fibre particles)

The fibre content (st) in wt. % is as follows:

$$\text{St (wt. \%)} = \frac{\text{Mass}_{\text{steel fibre}}\,[\text{g}]}{(\text{Mass}_{\text{shotcrete}} - \text{Mass}_{\text{steel fibre}})\,[\text{g}]}$$

The fibre content is to be indicated to an accuracy of 0.1 wt.%. As a rule, the fibre content of the placed sprayed concrete equals roughly 70 % of the fibre content of the initial mix.

1) List of suppliers available from ÖVBB

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12.7 Documentation of mix production

As a rule, concreting statistics and batch protocols have to be printed out daily for each sprayed concrete grade. Access to other batch protocols, by numbers of delivery notes, must be possible for up to 3 years after production. (Usually, batch protocols are not available online.)

13. QUALITY MANAGEMENT

Quality Management scheme for sprayed concrete production

Over and above the general, site-specific quality-management schedule, the following measures, as listed in Table 13/1 and Table 13/2, are recommended for sprayed concrete production in the course of production control.

Table 13/1: Quality management for sprayed concrete production

QM measures before shotcreting	
Activity	Relevant documentation
Establish requirements to be met by sprayed concrete	Conformity according to contract
Determine spraying method and type of mix	see Table 5/1
Constituent material and preconstruction testing	see Tables 11/1/1 and 11/1/2
Decide on responsibility for execution	Organisation chart – mailing list for documents and records Agreement on division of responsibilities between producer and user
Maintenance	Establish maintenance schedule
Test schedule	see Tables 11/2/1 to 11/2/5
Select test equipment and decide on test methods	Test instructions Test records

Table 13/2: Quality management for sprayed concrete production

QM measures during shotcreting	
Activity	Relevant documentation
Machine and nozzle operation	Suitable staff
Ensure occupational health and safety	Process instructions by health and safety officer
Execution and acceptance testing	Comparison of actual conditions with contract specifications
Non-compliance with parameters specified	Catalogue of measures according to contract

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14. RECOMMENDATIONS FOR TENDERING

The relevant Austrian Standards, in particular ÖNORM B 2203 and/or ÖNORM B 2203-2 and prior art, apply.

14.1 General requirements

The following requirements have to be included, among others, in the invitation to tender and taken into consideration under the corresponding items of the specifications.

- Filling of unavoidable (process-related) overbreak with sprayed concrete and operational impairment due to shotcreting of system-related steel inserts (reinforcing mesh, steel arches, lagging plates, anchor heads, etc.).
- Sprayed concrete to fill up overbreak due to specifications or geological conditions.
- Repair of defects in sprayed concrete with structural functions (SpC III), except for system-related local deficiencies and inhomogeneities in SpC II.

As a matter of principle, it is up to the contractor (user of sprayed concrete) to decide whether to use the dry-mix or wet-mix shotcreting method.

14.2 Contractual provisions

Among others, the following items have to be included in the contract:

- Early strength classes
- Requirements to be met by the sprayed concrete (sprayed concrete grade, with specification of exposure classes)
- Agreement on testing frequency classes and/or exceptions
- Assumption of costs of preconstruction, conformity, identity and structural testing
- Sprayed concrete thickness has to be specified through indication of average thickness and minimum thickness, see It. 12.5.4.
- Minimum thickness has to be specified with due consideration of the surface structure to be expected (e.g. projecting edges of solid rock)
- Provisions regarding possible quality defects and inadequate thickness
- Specification of requirements regarding the smoothness of the sprayed concrete surface
- Definition of surfaces and cubatures to be used as a basis for payment
- Indications regarding the location of shotcreting and possible operating conditions (e.g. working face, roof, floor, slope support, water ingress)
- Specification of unit of measurement (m^2 or m^3)
- Special testing procedures
- Tests according to Tables 11/2/1 to 11/2/5 "according to requirements"
- Specification of test methods for the determination of strength classes within the framework of quality testing (e.g. admissibility of test procedure according to It. 7.4)

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15. STANDARDS, GUIDELINES, BIBLIOGRAPHY

15.1 Standards referred to in the text

ÖNORM B 2203-1	Untertagebauarbeiten – Werkvertragsnorm – Teil 1: Zyklischer Vortrieb; Ausgabe 12/01.
ÖNORM B 2203-2	Untertagebauarbeiten – Werkvertragsnorm – Teil 2: Kontinuierlicher Vortrieb; (in Vorbereitung).
ÖNORM B 3131	Gesteinskörnungen für Beton – Regeln zur Umsetzung von EN 12620; Ausgabe 06/03.
ÖNORM B 3303	Betonprüfung; Ausgabe 09/02.
ÖNORM B 3309	Aufbereitete hydraulisch wirksamer Zusatzstoffe für die Betonherstellung; Ausgabe 09/99.
ÖNORM B 3310	Zement für Bauzwecke; Ausgabe 09/95.
ÖNORM B 3327-1	Zemente gemäß ÖNORM EN 197-1 für besondere Verwendungen - Teil 1: Zusätzliche Anforderungen; Ausgabe 01/02.
ÖNORM B 4700	Stahlbetontragwerke – EUROCODE-nahe Berechnung, Bemessung und konstruktive Durchbildung; Ausgabe 06/01.
ÖNORM B 4710-1	Beton; Teil 1: Festlegung, Herstellung, Verwendung und Konformitätsnachweis (Regeln zur Umsetzung der ÖNORM EN 206-1); Ausgabe 04/04.
ÖNORM EN 149	Atemschutzgeräte – Filtrierende Halbmasken zum Schutz gegen Partikeln – Anforderungen, Prüfung, Kennzeichnung; Ausgabe 12/91.
ÖNORM EN 196-1	Prüfverfahren für Zement – Bestimmung der Festigkeit; Ausgabe 07/95.
ÖNORM EN 196-2	Prüfverfahren für Zement – Chemische Analyse von Zement; Ausgabe 07/95.
ÖNORM EN 196-3	Prüfverfahren für Zement – Bestimmung der Erstarrungszeiten und der Raumbeständigkeit; Ausgabe 07/95.
ÖNORM EN 196-7	Prüfverfahren für Zement – Verfahren für die Probenahme und Probeauswahl von Zement; Ausgabe 05/92.
ÖNORM EN 196-21	Prüfverfahren für Zement – Bestimmung des Chlorid-, Kohlenstoff-, Dioxid- und Alkalianteils von Zement; Ausgabe 05/92.
ÖNORM EN 197-1	Zement – Teil 1: Zusammensetzung, Anforderungen und Konformitätskriterien von Normalzement; Ausgabe 12/00.
ÖNORM EN 450	Flugasche für Beton – Definitionen, Anforderungen und Güteüberwachung; Ausgabe 09/95.
ÖNORM EN 459-2	Baukalk – Teil 2: Prüfverfahren; Ausgabe 02/03.
ÖNORM EN 480-1	Zusatzmittel für Beton, Mörtel und Einpressmörtel – Prüfverfahren – Teil 1: Referenzbeton und Referenzmörtel für Prüfungen; Ausgabe 01/98.
ÖNORM EN 480-2	Zusatzmittel für Beton, Mörtel und Einpressmörtel – Prüfverfahren – Teil 2: Bestimmung der Erstarrungszeit; Ausgabe 12/96.
ÖNORM EN 480-6	Zusatzmittel für Beton, Mörtel und Einpressmörtel – Prüfverfahren –Teil 6: Infrarot-Untersuchung; Ausgabe 12/96.
ÖNORM EN 480-8	Zusatzmittel für Beton, Mörtel und Einpressmörtel – Prüfverfahren - Teil 8: Bestimmung des Feststoffgehaltes; Ausgabe 12/96.

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ÖNORM EN 480-10	Zusatzmittel für Beton, Mörtel und Einpressmörtel –Prüfverfahren - Teil 10: Bestimmung des wasserlöslichen Chloridgehaltes; Ausgabe 12/96.
ÖNORM EN 480-12	Zusatzmittel für Beton, Mörtel und Einpressmörtel – Prüfverfahren – Teil 12: Bestimmung des Alkaligehaltes von Zusatzstoffen; Ausgabe 01/98.
ÖNORM EN 932-1	Prüfverfahren für allgemeine Eigenschaften von Gesteinskörnungen – Teil 1: Probenahmeverfahren; Ausgabe 01/97.
ÖNORM EN 933-1	Prüfverfahren für geometrische Eigenschaften von Gesteinskörnungen – Teil1: Bestimmung der Korngrößenverteilung – Siebverfahren; Ausgabe 12/97.
ÖNORM EN 934-2	Zusatzmittel für Beton, Mörtel und Einpressmörtel – Teil 2:Betozusatzmittel – Definitionen und Anforderungen; Ausgabe 02/02.
ÖNORM EN 934-5	Zusatzmittel für Beton, Mörtel und Einpressmörtel – Teil5: Zusatzmittel für Spritzbeton – Definitionen, Anforderungen und Konformitätskriterien; Entwurf 09/03.
ÖNORM EN 1008	Zugabewasser für Beton – Anforderungen und Prüfung; Ausgabe 05/93.
ÖNORM EN 1097-3	Prüfverfahren für mechanische und physikalische Eigenschaften von Gesteinskörnungen – Teil 3: Bestimmung von Schüttdichte und Hohlraumgehalt; Ausgabe 08/98.
ÖNORM EN 1542	Produkte und Systeme für den Schutz und die Instandsetzung von Betontragwerken – Messung der Haftfestigkeit im Abreißversuch; Ausgabe 09/99.
ÖNORM EN 12350-5	Prüfung von Frischbeton – Teil 5: Ausbreitmaß; Ausgabe 04/00.
ÖNORM EN 12390-3	Prüfung von Festbeton – Teil 3: Druckfestigkeit von Probekörpern; Ausgabe 05/02.
ÖNORM EN 12504-1	Prüfung von Beton in Bauwerken –Teil 1: Bohrkernproben – Herstellung, Untersuchung und Prüfung der Druckfestigkeit; Ausgabe 09/90.
ÖNORM EN 12620	Gesteinskörnungen für Beton; Ausgabe 03/03.
ÖNORM EN 13263	Silikatstaub für Beton – Definitionen, Anforderungen und Konformitätsnachweis; Ausgabe 08/98.
prEN 14487-1	Spitzbeton – Teil 1: Definitionen, Anforderungen und Konformität; Ausgabe 09/02.
prEN 14488-1	Prüfung von Spritzbeton: Probenahmen Ausgabe 06/02.
ASTM C 227-81	Prüfung der potentiellen Alkaliempfindlichkeit von Zementzuschlagsgemischen an Mörtelprobekörpern; Ausgabe 1990.
ASTM C 289-97	Standard Test Method for Pontential Reactivity of Aggregates (Chemical Method); Ausgabe 1997.
ASTM C 403-95	Ermittlung der Erstarrungsgeschwindigkeit von Betonmischen durch Prüfung des Eindringwiderstandes; Ausgabe 1995.
DIN 51302-1	Werkstoffprüfmaschinen - Teil 1: Prüfung von Zug-, Druck- und Biegeprüfmaschinen – Grundsätzliche Prüfbedingungen; Ausgabe 03/85.
ISO 758	Liquid chemical products for industrial use. Determination of densitiy at 20 °C.
ISO 1158	Plastics – Vinyl chloride homopolymers and copolymers – Determination of chloride.
ISO 4316	Surface active agents – Determination of pH of aqueous solutions – Potentiometric method.

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15.2 Guidelines and regulations

Austrian Association for Concrete and Structural Engineering

ÖVBB – Richtlinie	Herstellung und Verarbeitung von Fließbeton; Ausgabe 1977.
ÖVBB – Richtlinie	Herstellung und Prüfung von Beton mit LPV-Zusatzmittel; Ausgabe 1988.
ÖVBB – Richtlinie	Frost-Tausalz-beständiger Beton; Ausgabe 1989.
ÖVBB – Richtlinie	Innenschalenbeton; Ausgabe 10/03.
ÖVBB – Richtlinie	Faserbeton; Ausgabe 03/02
ÖVBB – Richtlinie	Erhaltung und Instandsetzung von Bauten aus Beton und Stahlbeton; Ausgabe 12/03.

Austrian Standards Institute

ÖN – NP 10	ON Handbuch: Zusammenstellung der Prüfverfahren (PVB) gemäß ÖNORM B 3303; Ausgabe 10/02.

Austrian Road and Transport Research Society

RVS 7 TU	Leistungsbeschreibung Tunnelbau.
RVS 8 TU	Technische Vertragsbedingungen für Tunnelbau.
RVS 8.01.71	Betonzusätze - Luftporenbildende Betonzusatzmittel; Ausgabe 05/89.
RVS 9.32	Statisch konstruktive Richtlinien - Geschlossene Bauweise im Lockergestein unter Bebauung; Ausgabe 05/04.
RVS 9.35	Merkblatt - Betondeckung der Stahleinlagen; Ausgabe 06/02.
RVS 11.064	Prüfverfahren – Beton Teil I bis III; Ausgabe 09/84 bis 12/85.
RVS 12.241	Bauprodukte und Bauleistungen; Beton; Qualitätssicherung gemäß ÖNORM B 4710-1; Ausgabe 12/01.

German Reinforced Concrete Comittee

DAfStb-Richtlinie	Vorbeugende Maßnahmen gegen schädliche Alkalireaktion im Beton (Alkali-Richtlinie); Ausgabe 05/01.
DAfStb-Richtlinie	Richtlinie für hochfesten Beton; Ausgabe 95.

German Association of Concrete and Structural Engineering

DBV-Merkblatt	Bemessungsgrundlage für Stahlfaserbeton im Tunnelbau; Ausgabe 96.
DBV-Merkblatt	Technologie des Stahlfaserbetons und Stahlfaserspritzbetons; Ausgabe 96.
DBV-Merkblatt	Stahlfaserbeton; Ausgabe 10/02.
DBV-Merkblatt	Kunststoffmodifizierter Spritzbeton/Spritzmörtel; Ausgabe 96.
DBV-Merkblatt	Technische Lieferbedingungen für Kunststoffe für Spritzbeton/Spritzmörtel; Ausgabe 96.

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Other publications

EFNARC — European Specification for Sprayed Concrete. Europäischer Verband der Hersteller und Anwender von Spezialprodukten im Bauwesen. Hampshire 1996.

JSCE-SF4 — Method of Test for Flexural Strength and Flexural Toughness of Steel Fibre Reinfored Concrete. Concrete Library of JSCE, Japan Society of Civil Engineers, 3, 58-61. 1984.

15.3 Additional standards, guidelines and reports to be taken into consideration

ÖNORM B 3324-1 Baukalk – Einteilung, Anforderungen und Gütesicherung; Ausgabe 04/95.

ÖNORM B 3327-2 Zemente gemäß ÖNORM EN 197-1 für besondere Verwendungen – Erhöht sulfatbeständige Zemente; Ausgabe 04/01.

ÖNORM B 5017 Hochleistungsbeton im Siedlungswasserbau (HL-SW-Beton) Herstellung, Verwendung und Gütenachweis; Ausgabe 10/00.

ÖNORM EN 196-61 Prüfverfahren für Zement – Bestimmung der Mahlfeinheit; Ausgabe 05/92.

ÖNORM EN 197-2 Zement – Teil2: Konformitätsbewertung, Ausgabe 12/00.

ÖNORM EN 206-1 Beton – Teil 1: Festlegung, Eigenschaften, Herstellung und Konformität; Ausgabe 05/01.

ÖNORM EN 933-2 Prüfverfahren für geometrische Eigenschaften von Gesteinskörnungen – Teil 2: Bestimmung der Korngrößenverteilung – Analysen - Siebe; Ausgabe 03/96.

ÖNORM EN 933-4 Prüfverfahren für geometrische Eigenschaften von Gesteinskörnungen – Teil 4: Bestimmung der Kornform – Kornformkennzahl; Ausgabe 04/00.

ÖNORM EN 934-3 Zusatzmittel für Beton, Mörtel und Einpressmörtel – Teil 3: Zusatmittel für Mauermittel – Definitionen, Anforderungen und Konformität; Ausgabe 10/98.

ÖNORM EN 934-4 Zusatzmittel für Beton, Mörtel und Einpressmörtel – Teil 4: Zusatmittel für Einpressmörtel für Spannglieder – Definitionen, Anforderungen und Konformität; Ausgabe 07/00.

ÖNORM EN 934-6 Zusatzmittel für Beton, Mörtel und Einpressmörtel – Teil 6: Probenahme, Konformitätskontrolle, Bewertung der Konformität, Kennzeichnung und Beschriftung; Ausgabe 07/00.

ÖNORM EN 1367-1 Prüfverfahren für thermische Eigenschaften und Verwitterungsbeständigkeit von Gesteinskörnungen – Teil 1: Bestimmung des Widerstandes gegen Frost-Tau-Wechsel; Ausgabe 05/00.

ÖNORM EN 12350-1 Frischbeton – Teil 1: Probenahme; Ausgabe 04/00.

ÖNORM EN 12350-6 Prüfung von Frischbeton – Teil 6: Frischbeton-Rohdichte; Ausgabe 04/00.

ÖNORM EN 12350-7 Prüfung von Frischbeton – Teil 7: Luftgehalte – Druckverfahren; Ausgabe 10/00.

ÖNORM EN 12390-1 Prüfung von Festbeton – Teil 1: Form, Maße und andere Anforderungen für Probekörper und Formen; Ausgabe 05/01.

ÖNORM EN 12390-2 Prüfung von Festbeton – Teil 2: Herstellung und Lagerung von Probekörpern für Festigkeitsprüfungen; Ausgabe 05/01.

ÖNORM EN 12390-7 Prüfung von Festbeton – Teil 7: Dichte von Festbeton; Ausgabe 05/01.

ÖNORM EN 12636 Produkte für den Schutz und die Instandsetzung von Betontragwerken – Prüfverfahren – Bestimmung der Verbundwirkung - Beton-Beton; Ausgabe 09/99.

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ÖNORM EN 12620	Gesteinskörnungen für Beton; Ausgabe 03/03
ÖNORM EN 13501-1	Klassifizierung von Bauprodukten und Bauarten zu ihrem Brandverhalten – Teil 1: Klassifizierung mit den Ergebnissen aus den Prüfungen zum Brandverhalten von Bauprodukten; Ausgabe 06/02.
ÖNORM EN 13501-2	Klassifizierung von Bauprodukten und Bauarten zu ihrem Brandverhalten – Teil 2: Klassifizierung mit den Ergebnissen aus den Feuerwiderstandsprüfungen, mit Ausnahme von Lüftungsanlagen; Ausgabe 01/04.
prEN 14487-2	Spritzbeton (Ausführung) Arbeitspapier N 85; Ausgabe 02/00.
prEN 14651	Precast concrete products-Test method for metallic fibre concrete – Measuring the flexural tensile strength; Ausgabe 03/03.
prEN 14721	Precast concrete products-Test method for metallic fibre concrete – Measuring the fibre content in fresh and hardened concrete; Ausgabe 03/03.
prEN 12488-2	Prüfung von Spritzbeton: Druckfestigkeit.
prEN 12488-3	Prüfung von Spritzbeton: Biegefestigkeit.
prEN 14488-4	Prüfung von Spritzbeton: Verbundfestigkeit.
prEN 12488-5	Prüfung von Spritzbeton: Determination of energy absorptioncapacity of fibre reinforced slab; Ausgabe 11/02.
prEN 12488-7	Prüfung von Spritzbeton: Fasergehalt.
ÖNORM/ÖVE–EN 45001	Allgemeine Kriterien zum Betreiben von Prüflaboratorien; Ausgabe 06/90.
ÖNORM/ÖVE-EN 45002	Allgemeine Kriterien zum Begutachten von Prüflaboratorien; Ausgabe 06/90.
ÖNORM/ÖVE EN 45003	Akkreditierungssysteme für Kalibrier- und Prüflaboratorien - Allgemeine Anforderungen für Betrieb und Anerkennung; Ausgabe 09/95.
ÖNORM S 2072	Eluatklassen (Gefährdungspotential) von Abfällen; Ausgabe 12/90.
ASTM C 227-90	Standard Test Method for Pontential Alkali Reactivity of Cement- Aggregate Combunations (Mortar – Bar Method).
ASTM C 1018-94b	Standart Test Method for Flexural Toughness and First-Crack Strenght of Fibre-Reinforced Concrete (Using Beam with Third- Point Loading). Book of ASTM standards, Volume 04/02. ASTM. Philadelphia 1995.
DIN 4226-1	Gesteinskörnungen für Beton und Mörtel – Teil 1: Normale und schwere Gesteinskörnungen; Ausgabe 07/01.
DIN 51302, Teil 2	Werkstoffprüfmaschinen – Prüfung von Zug- Druck- und Biegeprüfmaschinen – Zusätzliche Prüfung von Druckprüfmaschinen für Baustoffe; Ausgabe 08/96.
DIN 18551	Spritzbeton; Herstellung und Güteüberwachung: Ausgabe 03/92.
SIA 198	Untertagebau; Ausgabe 1993.
SN 530198	Tunnelnorm Schweiz; Allgemeine Grundlagen.
SN 530198-1	Tunnelnorm Schweiz; Projektierung Bahntunnel.
SN530198-2	Tunnelnorm Schweiz; Bautechnik Untertagebau.

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LIST OF ANNEXES

Annex 1	Standard form "Designation of samples"
Annex 2	Penetration needle test – Test protocol
Annex 3/Sheet 1	Bolt-driving method – Test protocol
Sheet 2	Bolt-driving method – Test protocol
Annex 4/Sheet 1	Example – Evaluation of fine dust concentration
Sheet 2	Example – Evaluation of fine dust concentration
Sheet 3	Example – Evaluation of fine dust concentration
Annex 5	Conformity certificate – Calculation of design sprayed concrete thickness
Annex 6	Standard form „Early strength classes of fresh sprayed concrete“

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ANNEX 1

Standard form "Designation of samples"

Baustelle: .....
Probenbezeichnung: .....
Produktbezeichnung:
Produktbezeichnung: ..... Chargennr.: .... Lieferscheinnr.: ..... Hersteller bzw. Lieferant: .....
Datum der Produktlieferung: ..... Entnahmedatum: ..... Entnahmezeit: ..... Entnahmeort: ..... Art der Probenentnahme: ..... Aufzubewahren bis .....
Angelieferte Menge: .....
Art der Anlieferung: ❍ Silo ❍ Sack ❍ Tank ❍ Fass
Entnommen von: .....
Datum: ..... Unterschrift Probennehmer: ..... Unterschrift Werks- oder Baustellenvertreter: .....

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ANNEX 2

Penetration needle test – Test protocol

Penetrationsnadelverfahren

Nr.:	Datum:	Stollen/Tunnel:
	T-Luft:	Station:
	T-Mischgut:	Lage:
	Bindemittel:	Gesteinskörnung:
	EB:	Bearbeitet:
	SBM:	

☐ Ende der Spritzarbeit

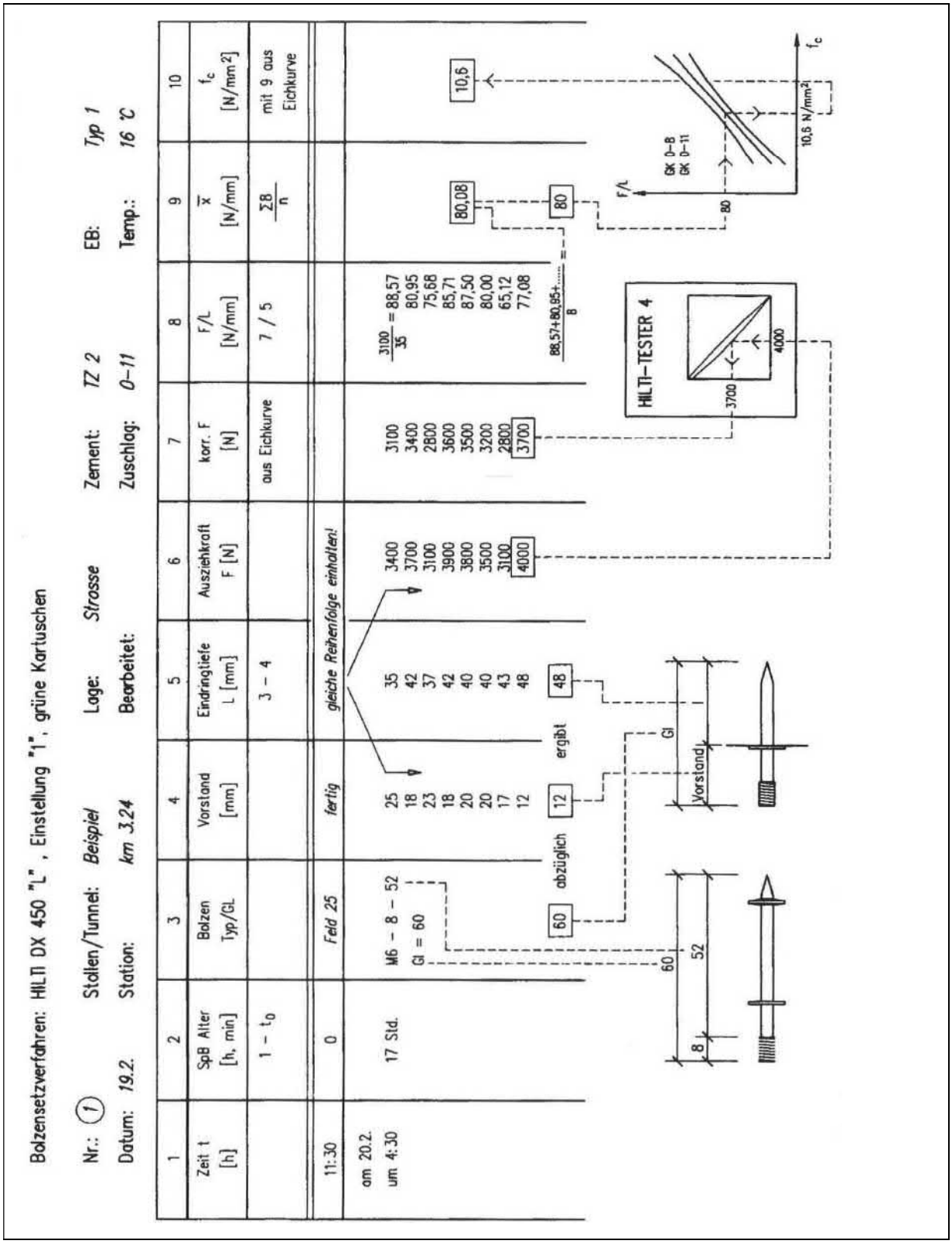
Nadel ∅ 3 mm, Spitze unter 60° geneigt

Zeit	SpC-Alter	Eindringkraft	Mittelwert	fc [N/mm²]
		10 Messungen		aus Eichkurve

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ANNEX 3 / SHEET 1

Bolt-driving method – Test protocol



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Bolt-driving method – Test protocol

Bolzensetzverfahren: HILTI DX 450 "L" mit Kolben 45/NKL

Kolbenführung 45/KFL, Bolzenführung 45/FL1 und Standplatte 45/SL1, Einstellung "1", grüne Kartusche 6.8/11 MGR.

Nr.: Stollen/Tunnel: Lage: Bindemittel: EB:

Datum: Station: Bearbeitet: Gesteinskörnung: Temp.:

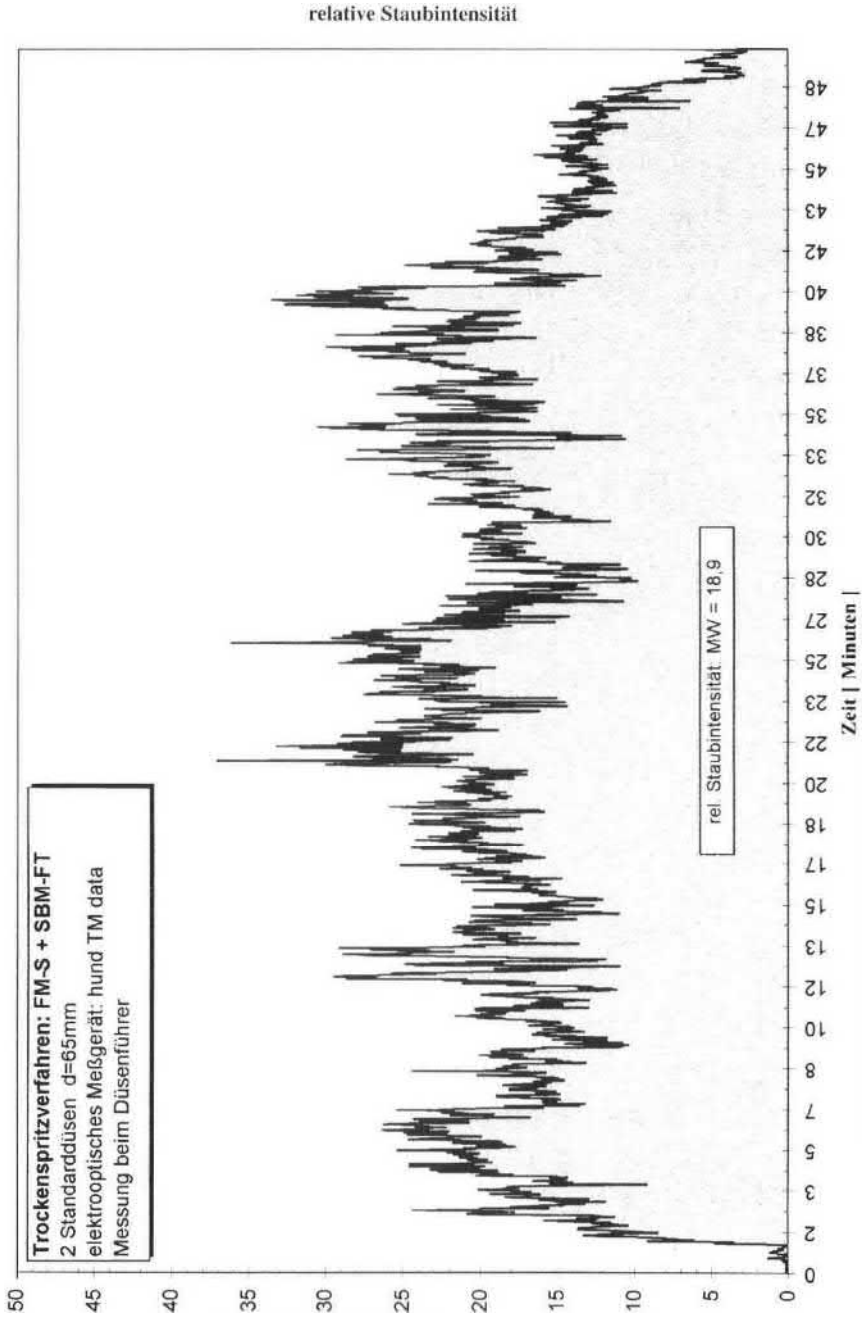
1	2	3	4	5	6	7	8	9	10
Zeit t [h]	SpC-Alter [h, min]	Bolzen Typ/GL	Vorstand [mm]	Eindringtiefe L [mm]	Ausziehkraft F [N]	korr. F [N]	F/L [N/mm]	x [N/mm]	f_c [N/mm²]
	1 – t_0			3 – 4		aus Eichkurve	7 / 5	$\frac{\sum 8}{n}$	mit 9 aus Eichkurve

ANNEX 3/SHEET 2

Example: electro-optical dust meter: hund TM data

Dry shotcreting method (FM-S + SBM-FT), 3.3 % moist aggregate, 2 standard nozzles ∅ 65 mm, ejection pressure 2.5 bar, output 2 x 4.21 m³/h, excavated cross section 55 m², crown heading, blowing ventilation.

Nozzle operator applying first layer of sprayed concrete: 0.8 hours

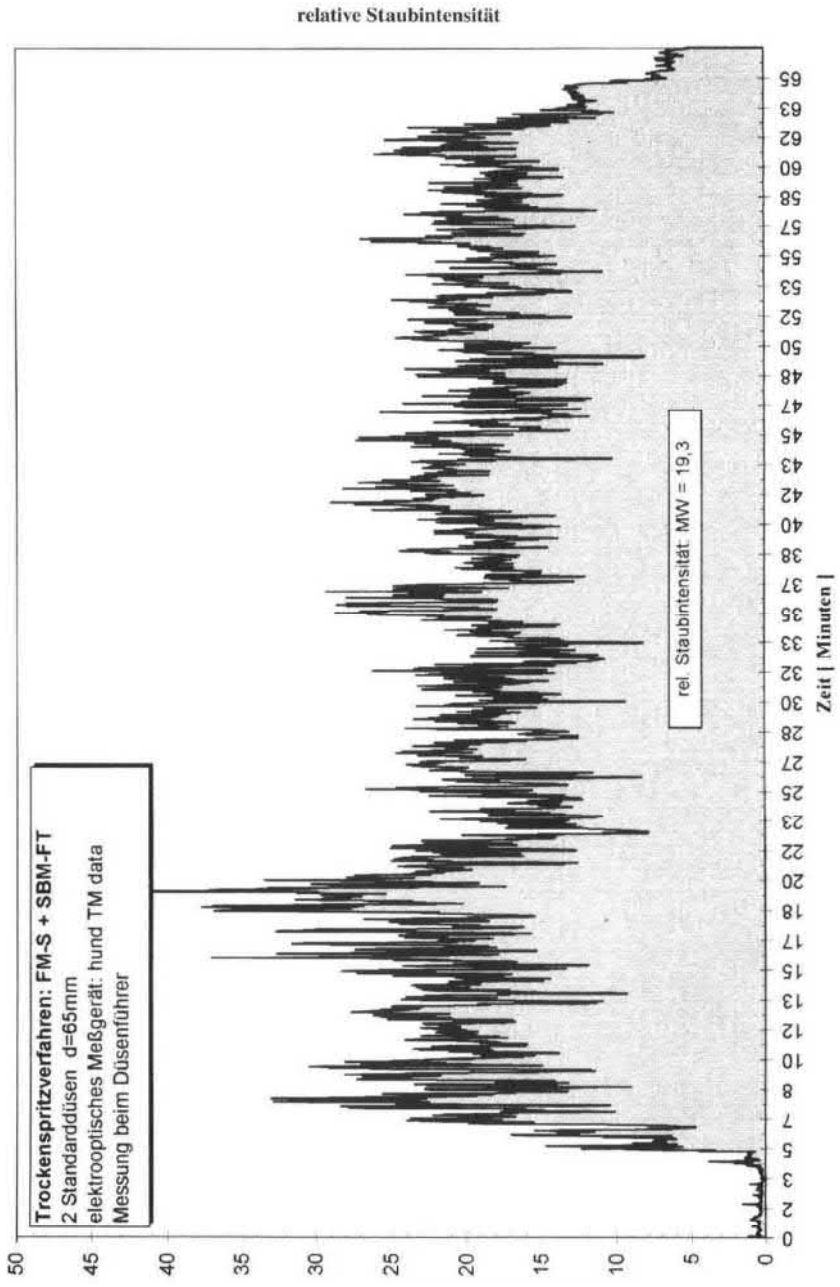


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ANNEX 4/SHEET 2

Nozzle operators performing other activities: 4.8 hours
measured relative dust intensity 1.41[-]

Nozzle operator applying second layer of sprayed concrete: 1.0 hour



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ANNEX 3/ SHEET 2

Evaluation:

Activity	measured rel. dust intensity [-]	conversion factor	fine dust concentration [mg/m³]
1st sprayed concrete layer	18.9	1.1	20.79
other activity	1.41	1.5	2.11
2nd sprayed concrete layer	19.3	1.1	21.23

Daily average of fine dust: $(20.79 \times 0.80 + 2.11 \times 4.8 + 21.23 \times 1.00) / 8 = 5.99 < 6$ mg/m³

Hourly average of fine dust: 1st sprayed concrete layer: 20.79 > 12 mg/m³
2nd sprayer concrete layer: 21.23 > 12 mg/m³

The maximum permissible concentration of fine dust is allowed to be reached twice a day (for one hour each), but not consecutively, provided the daily average of 6 mg/m³ is not exceeded.

Result of evaluation based on the above example:
The criteria according to Table 3/2 are not met and protective measures therefore have to be taken!

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Quality Test – Establishment of design sprayed concrete thickness

If the required sprayed concrete strength class is not reached in the quality test, the strength class requirements may be changed accordingly, provided the sprayed concrete is of adequate thickness.

Therefore, in areas in which the required sprayed concrete strength class is not reached, the design thickness ("d") of the sprayed concrete may be increased by "d_1" - clearance permitting - according to the following equation:

$$d_1 = \left(\frac{F}{M} - 1 \right) \cdot d$$

F required sprayed concrete strength class in N/mm²

M measured sprayed concrete strength in N/mm²

d design sprayed concrete thickness in cm

d_1 additional sprayed concrete thickness in cm

If the sprayed concrete thickness cannot be increased for reasons of insufficient clearance, the sprayed concrete found to be inadequate has to be removed upon the principal's request and replaced at the contractor's expense.

If the design strength is not reached, the principal is entitled to claim a discount instead of demanding an increase of the sprayed concrete thickness, with the unit price being reduced by 2% for each percentage point by which the actual sprayed concrete strength falls short of the design strength. The surface from which the drill core has been obtained is used as a basis for calculation of the price reduction.

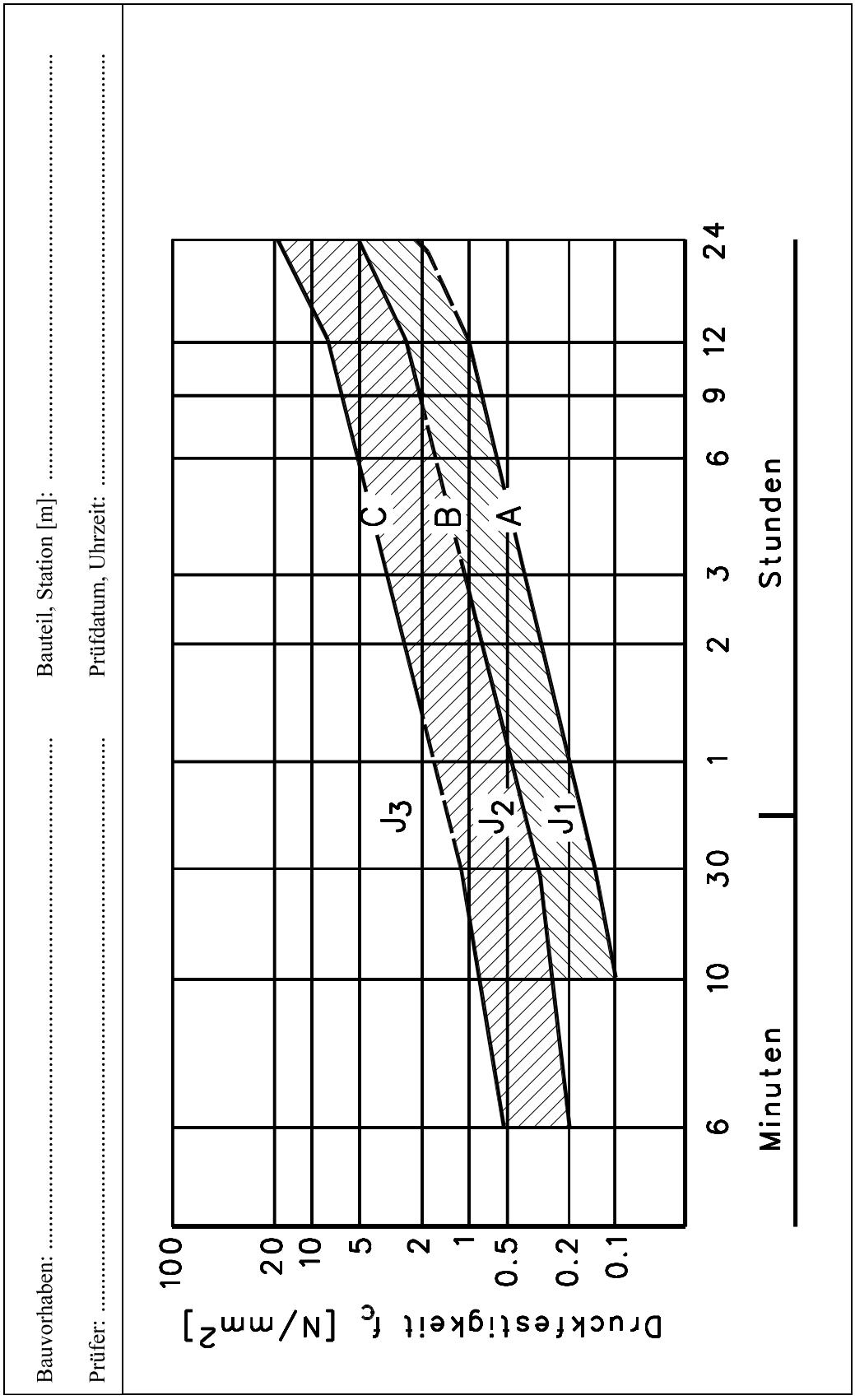
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ANNEX 6

Musterblatt „Frühfestigkeitsklassen des Jungen Spritzbetons“

Bauvorhaben: ..... Bauteil, Station [m]: .....

Prüfer: ..... Prüfdatum, Uhrzeit: .....



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VERÖFFENTLICHUNGEN DER ÖSTERREICHISCHEN VEREINIGUNG FÜR BETON- UND BAUTECHNIK

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Merkblatt “Kreisverkehre mit Betonfahrbahndecken” (Ausgabe 2006)

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Richtlinie “Innenschalenbeton” (Ausgabe 2003)

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Richtlinie "Nachträgliche Verstärkung von Betonbauwerken mit geklebter Bewehrung" (Ausgabe 2002)

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Inner Shell Concrete

GUIDELINE

Österreichische Vereinigung
für Beton- und Bautechnik

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UND VIELES MEHR .....

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Österreichische Vereinigung
für Beton- und Bautechnik

Guideline

Inner Shell Concrete

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completeness and correctness of the information contained therein.

PREFACE

The Guideline on Inner Shell Concrete, first published in 1995, was revised by the ÖVBB Working Party on „Concrete in Tunnelling“ in 2003. The main purpose of the revision was to incorporate the new European standards in the field of concrete engineering, applicable also in Austria, and to consider the most recent findings of construction practice. At the same time, the Guideline was extended to include provisions regarding the construction of intermediate ceilings and partitions for ventilation ducts.

The Working Party comprises representatives of principals, contractors, university research and testing institutes, as well as concrete manufacturers and design engineers.

This Guideline contains a practice-oriented set of rules for reinforced and non-reinforced inner shells, covering planning, design, tendering, production and testing, with a special emphasis on the requirements of modern traffic tunnel construction.

The intended incorporation of the Guideline on Inner Shell Concrete into the binding set of rules of the Austrian Road and Transport Research Society in the near future is to contribute towards its uniform application and, thus, a further improvement of the quality of inner shells.

Vienna, August 2006 Baurat h.c. Dipl.-Ing. Dr. techn. Helmut Huber

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0 PRELIMINARY REMARKS 1

1. SCOPE 1

2. DEFINITIONS 1

3. CONCRETE 3

3.1 Principles of Concrete Composition, Requirements 3
3.1.1 Workability *4*
3,1.2 Timing of formwork removal, stripping strength *5*
3.1.3 Avoidance of cracks *5*
3.1.4 Functional properties of the finished structure *6*
3.1.5 Increased fire resistance *11*
3.2 Constituent materials of concrete 11
3.2.1 Cement 11
3.2.2 Additives *12*
3.2.3 Mineral aggregates *12*
3.2.4 Water *14*
3.2.5 Admixtures *14*
3.2.6 Fibres *14*
3.3 Preconstruction testing 14
3.4 Conformity control 16
3.4.1 Conformity testing *16*
3.4.2 Identity test *17*
3.4.3 Structural testing *18*
3.4.4 Control samples *19*

4. STRUCTURAL MEASURES 19

4.1 General remarks 19
4.2 Waterproof inner shell (WDI) 20
4.3 Minimum structural requirements to be met by the floor and the abutment 21
4.4 Timing of concrete placement 21
4.5 Stripping strength in mined tunnels 21
4.6 Stripping strength in tunnels built by the cut-and-cover method 22

5. PREPARATIONS FOR CONCRETE PLACING 23

5.1 Preparing the substrate 23
5.1.1 Ingress of water *23*
5.1.2 Evenness of the concrete substrate *23*
5.1.3 Preparation of the concrete substrate *24*
5.2 Concrete joints 24
5.2.1 Construction joints *24*
5.2.2 Movement joints *24*
5.2.3 Joint sealing *25*
5.3 Intermediate layers between the substrate and the concrete 27
5.3.1 Laying and fastening *28*
5.3.2 Separation layers *28*
5.3.3 Sheet drainage systems *28*
5.3.4 Sealing layers *28*
5.4 Formwork 28
5.4.1 In-place formwork *29*
5.4.2 Travelling formwork *29*
5.5 Release agents 29
5.6 Reinforcement 30
5.6.1 Sealed inner shells *30*
5.6.2 Inner shells without sealing *30*
5.7 Construction tolerances 30
5.7.1 Surveying tolerances *31*
5.7.2 Formwork tolerances *31*
5.7.3 Geometrical tolerance *31*
5.7.4 Total tolerance *32*

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6. PRODUCTION AND PLACING OF CONCRETE 33

6.1 Mixing plant 33
6.1.1 Stand-by mixer 34
6.2 Transport 34
6.3 Conveying, placing, compacting 34
6.3.1 Conveying 34
6.3.2 Placing 34
6.3.3 Compaction 35

7. REQUIREMENTS AND MEASURES AFTER CONCRETE PLACING 35

7.1 Stripping 35
7.2 Concrete curing 35
7.2.1 Standard curing 35
7.2.2 Special measures 36
7.3. Concrete surfaces 36
7.3.1 Requirements 36
7.3.2 Repair measures 36
7.3.3 Surface protection 37
7.4 Grouting of the roof cavity and other arch areas 37
7.5 Repair measures in waterproof concrete 37

8. SPECIAL PROCEDURES 38

8.1 Sprayed concrete inner shells 38
8.2 Concrete segmental linings 38
8.3. Fibre-reinforced concrete 39

9. INTERMEDIATE CEILING AND PARTITION FOR VENTILATION DUCTS IN TRAFFIC TUNNELS 40

9.1 Intermediate ceiling 40
9.1.1 Concrete for intermediate ceilings 40
9.1.2 Design measures 41
9.1.3 Concrete production, placing, curing 42
9.2 Partition 42
9.2.1 Concrete for partitions 42
9.2.2 Design measures 43
9.2.3 Concrete production, placing, curing, concrete surface 44
9.3 Sealing of ventilation ducts against intermediate ceilings and partitions 44

10. RECOMMENDATIONS FOR TENDERING 45

11. NORMEN, RICHTLINIEN, VORSCHRIFTEN UND LITERATUR 46

11.1 Angeführte Normen 46
11.2 Richtlinien und Vorschriften 47
11.3 Zusätzlich zu beachtende Normen, Richtlinien 47
11.4 Literatur und Sachstandsberichte 48

ANNEX 1 49

ANNEX 2 50

ANNEX 3 51

ANNEX 4 52

ANNEX 5 54

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0 PRELIMINARY REMARKS

The provisions of RVS 1.0 apply in the countries of the EEA.

1. SCOPE

This Guideline applies to the production of inner shells from normal concrete, preferably for mined traffic tunnels, penstocks, shafts and cavities as well as arch-shaped structures built by the cut-and-cover method. Waterproof concrete structures built by the cut-and-cover method (see ÖVBB Guidelines on Waterproof Concrete Structures – White Tanking) are exempted from the scope of this Guideline.

As a matter of principle, the Austrian Standards and Guidelines specified under Item 11[1] apply in their current versions, in particular ÖNORM B 4710-1.

The composition of inner shell concrete (cement, additives, mineral aggregates, water, admixtures) is to be such as to guarantee achievement of the required concrete properties under the conditions to be expected at the construction site.

There are different types of inner shells:

- reinforced inner shells with and without sealing
- non-reinforced inner shells with and without sealing
- waterproof inner shells (WDI) for special requirements

The Guideline also applies to intermediate ceilings and partitions, but not to the production of safety barriers and concrete guardrails in traffic tunnels and to small structural components.

2. DEFINITIONS

Abutment (bench)

Foundation of the concrete arch.

Additive

Finely dispersed substance used in concrete, added to the concrete during mixing in order to improve certain properties (e.g. fly ash according to ÖNORM EN 450, prepared hydraulically active additives (AHWZ) according to ÖNORM B 3309 or silica dust according to ÖNORM EN 13263) or to obtain certain properties.

Arch

Upper part of the inner shell resting on a foundation (abutment).

Arch stripping time

The point in time when the formwork is removed from the arch and/or the inner shell (the structure being able assume the load of the deadweight of the inner shell and/or the arch).

Binder

Cement to which a hydraulically active additive can be added and which meets the requirements of the application concerned e.g. fly ash, silica dust, slag sand).

[1] Any deviation from an Austrian Standard (ÖNORM) is indicated in the text.

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C_3A-free cement

Cement according to ÖNORM B 3327-1.

Fibre-reinforced concrete classes BB (increased fire resistance)

For arch concrete according to Annex 5: BB IG, BB 2 G)

Inner shell

Load-bearing, permanent concrete lining of an underground cavity, e.g. gallery, tunnel, underground chamber, shaft, etc. The inner shell can be formed and concreted either in one go (full-round formwork) or in two or several sections (inverted arch, abutment, floor, arch).

Joints

- Construction joints
  result from the interruption of concrete placing on a structural part forming a static unit.
- Movement joints
  are engineering joints in structures with interrupted reinforcement, serving to absorb movements in different directions. There are different types of movement joints - with or without joint fillers and with or without waterstops.
- Expansion joints
  are movement joints with joint fillers.
- Rigid joints
  are movement joints without joint fillers. They form the area of contact between two independent parts of a structure to be jointed through concreting.
- Dummy joints
  are joints with or without continuous reinforcement, separating the concrete cross section only partly. As a rule, dummy joints are placed as „planes of weakness“ in areas of high stress concentration through cutting after concrete placing. The transfer of forces is partly maintained.

Sealing (sheeting seal)

Covering of surfaces, mostly by means of waterproof plastic sheeting.

Section length

Length of a concreting section, usually the distance between movement joints.

Strip cycle time

Period of time between the completion of concrete placing and the removal of formwork.

Stripping strength

Compressive strength of concrete at the time of formwork removal.

Swell factor of swellable waterstops

Ratio of the effective ultimate cross section according to It. 5.2.3.3. to the effective initial cross section, with free expansion in the direction of action.

Tunnel cement

Cement for inner shell concrete according to ÖNORM EN 197-1 with additional properties according to ÖNORM B 3327-1 (e.g. WT38, WT42).

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Water-binder ratio (W/B ratio)

Mass ratio of effective water content to cement content (eligible binder content) in fresh concrete.

Waterproof inner shell - WDI

Load-bearing, permanent concrete lining which also fulfils a sealing function.

3. CONCRETE

3.1 Principles of Concrete Composition, Requirements

A variety of partly conflicting requirements have to be met for the production of inner shell concrete. On the one hand, the development of a sufficiently high concrete temperature is considered necessary to ensure a rapid build-up of concrete strength and, thus, permit the removal of formwork at the earliest possible point in time; on the other hand, cracking is likely to occur under such circumstances. Special requirements in terms of exposure classes (e.g. XA or XF) may also result in high concrete temperatures, which in turn promote cracking. However, if the reactions occur too slowly, stripping is delayed.

To obtain the appropriate composition of concrete for inner shells, the constituent materials must be optimised in both qualitative and quantitative terms as a prerequisite for achievement of the desired results in terms of

- workability,
- stripping time and stripping strength,
- avoidance of cracking, and
- functional properties of finished structure.

The use of water-saving admixtures (BV, FM, LP, LPV) and small quantities of binder and water in inner shell concrete, to be produced in compliance with the requirements specified, helps to reduce temperature and shrinkage stress. The requirements of Table 3/2 and the indicative values of Table 3/3 apply. The indicative values shown in the Table refer to the usual strength classes and design arch thicknesses of up to 60 cm.

In general, testing for special concrete properties (e.g. exposure classes) is to be performed in hardened concrete (principle of equivalent concrete performance according to ÖNORM B 4710-1, It. 5.2.5.3).

To reduce thermal stresses, the use of CEM II type cement and/or a certain quantity of type II additives according to ÖNORM B 4710-1, e.g. fly ash, with the binder is recommended. The use of very fine additives may also result in improved workability of the fresh concrete and a denser concrete texture („filler effect“). As a rule, prepared hydraulically active additives (AHWZ according to ÖNORM B 3309) are to be used to obtain the desired properties.

The cement grades used in tunnel construction have to meet the requirements of ÖNORM B 3327-1.

Besides increased sulphate resistance, C_3A-free cement grades offer the advantage of very low heat development; they significantly reduce the risk of thermal stress cracking and are therefore particularly well-suited for waterproof inner shells (WDI) according to It. 4.2. Given the appropriate fresh-concrete temperature, the amount of cement and additives used must be such as to ensure the required stripping strength as well as compliance with the specified functional properties of the finished structure.

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Besides the composition of the concrete, the fresh-concrete temperature has an influence on temperature development and the rate of setting of inner shell concrete, which in turn is essential for early removal of formwork; the rate of setting also has an impact on maximum concrete temperatures and, thus, the avoidance of cracking. Fresh-concrete temperatures of between 13°C and 18°C have been found to be particularly favourable. Fresh-concrete temperatures of below 10°C strongly delay the build-up of strength, while temperatures above 22°C promote crack formation. Fresh-concrete temperatures of more than 27°C are not permitted.

The temperature development in concrete depends on the fresh-concrete temperature, the heat build-up (hydration heat of cement and/or binder, cement/binder dosage), the thickness of the structural component, and external influences (e.g. ambient air temperature, rate of air flow). To avoid cracking as much as possible (separation cracks), the specified temperature values (fresh-concrete temperature, temperature rise in concrete) have to be complied with. If the expected maximum temperature of the structural component according to Table 3/2 is exceeded, additional measures according to Table 3/1 have to be provided for.

3.1.1 Workability

The usual consistency testing methods do not cover the entire range of fresh-concrete properties reflected in the overall notion of „workability“. However, the simple slump test adequately serves to assess the pumpability of concrete mixes.

The consistency of inner shell concrete must be adjusted to the conditions of concrete placing. As a rule, a consistency in the upper F 45 range is considered appropriate for non-reinforced arch concrete. For reinforced inner shells a consistency class (depending on the amount of reinforcement) of up to F 52 for the floor and up to F 59 for the arch is best suited. Note that working conditions are different for fibre-reinforced concrete. Particular attention is to be paid to consistency changes, especially if long hoses are used for pumping.

The type of mineral aggregate, the grain size distribution, and the grain shape have an influence on workability. Very fine additives, such as prepared hydraulically active additives, help to obtain easily movable, cohesive mix masses (filler effect).

Void-forming plasticisers with limited air entrainment (combinations of BV, FM, LP and/or LPV admixtures) not only make the concrete more durable and increase the ultimate strain of the hardened concrete, but also have a favourable effect on workability; the maximum range of variation of the air void content is between 2.5% and 5.0%.

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

Table 3/1 Favourable and unfavourable conditions for the avoidance of cracks

Favourable conditions	Unfavourable conditions
a) C_3A-free cement grades according to ÖNORM B 3327-1 and hydraulically active additives according to ÖNORM B 3309 b) Use of admixture combinations BV, FM, LP, LPV to reduce total amount of water (max. total water 170 l/m³) c) Low fresh-concrete temperature 13°C – 18°C (stripping strength must be guaranteed) d) Low temperatures of structural component e) Short section lengths, avoidance of constraint f) Use of heat-conducting formwork (e.g. steel formwork) g) Even excavation surfaces h) Formwork removal after more than 12 hours to reduce rate of cooling i) Separating layers for improved sliding j) Adequate curing, e.g. curing membrane, non-wovens (It. 7.2.1), curing wagon (It. 7.2.2 k) High air humidity	a) Fresh-concrete temperature > 22°C b) Formwork removal within less than 12 hours c) Stripping strength of more than 3.0 N/mm² d) Draught air (high rate of air flow) e) Large difference between concrete temperature and ambient temperature f) Movement of inner shell severely constrained (dowelling effect)

3,1.2 Timing of formwork removal, stripping strength

In order to avoid cracking, formwork should not be removed too early. To maintain the usual 24-hour cycle for one concreting section, arch formwork is removed 10 to 14 hours after placing, which is considered favourable from the viewpoint of concrete technology. If formwork is removed less than 10 hours after concrete placing, measures need to be taken to prevent excessive cooling and drying (according to It. 7.2).

Concrete strength at the time of formwork removal should not be too high, as this would be associated with a very high concrete temperature at the time of maximum sensitivity to cracking during formwork removal. In the case of arch concrete, the stripping strength values measured in the structure at the time of formwork removal usually range between 1.5 N/mm² and 3.0 N/mm² (according to It. 4.5).

To achieve the required stripping strength, the cement contents recommended in Table 3/3 are to be observed.

3.1.3 Avoidance of cracks

Cracking in arch concrete is usually caused by residual stresses and/or confining stresses due to the inability of the concrete to contract during cooling and to shrinkage. It is advisable to keep the maximum concrete temperature low and to ensure low rates of cooling and shrinkage (see Table 3/1) in all cases.

Therefore, the concrete temperatures specified in Table 3/2 should be observed.

Shrinkage can be reduced by keeping the total water quantity within the limits indicated in Table 3/2 and by applying an appropriate after-treatment. For watertight inner shells, concrete with reduced shrinkage (RS) according to ÖNORM B 3303, It. 7.13.1 and/or strongly reduced shrinkage (RRS) according to ÖNORM B 3303, It. 7.13.2 is to be used. If the total water content is $\leq$ 170 l/m³, testing for strongly reduced shrinkage is not required.

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

The measures taken have to be adjusted to local building site conditions; unfavourable conditions have to be offset by favourable measures (conditions) of equivalent impact to avoid cracking as much as possible.

3.1.4 Functional properties of the finished structure

The concrete grade (compressive strength class, including concrete age at evaluation, short designation according to Table 3/2, possibly additional requirements) is to be specified in the schedule of specifications (example see Annex 3). As a rule, testing for exposure classes is to be performed in hardened concrete.

If the structure is exposed to special physical and chemical attacks, e.g. expansive attack through sulphate (XAT), solvent attack (XAL), or frost attack (XF), and for waterproof inner shells (WDI), the concrete texture should be as dense as possible and largely crack-free. The requirements to be met by inner shell concrete for different applications are summarised in Table 3/2.

3.1.4.1 Compressive strength class

The compressive strength class is specified according to the requirements of the structure, usually either C 20/25 or C 25/30. To account for the post-hardening effect of additives of type II and/or according to ÖNORM B 3309, the compressive strength class is to be related to the oldest possible concrete (56, 90 days). If testing is performed after 56 or 90 days, the concrete age at the time of testing is to be indicated in brackets after the strength class, e.g. C25/30 (56).

3.1.4.2 Concrete with increased density of the concrete texture (XC3, XC4)

To ensure an adequate density of the concrete texture and the corresponding durability of the concrete, exposure classes XC3 or XC4, depending on the application in question, are required. Addition of a combination of BV + LP and/or LPV admixtures (according to ÖVBB Guideline) is obligatory. In the event of a chemical attack, the penetration of harmful liquids is slowed down in concrete of high density. Testing for exposure classes XC3 or XC4 is to be performed in hardened concrete (test according to ÖNORM B 3303). For concrete temporarily exposed to strong solvent attack and/or expansive attack by sulphate in concentrations of 400 to 1500 mg/l and for waterproof inner shells, the depth of penetration must not exceed 25 mm (XC4).

3.1.4.3 Frost attack without thawing agent (XF3)

In portal areas of tunnels (usually up to 1000 m in length) arch concrete must be frost-resistant (XF3) according to Table 3/2.

3.1.4.4 Concrete for applications subject to expansive chemical attack (XAT)

Given the fact that inner shell concrete cannot be protected against expansive attack from mountain water or repaired through subsequent measures, justifiable preventive measures must be taken even if only a slight attack of this type is to be suspected. This also applies to inner shell concrete with sealant sheeting.

As the sulphate concentration in mountain water may vary strongly, the risk of sulphate attack must be assessed in at least three samples taken at different points in time.

For applications subject to sulphate attack with an SO_4^{-2} concentration of between 200 and 400 mg/l, exposure class XC3 must be demonstrated in hardened inner shell concrete; the use of C_3A-free cement is recommended.

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

If the SO_4^{-2} concentration is between 400 and 1500 mg/l SO_4^{-2} , testing for exposure class XC4 and the use of C_3A-free cement is mandatory, although not provided for in the ÖNORM.

If the SO_4^{-2} concentration of the attacking medium exceeds 1500 mg/l, the provisions of ÖNORM B 4710-1 apply.

3.1.4.5 Concrete for applications exposed to solvent chemical attack (XAL)

For road and tunnelling applications exposure class XAL is usually required to protect the ground water against pollution by harmful liquids (e.g. high-density tunnel floor to prevent pollution through liquids escaping in the event of tanker accidents). Hence, the density of the concrete structure (XC4) and the avoidance of cracking are particularly important. Concrete grade IXAL according to Table 3/2 is to be used for applications exposed to slight solvent attack and short-term strong solvent attack. Short-term strong solvent attack is defined as the impact of highly solvent substances for a limited period of time as a result of accidents.

3.1.4.6 Frost attack with thawing agent (XF4)

Many years of experience with road tunnels in Austria have shown that frost-resistant arch concrete of exposure class XF3, combined with the usual light-enhancing tunnel paint coats according to the ÖVBB Information Sheet on Paint Coats for Inner Shells of Tunnels, is sufficiently durable.

If no protective measures (paint coats) are provided for, exposure class XF4 is required for areas exposed to splash water contaminated with thawing agents, e.g. in road tunnels. However, a higher risk of crack formation is to be expected under such circumstances. Therefore, arch concrete resistant to frost and thaw cycles should only be specified in exceptional cases (e.g. short road tunnels without paint coat).

As a matter of principle, the use of XF4 arch concrete in state-of-the-art traffic tunnel usually does not result in the desired increase of structural quality. Even if all standards of concrete production are complied with, exposure to frost and thaw cycles may result in weathering (higher water content and unfavourable distribution of voids due to steel formwork and consistency of pumped concrete).

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

Table 3/2 Requirements to be met by inner shell concrete – Testing in hardened concrete

	Arch concrete (standard)	Floor, inverted arch, abutment (standard)	Arch concrete and floor concrete with special properties				
			Frost attack without thawing agent and/or with tunnel paint coat (portal)	Frost attack with thawing agent without tunnel paint coat	Water-proof inner shell	Sulphate attack SO_4^{-2} 400-1500 mg/l	Solvent attack
Abbreviations of concrete grades [8]	IG	IS	ISP/ IGP	IGT	WDI [5]	IXAT	IXAL
Exposure classes [1] according to ON B 4710-1 covered	XC3	XC3	XC3/XF3	XC4/XF4	XC4/XF3/ XA1T [2]/ XA1L C_3A-free	XC4/XF3/ XA1T[2]/ C_3A-free	XC4/XF3/ XA1L
Usual strength class	C20/25 (56) C25/30 (56)	C20/25 (56) C25/30 (56)	C25/30 (56) C20/25(56)	C20/25 (56) C25/30 (56)	C25/30 (56)	C25/30 (56)	C25/30 (56)
Max. permissible temp. increase in concrete according to ÖNORM B 3303 in K	15	15	15	17	13	13	17
Shrinkage [3] [6]	RS	RS	RS	RS	RRS	RS	RRS
Cement according to ÖNORM B 3327-1	WT38, WT42	WT38, WT33 [7]	WT38, WT42	WT38, WT38 C_3A-free	WT38 C_3A-free WT33 C_3A-free	WT38 C_3A-free, WT33 C_3A-free	WT38, WT42
Total water content (target value) l/m³ [4]	max. 190	max. 190	max. 190	max. 170 [3]	max. 170 [3]	max. 170[3]	max. 170[3]
Mineral aggregates	F2, FNR	F2, FNR	F2	F1	F2	F2	F2
Grading line classes SK	SK2[12]	SK2[12]	SK2[12]	SK1	SK1[12]	SK1[12]	SK1[12]
Max. W/B value	0.65	0.65	0.65	0.52	0.60	0.60	0.60
Air content (GK22) %	2.5 – 5.0	2.5 – 5.0	2.5 – 5.0	4.0 – 7.0	2.5 – 5.0	2.5 – 5.0	2.5 – 5.0
Microprocessor control according to ÖNORM B 4710-1 required	yes	yes	yes	yes	yes	yes	yes
Fresh-concrete temperature °C	≤ 27	≤ 27	≤ 27	≤ 27	≤ 27	≤ 27	≤ 27
Max. expected temp. of structural component	40	45	40	45	40	40	45
Max. permissible temp. of structural component[11]	45	50	45	50	45	45	50
Preconstruction test in hardened concrete [1]	XC3	XC3	XC3, XF3, L300 [9]	XC4, XF4, L300 AF[9],	XC4, XF3 L300 [9] [10],	XC4, XF3 L300 [9] [10]	XC4, XF3 L300 [9] [10]
Conformity, identity test in hardened concrete	XC3	XC3	XC3, L300 [9]	XC4, L300 AF [9]	XC4, L300 [10]	XC4 L300 [10]	XC4 L300 [10]
Standard stripping time in h	≥ 10	-	≥ 10	≥ 10	≥ 12	≥ 10	≥ 10
Min. stripping time in h with special measures acc. to It. 7.2.2	8		8	8	8	8	8

1) To keep heat build-up as low as possible, hardened concrete normally has to be tested for exposure classes to establish the optimum concrete composition. Testing in hardened concrete can be limited to the parameters specified.

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

2) No additional measures for arch and floor concrete required in case of sulphate concentrations of up to 400 mg/l (use of C_3A-free cement is recommended from 200 mg/l). In case of sulphate concentrations within the 400 – 1500 mg/l SO_4^{-2} range, testing for exposure class XC4 and the use of C_3A-free cement are required (exposure class XA1T C_3A-free). If the sulphate concentration exceeds 1500 mg/l SO_4^{-2} the requirements of ÖNORM B 4710-1 for XA2T apply.

3) RRS – strongly reduced shrinkage: in inner shell concrete with a total water content of max. 170 l/m³ (target value) strongly reduced shrinkage (RRS) is deemed to have been established. If the mix formulation does not permit compliance with this limit, strongly reduced shrinkage (RRS) has to be demonstrated according to ÖNORM B 3303, It. 7.13.2. The total water content established through conformity or identity testing must not deviate from the target value by more than the value permissible according to ÖNORM B 4710-1, Table 17.

4) Total water content according to ÖNORM B 4710-1, Sect. 3.1.29.

5) Corresponds to the requirements of W40 and BS1A of the Guideline on Waterproof Concrete Structures – White Tanking, except for the permissible placing temperature of < 27 °C. The higher permissible placing temperature is possible on account of the more favourable environmental conditions of inner shell concrete.

6) Shrinkage (RS, RRS) according to ÖNORM B 3303 It. 7 .13 is to be established during preconstruction testing and upon delivery at least once a year.

7) For thick floor slabs and abutments > 1.2 m WT 33 C_3A-free and AHWZ.

8) IG = Inner shell, arch, normal
IS = Inner shell, floor, normal
IGP = Inner shell, arch, portal
ISP = Inner shell, floor, portal
IGT = Inner shell, arch, exposure to thawing agent
WDI = Waterproof inner shell
IXAT = Inner shell (arch, floor) exposure to sulphate attack (400 – 1500 SO_4^{2-})
IXAL = Inner shell (arch, floor) exposure to short-term strong solvent attack

9) Requirements to be met by L 300 and AF according to ÖNORM B 4710-1, Table NAD 10

L 300:	for XF2 and XF3:	min. 1.0 %
	for XF4:	min. 1.8 %
AF:	for XF4:	max. 0.18 mm

10) Testing for XF3 and/or L300 only if necessary, e.g. portal area.

11) If the maximum permissible temperature of the structural component is exceeded, additional measures have to be taken to ensure compliance with the temperature requirement during continued concrete placing. The values specified in ÖNORM B 4710-1, Table 19, apply. However, if the temperature is exceeded, another measurement has to be performed in the subsequent concreting section. The tolerance of individual results of conformity testing (ÖNORM B 4710-1, Tale. 17) is 2K.

12) If 4 grain fractions are used, 2 mineral aggregates with a minimum grain size of less than 4 mm are permitted, one with a maximum grain size of 4 mm and the other with a maximum grain size of 16 mm. Except for concrete grade IGT, the use of 0/16 mm grain mixtures is permitted.

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

Table 3/3 Proposed composition (mix ratio) of inner shell concrete to be established through testing in hardened concrete

	Arch concrete (standard)	Floor, inverted arch, abutment (standard)	Arch concrete and floor concrete with special properties				
			Frost attack without thawing agent and/or with tunnel paint coat (portal)	Frost attack with thawing agent without tunnel paint coat	WDI	Sulphate attack SO_4^{-2} 400-1500 mg/l	Solvent attack
Abbreviations of concrete grades	C20/25(56) IG/ GK..[3)]	C20/25 (56) IS/ GK..[3)]	C20/25(56) ISP/IGP/ GK..[3)]	C25/30(56) IGT/ GK..[3)]	C25/30(56) WDI/ GK..[3)]	C25/30(56) IXAT/ GK..[3)]	C25/30(56) IXAL/ GK..[3)]
Recommended cement content [1)] kg/m³	250-270	210-240	250-270	270-290	250-270	250-270	250-270
Prepared hydraulically active additives (AHWZ) kg/m³	70 - 50	80 - 60	70 – 50	80 - 60	70 - 50	70 - 50	70 - 50
Maximum water content l/m³	≤ 190	< 190	≤ 190	≤ 170	≤ 170	≤ 170	≤ 170
Maximum grain size of mineral aggregate	GK 16, GK 22, GK 32	GK 32, GK 45	GK 22, GK 32	GK 22, GK 32	GK 16, GK 22	GK 22, GK 32	GK 22, GK 32
Mineral aggregates	F2, FNR	F2, FNR	F2	F1	F2	F2	F2
Grading curve classes SK	SK2	SK2	SK2	SK1 [2)]	SK1 [2)]	SK2	SK2
Mineral aggregates Range 2/3 (A+B) – B if ϱ = 2700 kg/m³ g/m³	1850 - 1920	1870 - 1940	1850 - 1920	1750 - 1870	1850 - 1920	1850 - 1920	1850 - 1920
Admixtures BV, FM, LP, LPV	Dosage according to air-content and workability requirements						
Air content %	2.5 – 5.0	2.5 – 5.0	2.5 – 5.0	4.0 – 7.0	2.5 – 5.0	2.5 – 5.0	2.5 – 5.0
W/B value (target)	≤ 0.65	-	≤ 0.65	≤ 0.52	≤ 0.60	≤ 0.60	≤ 0.60
Cement grade acc. to ON B 3327-1	WT38, WT42	WT38, WT42 for thick floors >1.2m: WT33 C_3A-free	WT38, WT42	WT38 WT38 C_3A-free	WT33 C_3A-free WT38 C_3A-free for thick floors >1.2m: WT33 C_3A-free	WT38 C_3A-free WT42 C_3A-free	WT38 WT42

1) Cement content of > 250 kg/m³ required to comply with usual stripping cycle.
2) Standard maximum grain size for non-reinforced inner shells: GK 32; for reinforced inner shells: GK 22.

3.1.4.7. Concrete for waterproof inner shells without sealing (WDI)

In water-impermeable inner shells complete waterproofing is ensured by the inner shell concrete. Hence, inner shell concrete not only has to meet the requirements of exposure class XC4, which specifies the required textural density of the concrete, but must also be largely free of water-permeable cracks. Thus, exceptionally good workability, strict limitation of the fresh-concrete temperature, the maximum concrete temperature and the rate of cooling, and a low rate of shrinkage are essential for concrete for waterproof inner shells. In particular, the use of cement generating a low level of hydration heat according to ÖNORM B 3327-1 (e.g. WT 38

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

C3A-free), the addition of prepared hydraulically active additives, and use of the smallest quantity of water possible in combination with admixtures (BV+LP or LPV) is recommended (see Table 3/3). Except for the permissible fresh-concrete temperature of $\leq$ 27°C, the requirements for waterproof concrete listed in Table 3/2 correspond to the requirements of Concrete Standard BS 1A of the ÖVBB Guideline on Waterproof Concrete Structures – White Tanking.

The structural measures specified in It. 4 are to be observed.

For thick concrete tunnel floors (thicker than 1.2 m) special measures have to be taken to diminish the build-up of heat (e.g. use of WT 33 C_3A-free cement and prepared hydraulically active additives).

Curing measures are to be timed in such a way as to prevent rapid cooling during the first 3 days and rapid drying during the first 7 days after stripping (according to It. 7.2).

3.1.5 Increased fire resistance

In order to comply with the requirements of fire protection, measures may have to be taken to increase the fire resistance of concrete. Under the impact of fire, the temperature front penetrates into the arch concrete, which results in the built-up of thermal stresses and, possibly, modifications of the properties of concrete and steel.

A rapid temperature increase results in explosion-like spalling of the surface layers of the concrete, with deeper layers – possibly also the reinforcement – being exposed (the extent of spalling depends, among other things, on the concrete strength, the moisture of concrete in the structure, and the confining stress preventing deformation of the structure). Spalling can be reduced or prevented through the addition of fine polypropylene fibres (see It. 8.3 and/or ÖVBB Guideline on Fibre-Reinforced Concrete, ÖVBB Guideline on Increased Fire Resistance of Concrete for Underground Traffic Structures).

The addition of fibres modifies the properties of fresh concrete (lower consistency, higher quantity of admixtures required, different air content), makes placing more difficult (concrete distribution and embedding of reinforcement are more difficult, vibratory energy and/or vibrator distribution for reinforced arch concrete have to be optimised), and results in modified properties of the hardened concrete (e.g. frost resistance). These modifications have to be established through preliminary testing and taken into account through appropriate measures (see also It. 8.3 and/or ÖVBB Guideline on Fibre-Reinforced Concrete and ÖVBB Guideline on Increased Fire Resistance of Concrete for Underground Traffic Structures).

3.2 Constituent materials of concrete

The origin of the constituent materials of the concrete is to be indicated and their suitability must be demonstrated before concrete placing is begun.

3.2.1 Cement

Cement grades bearing a CE or ÜA mark and standard-compliant according to ÖNORM EN 197-1 and B 3327-1 and EN 197-1 are to be used.

Requirements to be met by cement (heat build-up, water segregation, fineness, C_3A content, cement temperature) in addition to those specified in EN 197-1 are laid down in ÖNORM B 3327-1 (see also Table 3/2).

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

3.2.2 Additives

The addition of type II additives according to ÖNORM B 4710-1 serves to improve the workability of the concrete, to diminish heat build-up and to achieve a dense concrete texture.

As a rule, additives according to ÖNORM B 3309 (prepared hydraulically active additives) are to be used for targeted air entrainment. These additives are counted to the water/binder value through application of a k-factor of 0.8.

The additives have to be metered as individual components on the basis of weight. The mixing time must be sufficient to ensure homogeneous mixing of cement, additives and the mineral aggregates.

3.2.3 Mineral aggregates

Mineral aggregates have to meet the requirements of ÖNORM B 3131. The use of mineral aggregates is subject to the requirements of ÖNORM B 4710-1, except for the fact that 2 mineral aggregates may contain grain fractions with a minimum grain size of less than 4 mm, if 4 grain size groups are used. The use of grain mixtures of up to 0/16 mm is permitted, except for concrete grade IGT.

For inner shell concrete meeting the requirements of at least frost class F2, mineral aggregates according to ÖNORM B 4710-1, supplied in separate grain fractions from an on-site preparation plant or a standard-compliant plant, are used. For XF4 concrete frost class F1 is required.

The aggregate grading curve is to be selected in such a way as to ensure the required workability while keeping water consumption as low as possible. For recommended grading curve ranges, see Fig. 3/1, Fig. 3/2 and Fig. 3/3. The maximum grain size, adjusted to the specific working conditions (e.g. thickness of structural component, position of reinforcement, etc.), is to be as large as possible, with the permissible fraction of oversized grains being fully utilised; subject to compliance with the workability requirement, the fraction of oversized grains may be exceeded by another 5%. Maximum grain size GK 45 is recommended for non-reinforced concrete and thick structural components.

The maximum permissible percentage of settleable solids (fraction < 0.063 mm) is subject to the provisions of ÖNORM B 4710-1. In crushed mineral aggregates with maximum grain sizes of 32 mm and 45 mm, this percentage may be increased to 5 wt.%, if the aggregate is purely carbonate and the fraction smaller than 0.02 mm (determined by sedimentation test) does not exceed 3.0 wt.%. The total water content must be in accordance with Table 3/2.

The grading curve ranges shown in Fig. 3/1 to 3/3 are based on many years of experience regarding pumpability, workability and surface structure to be obtained with the appropriate fine-grained content.

For grading curves GK32 and GK22, pumping tests must be performed prior to concrete placement in the inner shell, if the 4/8 fraction > 10% and the mineral aggregate consists mainly of angular grains.

No special measures are required if the standard ranges are exceeded as far as the B line, provided the above rule regarding the 4/8 fraction is observed.

In special cases, the use of mineral aggregates slightly exceeding the B line in the 1 mm to 4 mm fraction and/or remaining below the standard range is permitted, if the required concrete properties are achieved; however, workability (pumpability, placability and surface structure of the concrete) need to be demonstrated through testing.

The fine-grained content must not be lower than the value specified in Table 3 / 4.

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

Table 3/4 Fine-grained content (fraction ≤ 0.125)

Maximum grain size	Minimum fine-grained content
GK 16	390 kg/m³
GK 22	370 kg/m³
GK 32	350 kg/m³

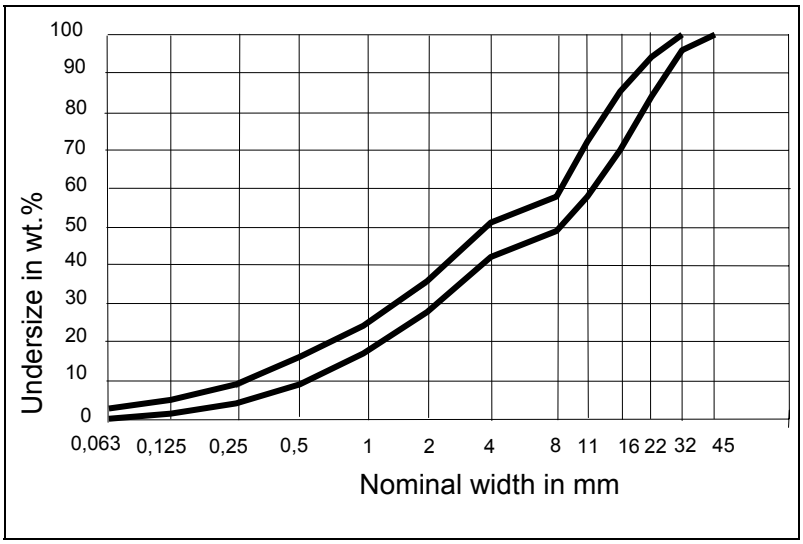


Fig. 3/1
Grading curve range for inner shell concrete
Maximum grain size 32 – standard range

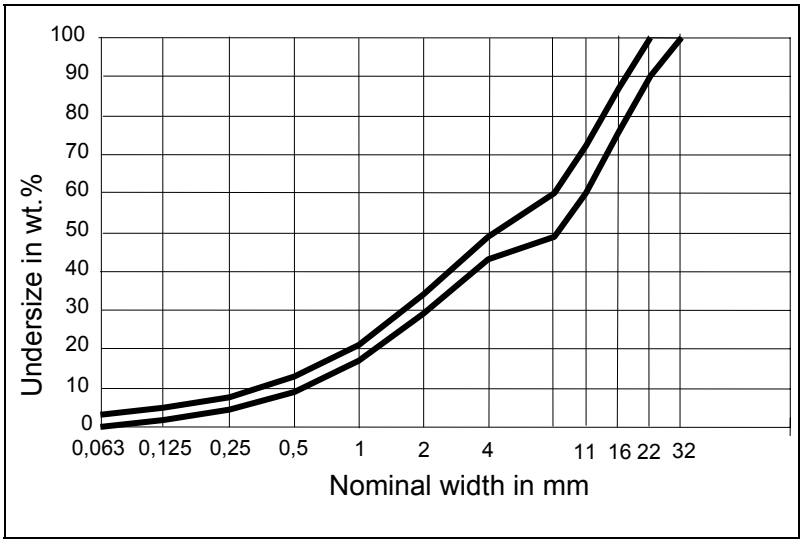


Fig. 3/2
Grading curve range for inner shell concrete
Maximum grain size 22 – standard range

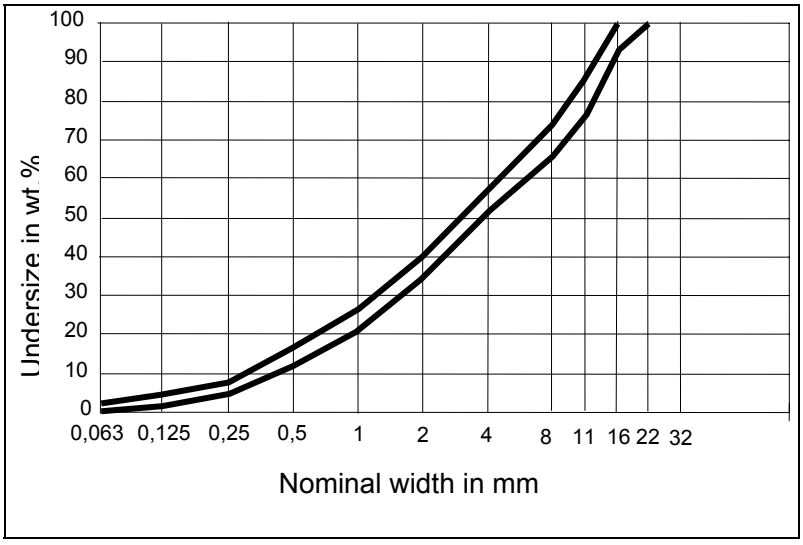


Fig. 3/3
Grading curve range for inner shell concrete
Maximum grain size 16 – standard range

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3.2.4 Water

As regards the characteristics of mixing water, ÖNORM B 4710-1 applies.

3.2.5 Admixtures

All admixtures have to meet the requirements of ÖNORM B 4710-1 and ÖNORM EN 934-2; for LPV products the requirements of the ÖVBB Guideline on LPV Concrete apply.

For the admixtures used, approval documents, test reports and test certificates, as required in the technical regulations and not older than three years, must be available.

The effectiveness of concrete admixtures and their mutual compatibility (if several admixtures are used) has to be established through preconstruction testing and must also be assessed in the course of conformity testing (see ÖNORM B 3303, It. 7.16).

3.2.6 Fibres

Fibres have to meet the requirements of the ÖVBB Guideline on Fibre-Reinforced Concrete.

3.3 Preconstruction testing

Preconstruction testing serves to demonstrate that all requirements are met with the constituent materials used and the allowances according to ÖNORM B 4710-1. In specifying these requirements (e.g. consistency), account must be taken of differences in the conditions of execution (non-reinforced, sealed inner shell, length of pumping hose, stripping time, presence of aggressive mountain water, etc.). The percentages of the constituent materials in the concrete mix (cement, additives, admixtures, aggregates and water) are determined in the preconstruction test.

The preconstruction test is to be performed by an accredited inspection body. The properties of the hardened concrete must always be tested by an accredited testing body. The testing and inspection bodies concerned must be able to provide evidence of their experience in the construction of inner shells for mined tunnels.

Concrete grades (arch concrete, floor concrete, abutment concrete, hot-weather and cold-weather placing formulations) of similar composition may be treated as concrete families and subjected to a common preconstruction test under the following conditions:

- same constituent materials (if admixtures BV and/or FM are different, a single fresh-concrete test is sufficient)
- cement dose $\pm$ 15 kg/m³
- dose of prepared hydraulically active additives $\pm$ 10 kg/m³
- F45, F52
- maximum grain size of mineral aggregates: next higher or lower grain size classes (e.g. preconstruction test for GK 22 also applies to GK 16 and GK 32).

The scope of the preconstruction test depends on the requirements to be met by the structure (see Table 3/2). Tests to be performed over and above the standard test programme shown in Table 3/5 (special test programme) are to be specified in the tender documents.

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

Table 3/5 Standard test programme for preconstruction testing

	Arch concrete	**Floor concrete Abutment concrete**
Optimisation of concrete composition, (optimum grading curve of mineral aggregate, maximum grain size, cement grade, percentage of additives, mixing time)	x	x
Slump (a_{10}, a_{90})	x	x
Bulk density of fresh concrete	x	x
Air content [5] (LP_{10},. LP_{90}) (with bulk density)	x	x
Bleeding (BL) as informative value	x	
Testing of constituent materials [1]	x	x
Strength at intended stripping time, temperature-controlled	x	
Compressive strength 7 d, 28 d or 56 d [2]	x	x
Temperature increase according to ÖNORM B 3303 It. 7.17 (requirements according to Table 3/2)	x	x [4]
Shrinkage RS and/or RRS for (WDI)	x[3]	-
Testing for exposure classes depending on requirements according to Table 3/2 in hardened concrete	x	x

1) The results of in-plant inspections can also be used for cement and additives.
2) Depending on age at time of testing
3) Not obligatory if total water content < 170 l/m^3
4) To be demonstrated for thick concrete floors only (thickness $\geq$ 1.2 m): $\Delta T \leq 17$ K as tested according to ÖNORM B 3303, It. 7.17.2.
5) Air content in the middle of permissible range

- Special tests

The scope of special tests and the required concrete age at the time of testing are to be specified:

Examples:

- Modulus of elasticity (e.g. stripping strength of structures built by cut-and-cover method; after 3, 7, 28, 56 or 90 days),
- Tensile splitting strength
- Testing for reinforced-fibre concrete classes BB 1G and BB 2G in large-scale test specimen according to Annex 5.
- Stripping strength

If formwork is removed after less than 16 hours, the compressive strength of arch concrete is to be determined for the earliest intended stripping time in temperature-controlled test specimens (20 cm cubes) (see Table 3/6). The test method is to be calibrated upon performance of the test (pendulum hammer) (see It. 3.4.3).

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

Table 3/6 Storage temperature of the temperature-controlled test specimen

Fresh-concrete temperature		**15 - 20 °C**
Storage temperature of the specimens	0 - 4 hours	20 °C
	4 - 8 hours	25 °C
	more than 8 hours	30 °C

3.4 Conformity control

3.4.1 Conformity testing

The conformity test (Table 3/7) is carried out during execution of construction work to demonstrate that the composition of the inner shell concrete is such as to ensure achievement of the required properties at the age specified, provided adequate production, curing and storage.

As a rule, conformity testing of fresh concrete is performed at the site of placement (e.g. upstream of pump, conveyor belt, slide). The influence of transport and pumping (above all changes of the air content) is to be determined at the beginning and in the course of concreting and has to be taken into consideration both in the evaluation of the results and for the dosage of admixtures (allowance for air content, consistency and fresh-concrete temperature) to demonstrate continuity of placing conditions. The correlation of concrete properties upstream and downstream of the pump is to be established at the same truck mixer, preferably at the same filling level. The required fresh-concrete values apply to the site of placement (e.g. concreting hose downstream of the pump).

Except for concrete grades IGT and FaB (fibre-reinforced concrete), the conformity test may also be performed at the mixing plant and/or at the tunnel portal, if the time of transport between the site of testing and the site of placement (e.g. concreting hose downstream of the pump) does not exceed 30 minutes and if continuity of placing conditions (consistency, air content and fresh-concrete temperature) can be demonstrated.

- Proof of continuity of placing conditions

The following maximum changes of conditions between the test site and the placing site (absolute values without statistical evaluations) are permissible:

Consistency 30 mm, air content 2.0 %, fresh-concrete temperature 2°C

The minimum sample quantity to be obtained for testing, deviating from ÖNORM B 3303, is 15 l.

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

Table 3/7 Conformity testing (minimum frequency)

	I	II
Test measure	Beginning of concreting to 10th concreting section[2)]	Continuous operation from 11th concreting section[2)]
Cement, Additives [1)]	1x month per cement and/or additive grade	
Mineral aggregate - grain size distribution [1)] 0/4 other	 1 x weekly 1 x weekly	 1 x weekly 2 x monthly
Fresh-concrete temperature, air temperature	3 x per section	1 x per section
Continuity of placing conditions	every third section	every 20th section
Printout of statistical data of microprocessor control	for concreting period to be specified	for concreting period to be specified
Temperature increase according to ÖNORM B 3303	1 x arch concrete and floor concrete per concrete family [3)]	for arch concrete and floor concrete per concrete family [3)] every 20th section and/or every 6 months
Consistency	5 x per section, continuous visual inspection	2 x per section, continuous visual inspection
Air content (fresh concrete)	5 x per section	2 x per section
Water content of concrete [4)]	every 3rd section	every 10th section
Compressive strength 7d	every 3rd section	-
Compressive strength 28d or 56d	every 3rd section	every 10th section
Shrinkage RS, RRS	1 / year	
Exposure classes according to Table 3/2 in hardened concrete (XC3, XC4, L300, AF)	for arch concrete, floor concrete, abutment concrete per concrete family [3)] for WDI: every 20th section and/or every 6 months for other inner shell concrete: every 40th section and/or every 12 months	

1) The results of in-plant inspection may also be used to demonstrate the required properties.
2) A concreting section is defined as a section placed with the same concrete grade by the same mixing plant within 24 h under approximately the same climatic and placing conditions.
3) The following concrete grades may be grouped as a concrete family:
   - same constituent materials (if admixtures BV and/or FM are different, fresh-concrete testing is the only additional requirement to be met)
   - Cement dosage ± 15 kg/m^3
   - AHWZ dosage ± 10 kg/m^3
   - total binder dosage + 10 Kg/m³ (cement + AHWZ)
   - W/B value max. + 0.02
   - F45, F52
   - Maximum grain size of mineral aggregates: next higher and lower grain size classes
4) Test according to ÖNORM B 3303, It. 6.4

3.4.2 Identity test

The identity test has to be performed by an accredited testing body or according to ÖNORM B 4710-1, Annex B, Section B2. It serves to determine the fresh-concrete properties and the compressive strength, and to produce test specimens for further tests in hardened concrete, which may also be performed by a construction-site laboratory, provided the latter is supervised by a duly qualified representative of the principal, who verifies and confirms the test results.

The identity test, to be initiated by the principal, is performed at the site of concrete placing (e.g. upstream of the pump, conveyor belt or slide) and serves to verify that the concrete placed

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

corresponds to the concrete grade evaluated by the manufacturer through conformity testing. To verify the identity of the concrete, the following properties have to be tested (Table 3/8).

Table 3/8 Identity test

Test measure	**Minimum frequency**
Consistency	every 20th concreting section
Air content	
Continuity of placing conditions	
Water content	
Compressive strength 28 d or 56d	
Exposure classes according to Table 3/2	for WDI concrete: every 20th concreting section for other inner shell concrete: every 40th concreting section

Compressive strength testing may be performed by an accredited testing body or at the construction-site laboratory. Testing of hardened concrete for exposure classes is also performed by an accredited testing body.

- Compressive-strength testing at the construction-site laboratory

The compressive strength is established through a test performed on a calibrated concrete compression tester in the presence of a representative of the principal, who confirms the readings obtained. Parallel samples have to be tested by an accredited testing body at intervals to be agreed upon (at least every 3 months).

Moreover, identity testing also serves to assess the proof of conformity established by the manufacturer for all concrete grades used in the contract section on the basis of the conformity tests performed by the manufacturer (ready-mix plant) since the last identity test (on-site mixing plant) and/or since the last external inspection.

3.4.3 Structural testing

The structural tests are to be performed and documented by the user.

- Stripping strength:

  The stripping strength is to be verified in each concreting section prior to the removal of formwork. The compressive strength of the arch of a mined tunnel at the time of formwork removal (max. 24 h) is to be determined at the structure, e.g. by means of the pendulum hammer according to the PT model by E. Schmidt. For structures built by the cut-and-cover method, the compressive strength at the time of formwork removal is established by means of the P model or the rebound hammer. The stripping strength is to be tested at the face of the roof and on the concrete surface of the wall area (concreting window). The pendulum hammer is to be calibrated within the framework of preconstruction testing of the concrete.

- Temperature development in the structure:

  The temperature development of arch concrete and ambient air is to be established in every 40th concreting section (every 20th concreting section in the case of WDI). The test is to be performed before the temperature starts to decline (as a rule within

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

36 hours). Two measuring points each in the roof and wall area, centrally located in the structural component, are to be provided for.

- Concrete cover of steel reinforcement (in reinforced inner shells):

  To avoid system errors, the required concrete cover of the steel reinforcement (minimum size) is to be verified for the first five concreting sections, and subsequently for every 40th concreting section, by means of a suitable concrete cover measuring device (e.g. Profometer by Hilti) according to RVS 9.35, It. 5 and It. 6 (also applies to intermediate ceilings and partitions).

- Verification of the thickness of the inner shell in hardened concrete (to be specified as a separate item in the tender documents in the case of reinforced inner shells):

  Compliance with the nominal thickness of the inner shell is an essential quality feature of double-shell structures. To avoid reductions in thickness in the roof area and, if applicable, in the abutment, wall and floor-arch transition areas, and to prevent direct damage to the sealing, the inner shell has to be tested by non-destructive methods. As a rule, the roof area and the areas along block joints are to be inspected. As regards the use of non-destructive testing methods, please refer to the corresponding Guideline [8].

3.4.4 Control samples

Table 3/9 Sampling for control purposes

Sample	Quantity	Frequency	Duration of storage from date of sampling
Cement	10 kg	once in 2 weeks	2 months
Additive	5 kg	once in 2 weeks	2 months
Admixture	1 l	once in 2 weeks	2 months

The samples have to be taken upon delivery of the concrete and stored under appropriate conditions. The duration of storage is counted as of the sampling date.

4. STRUCTURAL MEASURES

4.1 General remarks

Depending on their function, inner shells are designed as structures

- without reinforcement or
- with reinforcement

A sealing layer can be applied to both types of structures.

As a matter of principle, a tunnel can be designed either as a watertight tube or as a drained structure. The design decision depends on the following considerations:

- the possibility of free, pressure-reduced or pumped drainage of ground or mountain water into a receiving body of water,
- the expected volume of water,
- the expected water pressure,
- the impact on the hydrological environment,
- the construction costs,
- and the operating and maintenance costs.

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

As a rule, inner shells of drained tunnels are made from non-reinforced concrete.

Reinforced inner shells are usually required for watertight traffic tunnels and tunnels in urban areas; for watertight tunnels, preference is given to waterproof inner shells (WDI).

4.2 Waterproof inner shell (WDI)

A waterproof inner shell (WDI) is a structural element impervious to water without application of a sealing. The concrete used has to meet the requirements of XC3 according to ÖNORM B 4710-1; moreover, special concrete properties (Table 2/3) as well as special structural measures (Table 4/1) and appropriate working methods (e.g. separating layers) have to be specified in order to avoid crack formation and water leakages as much as possible.

Inner shells qualify as waterproof if no more than a few traces of moisture are visible on the inner side (e.g. wet patches, local discolourings and shades of dampness not extending beyond 20 cm). Waterproof inner shells (WDI) must meet the requirements of class A1 of the ÖVBB Guideline on Waterproof Concrete Structures – White Tanking.

More substantial water leakages, which do not show signs of incrustation after a period of observation to be specified, have to be repaired through grouting.

According to the tunnel design, a grid-shaped reinforcement is to be provided for on both the air side and the rock side of the concrete cross section. If possible, reinforcing bar diameters of more than 20 mm are to be avoided. To ensure proper concrete placing, the mesh width of the reinforcement must be at least 100 mm.

RSV 9.35 applies to the concrete cover of the reinforcement. If a concrete cover of more than 10 cm on the rock-side reinforcement cannot be avoided in an underground cavity, one of the following measures has to be taken:

- Additional skin reinforcement (min. CQS5) is to be provided for in areas with a thicker concrete cover.
- The design reinforcement is to be adjusted to the cross section and the alignment of the structure.
- Advance filling of the over-excavated cross section with concrete.

The formwork surface as well as stiffenings and stabilisers of formwork must be adjusted to local requirements in terms of permissible stresses and strains.

Slippage in the hinges of formwork elements, service girders and formwork wagons is to be minimised.

For continuous anchor holes (e.g. in cut-and-cover method) sheet-metal sleeves and sealing systems are to be used to exclude the passage of water and to ensure permanent waterproofing of the structure.

The number of construction joints is to be minimised. For excavated cross sections of up to 50 m², use of a full-round formwork wagon is recommended.

Construction joints have to be sealed by means of waterstops.

Between concreting sections, movement joints with expandable waterstops, at least 30 cm wide, have to be provided for. The joint itself may be designed as a rigid joint or with a compressible joint insert.

Compressible joint inserts are to be placed at the interface of structures with different deformation behaviour.

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

4.3 Minimum structural requirements to be met by the floor and the abutment

In all types of floors the joints must be aligned with those of the arch concrete. Additional longitudinal joints in the floor are possible. Additional separations of the arch are also permitted.

Floor slabs must be at least 30 cm thick.

As regards the minimum reinforcement and the concrete cover of floor slabs, ÖNORM B 4700 and/or RVS 9.35 and/or RVS 9.32 apply.

If the inner shell is designed as a waterproof structure (WDI), the floor has to meet the same requirements as the arch.

If drained tunnels (tunnels with sealing layers) are to be equipped with water-impermeable floor slabs and waterproof concrete abutments, standard section lengths of up to 12.50 m – deviating from the values specified in Table 4/1 – are permitted.

4.4 Timing of concrete placement

The timing of concrete placement depends on the rate of deformation of the outer shell after installation of the support and on the toughness of the inner shell.

Based on empirical values, placing of the inner shell is possible without additional measures up to a rate of deformation of the outer shell of 4 mm per month.

Other considerations apply to tunnels in swelling rock. Any of the following additional measures may have to be taken:

- increase of the support resistance (higher concrete strength)
- placing of bubble film or non-wovens, installation of deformation elements
- structural measures (ductile reinforcement, uniform elongation > 5‰ according to ÖN B 4753, fibres).

4.5 Stripping strength in mined tunnels

Statically speaking, the compressive strength of the concrete at the time of formwork removal depends on the size of the cavity, the geometry of the inner shell, and the thickness of the inner shell.

Based on empirical values, a minimum stripping strength of 2.0 N/mm² in the crown area is required for design cross sections with radii of $\leq$ 6.00 m. For such cross sections with wall thicknesses of > 25 cm, this level of strength offers a sufficient degree of safety during construction also for sections over-excavated by a value corresponding to the wall thickness.

Additional proof of structural strength (e.g. beam on elastic foundation, with due consideration of overbreak) or a higher level of stripping strength are required in the case of:

- special cross sections (e.g. niches),
- larger curvature radii,
- irregular thickness of the lining, e.g. due to large overbreak,
- unilateral load concentration and/or chimney-type rock failure in the roof area, overbreak of longer sections.

Compressive strength tests are performed according to 3.4.3, e.g. by means of the pendulum hammer.

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

4.6 Stripping strength in tunnels built by the cut-and-cover method

The compressive strength of the concrete required for structural reasons at the time of formwork removal is to be demonstrated on a case-by-case basis.

To obtain the rate of deformation, the modulus of elasticity has to be established through testing (preconstruction testing).

Table 4/1 Minimum structural requirements to be met by inner shells (arch)

Criterion	**Arch**				
	without reinforcement		**with reinforcement**		**WDI "Waterproof inner shell"**
Sealing	**without**	**with**	**without**	**with**	
Min. thickness in cm	20[1)]	25[1)]	30[1)]	30[1)]	40[2)]
Standard section length[3)] in m	12.5[4,5)]	12.5[5)]	12.5[5)]	12.5[5)]	10[6)]
Min. stripping cycle [7)]	8 h	8 h	8 h	8 h	8 h[8)]
Standard stripping cycle	10 h	10 h	10 h	10 h	12 h
Measures to minimise cracking					
a) Separation layers	recom-mended	present through sealing	recom-mended	present through sealing	required
b)Reinforcement	-	-	according to RVS 9.32	according to RVS 9.32	according to RVS 9.32
Joint design	Rigid joint	Rigid joint	Rigid joint	Rigid joint	Waterstops required for construction and block joints[9)]
Evenness of substrate	-	acc. to Annex 4	sufficient to apply separation layer	acc. to Annex 4	Special measures[9)]
Min. design thickness of concrete cover	-	-	RVS 9.35		

1) Rock tips and anchor heads must not penetrate into the cross section of the inner shell by more than 5 cm. The required minimum design thickness of the concrete cover must be guaranteed (e.g. exchange of reinforcement).
2) In special cases with external waterstop 30 cm
3) Limitation of section length to avoid cracking and improve concrete quality.
4) Exceptions e.g. for penstocks (longer sections permitted).
5) Near portals and in sections with strong temperature fluctuations (e.g. shafts), cutting of dummy joints to reduce section length by half is recommended (see It. 5.2.2).
6) Shorter connecting sections are to be provided for at the transition to structures with substantially different deformation behaviour.
7) See It. 3.1.3 and special measures according to It. 7.2.2.
8) Applicable only if C_3A-free cement is used (for hydration heat, not for sulphate resistance)
9) see detailed explanations in It 5.1.2.

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

5. PREPARATIONS FOR CONCRETE PLACING

5.1 Preparing the substrate

5.1.1 Ingress of water

Running water and water dripping from surfaces must be drained prior to concreting in order to prevent fines and binder being washed out and to avoid the build-up of water pressure during concrete placing.

The following measures can be taken:

5.1.1.1 Floor

- Placing of drainage strips, drainage bodies, drainage layers and drainage lines, e.g. gravel with a low fines content, pervious concrete, and the like.
- Water to be drained via longitudinal drainage lines and construction drainage systems or through pumping.

5.1.1.2 Crown and wall areas

- Adequately sized hoses connected to drainage systems (centre split pipes are to be used in exceptional cases only)
- Surface drainage systems (bubble film, non-wovens, foils, etc.)
- Complete sealing.

Sealing of the structure also offers the necessary protection of young concrete against the ingress of water.

5.1.2 Evenness of the concrete substrate

Prior to concrete placing, the substrate must be prepared appropriately both in the arch and floor areas.

In the case of umbrella sealings and/or watertight sheet sealing systems (with or without reinforcement), the evenness of the substrate must be ensured through the measures specified in Annex 4. In the case of saw-tooth excavation lines (grout curtain), the block joints should be aligned with the offset of the saw-tooth profile.

For waterproof inner shells, the air-side surface of the substrate (e.g. sliding film on sprayed concrete) should be such as to minimise interlocking between the waterproof inner shell and the sprayed concrete shell. In inner shells designed to take constraining forces, favourable conditions are deemed to exist if the depth from a measuring rod is less than 10 cm. A straight, 4 m measuring rod is to be used in the longitudinal direction of the tunnel; radially, a curved measuring rod is to be used, its curvature corresponding to the design radius and its length corresponding to an angle of 45°. The flank inclination of an unevenness must not exceed 1 : 10 relative to the measuring rod. If these requirements are not met, cracks must not be wider than 0.2 mm.

Anchor heads have to be grouted; compliance with the above surface criteria of the concrete substrate is required.

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

5.1.3 Preparation of the concrete substrate

Dirt and loose particles must be removed from the concrete substrate (e.g. sprayed concrete or rock, segmental lining).

Precautions must be taken to prevent cement slurries from penetrating into drainage systems and filter bodies.

If the floor is based on a rock foundation, loose material must be removed from the rock surface; if necessary, the rock surface is to be cleaned by means of compressed air or, conditions permitting, an air-water mixture.

In case if a loose soil foundation, the floor must be true to cross section; if necessary, the floor surface has to be drained through pumping and soaked areas have to be exchanged and compacted. If reinforcement is required, a granular sub-base must be installed.

5.2 Concrete joints

5.2.1 Construction joints

Construction joints are joints with or without friction locking resulting from the sequence of construction operations. If possible, construction joints in reinforced inner shells should be either vertical or horizontal. Generally speaking, all construction joints are to be cleaned (air, water or air-water mixture) before concrete is placed in the adjacent section.

As a rule, the transition to the contiguous concrete section must be „smooth“ as defined in ÖNORM B 4700, Section 3.4.4.5. Additional requirements have to be specified in the design documents.

Waterstops are required for construction joint (e.g. joint between floor and arch) in waterproof inner shells.

Under difficult conditions, the possibility of grouting of the contact surface is to be provided for.

5.2.2 Movement joints

Movement joints are structural joints with (expansion joint) or without (rigid joint) joint fillers. For rigid joints in inner shells, see Fig. 5.1. Rigid joints without waterstops can be used in the arch area of sealed tunnels. Compliance with the joint width specified in ÖNORM B 3800-4, It. 3.1, is not mandatory.

If movement joints are executed as dummy joints, the cross section of the structural component concerned is reduced by at least one third of its design thickness. Dummy joints must be cut early enough to avoid cracking due to constraining forces as much as possible. Moreover, the concrete must be sufficiently set to obtain clean cutting surfaces.

Shuttered movement joints have to be cleaned, if necessary. If joint inserts (foam panels, soft-fibre panels, stone wool panels) are used, these must be placed over the entire surface without spaces in between (bonding). The project-related fire protection requirements have to be observed.

In reinforced inner shells the profile of the inserted fillet must be such as to guarantee the required overlap of the reinforcement (e.g. triangular fillet).

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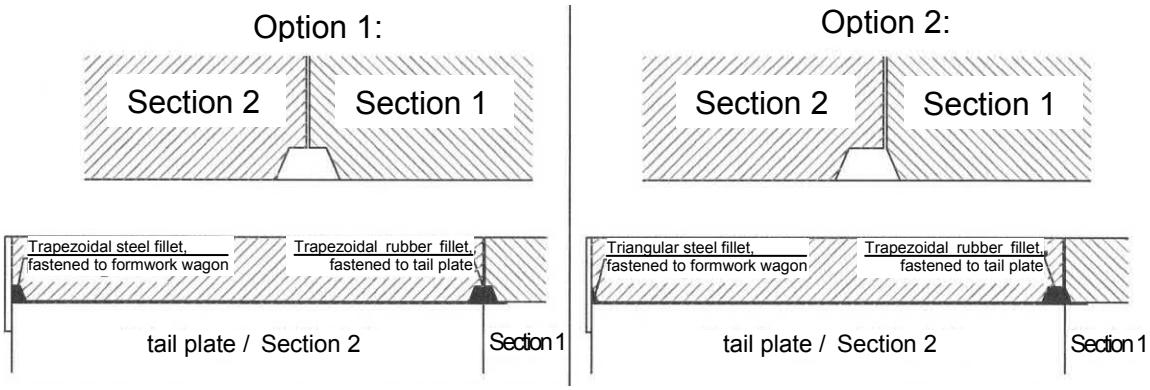


fig. 5/1 Examples of joints in inner shells of traffic tunnels

5.2.3 Joint sealing

The choice of material depends on the specific requirements as regards ease of working, fastening to sealing sheet webs, expandability, resistance to chemicals, and ageing.

All waterstops have to be transported, stored and placed according to the manufacturer’s instructions.

The width of the waterstop must be at least 30 cm and not more than 35 cm; a minimum thickness of 5 mm in the expansion area is required. The position of the waterstops must be indicated in the design drawings.

Except for the waterstop width, the requirements of It. 4.6 of the ÖVBB Guideline on Waterproof Structures – White Tanking have to be complied with for waterproof inner shells. Other than provided for in the Guideline, a minimum waterstop width of 30 cm – 35 cm is required for all water pressure classes.

Careful and watertight jointing of all waterstops to each other (expansion waterstop with external waterstop, expansion waterstop with swellable waterstop, etc.) is essential. All waterstops in contact with the sealing material must be compatible with the latter.

Waterstops have to be fastened in the desired position to prevent displacement in the course of concrete placing. To fasten the waterstops, the fastening devices provided by the manufacturer have to be used and/or the special placing requirements are to be observed. Waterstops have to be cleaned prior to placing of the concrete for the subsequent section

Halves of waterstops projecting from a concrete section must be cleaned thoroughly before concrete is placed in the contiguous section. If concrete placing in the neighbouring section does not follow immediately, the waterstops must be protected by appropriate means. Forms and formwork overlaps must be as tight as possible in the area around the waterstops to prevent leakage of cement slurry and fines.

In reinforced inner shells, the necessary overlap of the reinforcement must be ensured over the entire joint area.

In waterproof inner shells, grouting hoses are to be placed with all waterstops. Grouting with suitable substances may be necessary.

5.2.3.1 External waterstops

External waterstops must rest solidly on the formwork, the improved subgrade, the sealing, the sprayed concrete surfaces or other surfaces, the area of contact being clean and as plane as possible. In the floor area, special care must be taken to keep the web plates of the waterstops

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clean. To ensure that external waterstops in the roof area are fully functional, grouting hoses are to be provided for in the design.

As a rule, internal waterstops are to be used. However, if external waterstops are required (welding of sections with sealant sheeting – bulkheads), the possibility of subsequent grouting of cavities is to be provided for (e.g. waterstop with grouting hose).

5.2.3.2 Internal waterstops

In non-reinforced concrete (e.g. floor) the waterstop is to be secured in place by means of an ancillary device. Placing of additional grouting hoses is recommended, as they permit subsequent sealing of leakages through grouting. The use of swellable waterstops may be appropriate, since fastening in non-reinforced concrete requires additional measures.

5.2.3.3. Swellable waterstops

Swellable waterstops prevent water leakages, as they swell when in contact with water.

The swelling of waterstop materials must be sufficiently reversible (swell factor of the effective sealing material min. 200%); moreover, an appropriate swelling time and sufficient stability under higher water pressure or under the impact of major joint movements are essential.

Swelling must be reversible and independent of the chemical composition of the contact water. For joints exposed to substances other than water, the manufacturer has to demonstrate the sealing effect and the chemical resistance of the product. The component reacting with water must not be washed out or release deleterious substances into ambient water. It is important to bear in mind that swelling takes some time, which means that the sealing effect is not produced immediately.

The concrete surfaces on which swellable waterstops are to be placed should be as even as possible and free of pockets. The manufacturer's instructions are to be followed carefully. Preferably, waterstops are to be placed in grooves to keep them in the desired position.

- Swellable waterstops are to be placed in such a way as to protect them from uplift in fresh concrete.
- The structure of the substrate must not be disturbed by the swellable waterstop being fastened.
- The waterstop must be fastened on the substrate so as to prevent seepage also when not swollen. On a rough substrate, this can be achieved through the use of swellable putty, one-component PU putty or two-component bonding putty based on epoxy resin.
- Early swelling of waterstops prior to concrete pouring is to be prevented.
- As a rule, swellable waterstops are to be placed centrally in the concrete cross section; if this is not possible, a distance of at least 10 cm must be maintained on each side.

In traffic tunnels exposed to the risk of accidents involving hydrocarbon-containing liquids, swellable waterstops for the floor area must be resistant to hydrocarbon.

5.2.3.4 Grouting hoses

- Grouting hoses have to be placed in such a way as to protect them from uplift in fresh concrete.
- The grouting hoses (e.g. diameter, length) are to be adjusted to the grouting material to be used.

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5.2.3.5 Repair of joints and waterstops

If construction joints or expansion joints become pervious to water and/or waterstops are damaged, the following repair and/or maintenance measures have to be taken:

a) Water-permeable construction joints

If self-healing does not occur in water-permeable construction joints, grouting is necessary. It. 7.5 (repair or waterproof concrete) applies by analogy.

b) Water-permeable expansion joints

As regards the repair of expansion joints, the measures to be taken depend on whether the problem is due to leakage at the legs of the waterstop or a defect in the expansion area.

Leakages can be eliminated through

- grouting in the area of the legs of the waterstop
- grouting directly above the waterstop

If a leakage occurs at the legs of the waterstop, grouting of the defective spot by means of a bore packer is advisable. Epoxides, polyurethanes or acrylates can be used for this purpose. The choice of material depends of the requirements of the specific case.

Grouting can also be performed directly above the expansion joint. To this end, the expansion joint must be closed with a plastic hose over its entire length. Epoxide mortar has to be applied to prevent displacement of the hose under grouting pressure. Expansion joint grouting is performed via the plastic hose or by means of a bore packer via the joint flanks.

If the waterstop itself is damaged, it can be repaired according to c), provided the waterstop can be exposed. If these methods do not produce the desired success, a second sealing layer must be installed on the air side, with the expansion joint kept free from water through temporary measures (provisional sealing). This can be achieved through either flanging or bonding. To this end, flexible plastic strips are friction-locked to the concrete body at the flanks in waterproof fashion or bonded by means of epoxy resin.

c) Damaged waterstops

To repair a waterstop, the damaged area first needs to be exposed. After successful repair, the exposed areas of the waterstop have to be reprofiled by means of waterproof mortar (e.g. epoxy-resin mortar) to achieve friction-locking. Minor damage to PVC and PVC/NBR waterstops can be repaired with „patches“ welded onto the damaged part by means of hot-air blowers. Waterstops made of elastomers can be repaired through vulcanisation. If larger parts of the waterstop are damaged, these are to be bonded with a suitable piece of overlapping waterstop through thermal welding or application of an adhesive (polyurethane). If the damaged area of the waterstop is too large to permit overlapping and bonding, the damaged waterstop must be removed and replaced through flanging. If swellable waterstops are damaged, they must be replaced in all cases.

5.3 Intermediate layers between the substrate and the concrete

Intermediate layers between the substrate and the concrete include separation layers, sheet drainage systems and sealing layers.

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5.3.1 Laying and fastening

The individual webs of the intermediate layers have to overlap in such a way as to allow free drainage of mountain water behind the webs without contact with fresh concrete. In the case of a stronger ingress of water, hose drainage is to be provided for in order to avoid the formation of water pockets behind the intermediate layer. The edges of the individual webs must be either bonded or overlapped to prevent the penetration of concrete into the space between the intermediate layer and the rock and/or the sprayed concrete shell.

The intermediate layer must be fastened so as to prevent it from being displaced by the rising concrete or torn off the fastenings. As a rule, special nails are used for fastening.

As regards sealing, the specifications of RVS 8T, and additionally Issue 365 of Straßenforschung [1], apply.

5.3.2 Separation layers

Separation layers serve to diminish the adhesion and interlocking between the cavity lining and the rock and/or the sprayed concrete lining. They are used mainly in combination with non-sealed inner shells. They serve to diminish the build-up of restraint stresses in the cavity lining in the course of the setting process and the resulting crack formation. As a rule, mesh-reinforced, thin plastic sheeting, film-covered non-wovens or bubble film according to [1] are used.

5.3.3 Sheet drainage systems

Sheet drainage systems permit low-resistance drainage of mountain water to be collected in drainage lines (see ÖVBB Guideline on Tunnel Drainage Systems). As a rule, structured plastic panels (bubble film), special non-wovens or drain elements are used for this purpose.

5.3.4 Sealing layers

The installation of sealant sheeting permanently prevents the ingress of water into the cavity.

As regards the execution and testing of sealing layers, RVS 8T, and additionally [1], apply.

5.4 Formwork

Given the straight ground plan of most formwork elements, curves take a polygonal course. Permissible geometrical tolerances are to be observed.

In formwork design, care must be taken to ensure that dynamic strain through formwork vibrators, hydrostatic fresh-concrete pressure (e.g. uplift) and hydraulic pump pressure upon closure of the roof via the pump flanges does not result in unacceptable deformations of the formwork skin and the roof formwork.

All formwork must be set up according to the design as a stable and waterproof system. Formwork vibrators require a particularly stiff formwork and rigid fastening for the vibrations to be transferred to the concrete. Special care must be taken when executing formwork for facing concrete. Formwork edges are to be executed with great care (e.g. through insertion of triangular fillets).

Prior to its use, formwork must be cleaned thoroughly and treated with a suitable release agent to ensure that residues of the outer concrete skin do not stick to the formwork. The release agent applied to the formwork must not cause any physical or chemical damage to the concrete

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surface (e.g. dust formation). Wooden formwork is to be wetted or impregnated before the concrete is poured.

Elements used to lock formwork across concrete parts are to be laid in pipes to permit easy removal. The remaining openings are to be waterproofed (e.g. through grouting) and carefully sealed. For waterproof concrete components, watertight formwork anchoring systems are to be used.

5.4.1 In-place formwork

If the use of travelling formwork is not economically justifiable on account of the small number of standard concreting sections or the changing shape of the cross section, in-place formwork is used.

This type of formwork is assembled from prefabricated elements. Pre-bent or polygonally assembled steel girders or wooden structures are used as service girders. To move the formwork, the components are lowered via wedges and/or spindles; parts of the formwork may have to be dismantled by means of rope winches or hoists.

5.4.2 Travelling formwork

For longer standard sections the use of travelling formwork, which can be moved either mechanically or hydraulically, is used to save time and keep costs down.

Travelling formwork can be designed as full-round wagons or split formwork wagons. Arch formwork is placed on structural components concreted in advance. The wagons used for smaller cross sections (up to approx. 20m²) take up, place and remove the self-supporting formwork skin elements block by block. For larger cross sections, the formwork wagon is often assembled with the complete formwork skin for the entire length of the concreting section and serves both as a transport wagon and a stiffening structure during concrete pouring.

5.5 Release agents

As a matter of principle, release agents must be environmentally safe and compatible with the formwork material used. Preference is to be given to chemically/physically active release agents. Wax solutions and pastes may form a particularly resistant release film of great adhesive strength, which is essential if the formwork remains in place for a long time and is exposed to heavy stress and strain while the reinforcement is laid. Release agents must be applied to the thoroughly cleaned steel formwork in thin layers. Moreover, release agents must contain anti-corrosive additives (inhibitors).

The release agent used is to be compatible with paint coats and other coatings which may be subsequently applied.

Release agents must bear clear and indelible labels indicating the group of substances used. If dilution is permitted, the dilutant to be used and the degree of dilution are to be indicated. The following information should be specified on the label:

- instructions for use
- average quantity to be applied
- effect of overdosage
- instructions for the removal of residues of the release agent from the concrete surface
- fire hazard (hazard class), shelf life and storage conditions.

Moreover, the presence of hazardous substances is to be specified on the label.

For each delivery, the following information is to be specified on the container:

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- batch number,
- year and month of production,
- shelf life.

5.6 Reinforcement

In the case of self-supporting reinforcement, care must be taken to ensure adequate stability of the load-bearing structure.

The position of the reinforcement, as indicated in the design drawings, is to be secured through adequate measures, while keeping impairments to concrete placing to a minimum (exchange of reinforcement at the openings for pouring and vibrating is necessary). Overlaps of reinforcement mats should not be placed near concreting flanges and/or observation windows. The spacing between the reinforcement layers is to be maintained through basket supports or similar devices.

Overlaps of reinforcing mats must be arranged in such a way as to avoid the superposition of four mat layers (impairment of concrete placing).

RSV 9.35 applies to the concrete cover and its inspection.

The air-side concrete cover is to be ensured through the use of suitable spacers according to RVS 9.35 (e.g. triangular concrete fillets, min. 1/m²). The concrete spacers used must be long enough to extend over at least two neighbouring reinforcement bars which do not cross each other. The quality of the spacers must correspond, at least, to that of the inner shell concrete. Reinforcement overlaps must be positioned in such a way (moveable) as to prevent destruction of the spacers through formwork pressure.

5.6.1 Sealed inner shells

As a rule, reinforcement is not provided for in sealed inner shells. If reinforcement is required for structural reasons, the following design variants, depending on the conditions of the cavity in question and the sequence of construction operations, are possible:

- self-supporting reinforcement
- reinforcement fastened by means of a disk in offset position on the sealing (plane of weakness between disk and sealing is required)
- reinforcement laid on formwork; reinforcement with erection head and through-sealing (special case)

Care must be taken to ensure proper fastening of the reinforcement in front of the sealing layer in order to prevent damage to the sealing through displaced or bent reinforcement rods during concrete placing.

5.6.2 Inner shells without sealing

In inner shells without sealing, reinforcement is usually installed via assembly hooks drilled from the outside and longitudinal reinforcing rod spacers.

5.7 Construction tolerances

The actual geometry of the soffit (air-side) after completion of the lining may deviate from the design geometry to a certain extent (tolerance). This is due to unavoidable inaccuracies in site surveying and formwork erection. Moreover, the formwork wagon, the geometry of which is dimensionally inaccurate, experiences a certain amount of deformation during concrete placing. In tunnel curves the ideal ground-plan geometry is reproduced through a polygonal arrangement of the concreting sections. Except for the area of block joints, this results in a calculable lateral

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narrowing of the design cross section. (In the case of narrow curve radii, the geometry of the block sections is to be taken into account already during tunnel excavation.)

In bored traffic tunnels (with TBM), the provisions of the relevant Guidelines [5,6,7] are to be observed.

Given the unavoidable inaccuracies in construction practice, tolerances are to be calculated according to the following models:

5.7.1 Surveying tolerances

Given the unavoidable formwork surveying inaccuracies, tolerances must be taken into account.

Tolerances depend on:

- surveying possibilities (closed or open traverse)
- length of the tunnel

In view of the above, the tolerances required for construction practice are classified as shown in Table 5/1:

Tolerance class A1	Closed traverse: Surveying of a traverse with a starting point and an end point is possible (tunnel already cut through, with pilot gallery)
Tolerance class A2	Open traverse: Surveying of an open traverse only (e.g. placing of inner-shell concrete in a tunnel not yet cut through) Calculation of the break-through error is required. The accuracy depends on the tunnel length (TL). TL is defined as the sub-length until closure of the traverse.

5.7.2 Formwork tolerances

Tolerances must be taken into account during formwork erection due to dimensional inaccuracies and construction tolerances. These inaccuracies depend on the size of the formwork and are classified as follows:

B1	Inaccuracies in formwork production
B2	Inaccuracies in formwork erection
B3	Deformation of formwork during concrete placing

5.7.3 Geometrical tolerance

For tunnel cross sections in curves, the tolerances resulting from lateral narrowing due to the block polygon of the formwork wagon must be taken into account. These tolerances depend on the block length (L), the design width of the clearance (B) and the curve radius (R) of the tunnel axis; they are calculated according to the following equation (dimension in mm):

$$C = R + \frac{B}{2} - \sqrt{2,(R+\frac{B}{2})^2 - (\frac{L}{2})^2}$$

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5.7.4 Total tolerance

The projected geometry of the soffit of the tunnel lining must exceed the required minimum geometry by the sum total of the individual tolerance values listed in Table 5/1 (see example in Annex 2). The formwork and, if applicable, the reinforcement have to be designed accordingly. The tolerances taken into account are to be specified in the design drawings. Any other tolerances required are to be taken into account in the course of project execution.

Upon acceptance of the work, the minimum geometry required is to be demonstrated.

The geometrical tolerance is calculated by summing up the individual tolerances. Surveying tolerance A1 or A2 is to be selected, as applicable. The corresponding formwork tolerance B1, B2 or B3 and the geometrical tolerance C are to be added up and, together with the corresponding value for A1 or A2, represent the total tolerance.

Beyond the tolerance values, the soffit of the finished lining should not deviate from its design position by more than 10 cm at any point, measured in radial direction. For galleries, structures of minor importance and structures not under load from equipment mounted in the roof area, larger deviations are permitted, provided they do not occur abruptly.

The minimum thickness and/or design thickness of the lining must be complied with throughout the structure. Values below the required minimum (according to Table 4/1) are permitted in isolated spots (e.g. around anchor heads). In view of a possible deviation of the lining from the design geometry, corresponding allowances are to be provided for in the outer shell and/or the excavated rock surfaces.

An accuracy of $\pm$ 2.5 cm is required for prefabricated parts, cable ducts, installations and niche sizes. Niches must be positioned to an accuracy of $\pm$ 10 cm.

After completion of the inner shell, a new reference axis can be defined to optimise further support work.

Table 5/1 Tolerances for inner shells

Surveying tolerances				**Formwork tolerances**							**geometr. tolerances**
	A1	**A2**		**B1**		**B2**			**B3**		**C**
		TL[1] ≤ 1000 m	TL[1] > 1000 m	F[2, 5] ≤ 50 m²	F[2, 5] > 50 m²	Arch	Floor Type 1[3]	Floor Type 2[4]	F[2, 5] ≤ 50 m²	F[2, 5] > 50 m²	[± mm]
Position	±10 mm	±20 mm	±10 mm additional per 1000 m TL[1]			±20 mm	±20 mm	±50 mm	±10 mm	±20 mm	Equation acc. to It. 5.8.3
Height	±10 mm	±10 mm				±20 mm	±20 mm	±50 mm	±10 mm	±20 mm	
Radial				±10 mm	±15 mm						

1) TL Tunnel length until closure of traverse
2) F Cross section of clearance
3) The floor is not part of the outer shell.
4) The floor is part of the outer shell and is concreted in the course of tunnel driving.
5) To be taken into account for the floor only if full-round formwork wagon is used.

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

6. PRODUCTION AND PLACING OF CONCRETE

6.1 Mixing plant

Preconstruction testing of the mixing plant and on-site production testing are to be performed by an accredited inspection body or a qualified representative of the principal.

The mixing plant must be equipped with a microprocessor control system according to ÖNORM B 4710-1, It. 9.6.2.3.

- Storage and printout of mix formula
- Logging of all dosages of constituent materials for a batch or filling, including deviations from target weights.
- Measurement of the water content of at least 90% of the grain fraction under 4 mm by means of measuring probes with a tolerance range of $\pm$ 0.5% by weight and automatic correction of water added. The average water content of the remaining grain fractions is to be considered separately.
- Checking of actual and target values of all concrete components of each batch or filling, including deviations from target weights. The tolerances of Table NAD 12 b of ÖNORM B 4710-1 apply.
- Batch protocol: protocol number, delivery note number, date, time of day (beginning of mixing), formula number, batch size (quantity), mixing time, fresh-concrete temperature, actual and target weights of all concrete components, moisture, set tolerance, deviation of actual value from target, total water content, W/B value, residual water.
- Concreting protocol: the following data must be recorded, stored and printed out clearly upon request for the period of time and/or construction section selected:
  total number of batches, batches with dosage deviations from target weights or manual switching, mean value, maximum and minimum, standard deviation of weight of all concrete components (cement, additives, admixtures, total water, mineral aggregates) compared with target quantity, construction site, structural part, concrete grade, formula number, concreting time, mixing time, fresh-concrete temperature (for model protocol see Annex 1).
- A comparison of the batches with deviations from target weights and manual switching with the total number of batches provides an indication of the performance of the mixing plant. The statistical records of the weights of constituent materials used serve to demonstrate compliance with the required concrete composition for the section concerned and constitute a verifiable system of quality control. Actual weight errors are permitted in a maximum of 10% of the total number of batches, provided the dosing accuracy for the filling of the mixing plant is observed.
- If possible, the fresh-concrete temperature in the mixer is to be kept within a range of 13°C and 18°C to obtain concrete of good quality. In periods of hot weather, simple cooling measures, e.g. covering the sand to protect it from solar irradiation and/or spraying of coarse-grained aggregates, may have to be applied. Concrete with a fresh-concrete temperature of less than +5°C (at outside temperatures < 3°C) or more than +27°C (measured at the construction site, e.g. before pumping) must not be placed. If the fresh-concrete temperature is higher than 22°C, all other conditions should be as favourable as possible (see Table 3/1). For arch concrete a minimum fresh-concrete temperature of +10°C is required.

During the hot season, cooling of fresh concrete (e.g. nitrogen cooling, large-scale storage sites of mineral aggregates) may be necessary to comply with the maximum fresh-concrete temperature requirement (to be indicated in the tender documents).

If concrete is placed in winter, the water or the mineral aggregates have to be heated to a sufficient temperature. The mineral aggregates have to be mixed with water which has been pre-heated to a temperature of over 60°C.

The minimum mixing time in the mixer is 30 seconds.
The aggregate bin of the mixer must be covered to protect it from rain and snow.

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6.1.1 Stand-by mixer

Stand-by mixers are to be used only in the event of failure of the main mixer. The type of stand-by mixer is to be indicated prior to the beginning of concrete placing.

Stand-by mixer type 1: only permitted for completion of the structural component under construction (mixer and concrete grade according to ÖNORM B 4710-1). The concrete formula to be used is to be specified before concrete placing is begun.

Stand-by mixer type 2: mixers for short-term use (maximum of 3 concreting days) in the event of failure of the main mixer. These mixers have to meet the requirements of ÖNORM B 4710-1. Preconstruction testing of the concrete according to It. 3.3 of this Guideline is required. The frequency of conformity testing must be twice as high as the testing frequency specified in Table 3/7.

Stand-by mixer type 3: mixers meeting the same requirements as the main mixer in terms of mixer design and concrete grade.

6.2 Transport

Fresh concrete is to be protected from climatic influences during transport. Concrete of consistency classes > F38 must not be transported by means other than truck mixers.

Depending on the cement grade used, the concrete temperature and the air temperature, ready-mix concrete usually has to be placed after 105 minutes, at the latest. If this period is exceeded, evidence of prolonged workability (VV) must be produced. If concrete placing is interrupted for more than 3 hours (e.g. failure of a concrete mixer), timely vibration of the surface and execution of a construction joint are required.

6.3 Conveying, placing, compacting

6.3.1 Conveying

As a rule, arch concrete is conveyed by means of pumps; if suitable relay pumps are available, it can be pumped over a distance of up to 1500 m. If long pump hoses and relay pumps are used, a sufficient allowance for the required placing consistency and compliance with the required void content of the concrete are necessary.

In case of non-compliant consistency (loss of water, stiffening), correction is possible through the addition of a suitable plasticiser (to be kept in store if long pump hoses are used).

6.3.2 Placing

Arch concrete can be placed by means of a through-type concrete distributor, distributor pumps or manual handling via filling flanges.

The rate of concreting and the difference in concrete levels depend on the structural design of the formwork wagon. As a rule, the maximum rate of vertical rise is 2.0 m/h, with the maximum difference in concrete levels being approx. 1.0 m.

As a rule, the horizontal distance between the concreting window and the filling flange is 3.0 m.

Maximum head (distance of the pouring outlet of the concrete conveyor from the concrete level) 2.0 m.

The height of the individual concrete layers in the wall area must not exceed 0.5 m.

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

In case of manual handling of the concreting hose, the concrete stream is to be directed at the fresh concrete.

Flush closure of the roof is to be aimed at.

To check the quality of concrete placement in the roof area, inspection tubes are to be installed in longitudinal direction every 3.0 m to 4.0 m, the top of which must not be more than 2 cm from the highest point of the outer arch.

In the event of scheduled interruptions of concrete placement in the inverted arch, evidence according to ÖNORM B 4710-1, It. 4.2.7, is to be produced in respect of the maximum duration of the intended interruption.

6.3.3 Compaction

Concrete compaction is to be performed by means of high-performance internal or external vibrators. Depending on the formwork wagon design, formwork vibrators are to be positioned as regularly as possible, with one vibrator for approx. 3 m³ to 4 m³ of formwork skin.

The capacity of the vibrators is to be such as to ensure proper compaction of the arch concrete to its design thickness. Experience has shown that the effective depth of vibration is 40 cm to 50 cm. Only the formwork vibrators positioned at or around the concrete level and, at most, those immediately below are to be operated at the same time.

If necessary, the density of formwork vibrators is to be increased in the construction joint between the floor and the arch and/or in formwork areas where the formwork comes to rest on parts of the structure already completed.

Specific compaction schedules are to be elaborated for arch concrete, fibre-reinforced concrete for non-reinforced and reinforced inner shells, sealed reinforced inner shells, and waterproof inner shells.

7. REQUIREMENTS AND MEASURES AFTER CONCRETE PLACING

7.1 Stripping

The provisions of It. 3.1.2 and 4.6 are to be observed. The stripping time refers to the internal formwork of the arch concrete. As a rule, formwork on the face of the arch is removed after 4 – 5 hours so that the development of compressive strength can be observed.

After the removal of the internal formwork, forms usually remain in place for a longer period of time in niches and similar construction features, depending on their shape and size.

To prevent damage to edges, ring joint profiles, unless firmly attached to the steel formwork, also remain on the concrete for a longer period of time.

7.2 Concrete curing

7.2.1 Standard curing

As a rule, liquid curing agents according to RVS 11.064, Part II, are used for curing of inner shell concrete. The curing agents are to be applied in sufficient quantities over the entire surface as early as possible, preferably by spraying. Care should be taken not to impair the bonding of paint coats or other coatings to be applied at a later point in time. To prevent excessive cooling and drying, measures have to be taken to diminish strong air flows (e.g. covering a tunnel

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portal). Curing is not necessary, if air humidity is relatively high (> 90%) and the rate of air flow is low (≤ 1 m/s).

7.2.2 Special measures

If the formwork is removed prior to the standard stripping time, evidence must be provided of equivalent curing measures to protect the concrete immediately after stripping against rapid cooling for at least 3 days and against drying for at least 7 days in order to ensure sufficient hardening of near-surface areas under construction-site conditions and to avoid crack formation.

A multi-chamber curing wagon [2] with heat insulation and water-vapour spraying can be used for curing. The design of the control system (temperature- or time-dependent) must be such as to permit cooling of the concrete to ambient temperature within 3 days after stripping in approximately equal increments.

7.3. Concrete surfaces

7.3.1 Requirements

Concrete surfaces of inner shells have to meet the requirements of ÖNORM DIN 18202 in terms of dimensional, geometrical and positional tolerances. The requirements for facing concrete S, P and F according to ÖNORM B 2211 do not have to be met.

In wall areas, under inclined forms, voids of up to a void diameter of 2 cm cannot be avoided in practice and have no deleterious effect. In the case of reinforced inner shells, the depth of the voids must not exceed 1 cm. If the concrete surface has to meet special requirements, e.g. architectural design or resistance to frost-thaw cycles, additional measures have to be taken (e.g. non-wovens for drainage, paint coats).

7.3.2 Repair measures

Minor defects, which do not adversely affect the fitness of the finished structure for its intended use, do not need to be repaired. If repair measures have to be performed, it is important to bear in mind that the removal of a thin surface layer of concrete, e.g. by grinding, is always preferable to the application of a thin layer of mortar. This holds, in particular, for larger, shallow defective areas (see ÖVBB Guideline on Formed Concrete Surfaces).

When repairing defects (e.g. concreting pockets, voids deeper than 1.0 cm or deeper than 1.5 cm in non-reinforced inner shell concrete), the provisions of the ÖVBB Guideline on the Maintenance and Repair of Plain and Reinforced Concrete Structures regarding the preparation of the substrate and the materials to be used for repair (coatings, reprofiling mortar) have to be observed.

Large areas with defects to a depth of ≥ 2 cm have to be repaired by spraying them with suitable reprofiling mortars, e.g. to obtain the necessary concrete cover.

Continuous cracks > 0.3 mm in reinforced inner shells have to be friction-locked through grouting (e.g. fine cement, to be applied according to ZTV-RISS).

In non-reinforced inner shells grouting is not obligatory, if evidence of the safety of the structure is produced.

In traffic tunnels, unavoidable offsets of individual concrete sections of the inner shell against each other are usually concealed through joints (see It. 5.2.2). Defects in joints are to be repaired and levelled through grinding.

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For filler openings (filling flanges) deviations from the design inner surface of up to 1/5 of the concrete cover and/or a maximum of 5 cm are permitted. This also applies to reinforced inner shells, as the reinforcement is cut out and exchanged. The required thickness of the inner shell must, however, be observed in waterproof inner shells.

7.3.3 Surface protection

For additional protection of the concrete surfaces of inner shells, impregnating layers, sealings, paint coats or other types of coatings can be applied. Protective measures are particularly recommended in road tunnels for the lower part of the cross section (walls) and the portal areas to improve resistance to frost and thaw cycles (see ÖVBB Information Sheet on Coatings for Inner Shells of Tunnels).

The Information Sheet contains recommendations regarding the selection, assessment and application of such products as well as the preparation of the concrete surface (exposure of the granular skeleton through sand blasting or by means of water jets).

7.4 Grouting of the roof cavity and other arch areas

Once the arch concrete has sufficiently set, the cavities in the roof area are grouted at low pressure (ca. 1 – 2 bar) with stable binder slurry via the grouting holes. Grouting is considered to be complete when slurry starts to exit from the nearest tubes.

A stable binder slurry has to meet the requirements of Table 7/1. The parameters have to be established before grouting is begun.

Table 7/1 Requirements to be met by stable binder slurry

Requirements	**Test**
Water-binder value /W/B value) max. 0.80	Reduction roasting
Water segregation max. 10% after 2 h	1000 ml column
Viscosity (Marsh funnel) min. 30 sec	Marsh funnel
Compressive strength min. 15 N/mm² after 28 days [1)]	Cylinder d= 100 mm /d:h = 1

1) Testing for compressive strength is only required if the water-binder value of 0.80 is exceeded.

As an alternative for sealed tunnel sections, backfilling of the roof cavity by means of a hose produced and installed in the roof especially for this purpose, with a connecting flange at the end of the section, is possible.

In reinforced and sealed inner shells, care must be taken to ensure sufficient grouting of cavities between the sealing and the reinforced arch component. Grouting must be performed before the temporarily lowered mountain water is again raised to its normal level. Systematic grouting of abutments, walls and floor/arch transition areas may be necessary, in addition to grouting of the roof cavity. This measure serves to prevent damage to the sealing by exposed reinforcement.

7.5 Repair measures in waterproof concrete

If water-permeable cracks and/or unacceptable patches of moisture occur in structural components made of waterproof concrete (floor and abutments), the following maintenance and repair measures have to be taken:

If the rate of water flow is low and the crack flanks do not move to any significant extent, it is advisable first, if possible, to wait and see if the crack closes through self-healing. If not, grouting of defects has to be performed in due time. The materials best suited for grouting are

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epoxides, polyurethanes or acrylates. The choice of substance depends on the specific requirements and must be approved by the principal. Grouting is performed via grouting anchors fastened through bonding along the crack or drilled laterally at an angle of 45°. To prevent grout from escaping, the crack is closed with a filling compound between the packers. Grouting is performed from bottom to top until grout starts to escape from the next higher packer. After grouting, the filling compound and the packers are removed and drill holes, if any, are closed.

8. SPECIAL PROCEDURES

8.1 Sprayed concrete inner shells

Sprayed concrete for inner shells is to be produced and placed according to the ÖVBB Guideline on Sprayed Concrete. Moreover, the following supplementary provisions apply:

Fibres:
Steel fibres, also used in combination with steel reinforcement, primarily serve to improve the post-cracking behaviour of the concrete (testing for load-bearing capacity or functional properties of the finished structure according to the ÖVBB Guideline on Fibre-Reinforced Concrete). Glass and plastic fibres may serve to diminish early shrinkage cracking. Plastic fibres increase the fire resistance of concrete by reducing spalling.

Wet mix:
The water-binder value must not be higher than 0.50.

Design:
Sprayed concrete for tunnels with a single-pass lining ("monocoque design") has to meet the following requirements:

Sprayed concrete for the outer shell:
at least SpC 20/25(56)III/XC4/J_1 or J_2.

Sprayed concrete for the inner shell:
at least SpC 20/25/III/XC4, XF3 if necessary.

The frequency of conformity testing corresponds to Class III according to the ÖVBB Guideline on Sprayed Concrete.

If the outer shell is required to form a composite structure with the inner shell, the adhesive strength has to be at least 1.0 N/mm² according to the ÖVBB Guideline on Sprayed Concrete.

The bonding action (adhesive strength of the substrate and tensile adhesive strength of the sprayed concrete) is tested according to ÖNORM B 3303.

8.2 Concrete segmental linings

As a rule, segmental linings made of prefabricated concrete [4] are put in place in the course of tunnel excavation by means of a circular full-face tunnel boring machine. They are mainly used in tunnels with a uniform cross section.

The inner shell consists of prefabricated segmental linings, which are assembled on site to form a closed inner ring. Depending on the design, the prefabricated parts are jointed longitudinally and in transverse direction by suitable means; if necessary, the structure is made waterproof through appropriate joints and joint seals. The annular ring between the rock and the shell made of segmental linings, unavoidable for engineering reasons, is grouted continuously immediately after installation of the segmental linings.

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

Segmental linings offer the advantage of continuous and systematic tunnel support. A load-bearing shell is in place just behind the full-face TBM. In the case of very substantial rock deformation, the segmental linings must be designed to absorb such deformation (e.g. deformable intermediate layer, yielding segmental lining).

In addition to ÖNORM B 3308 and ÖNORM B 4705, the requirements of this Guideline apply by analogy to the production and testing of segmental linings. Sufficient curing is to be ensured.

If a waterproof system is required, the segmental linings must be dimensionally accurate. Depending on the requirements, the tolerances have to be agreed on a case-by-case basis for the project and system in question. The tolerances for the finished inner shell must correspond to It. 5.7.

The first linings produced are assembled without joint tapes to establish their dimensional accuracy and their geometry.

Neoprene sections and/or swellable waterstops are used as joint tapes.

8.3. Fibre-reinforced concrete

Fibre-reinforced concrete, as defined in the ÖVBB Guideline on Fibre-Reinforced Concrete, is a composite material consisting of a concrete matrix to which fibres are added in the course of production. On the one hand, the special properties of fibre-reinforced concrete, as specified in the Guideline, can be used to improve the load-bearing behaviour of inner shell concrete (e.g. arch concrete in areas subject to long-term deformations of the outer shell, large tunnel niches, portal sections), i.e. through fibre-reinforced concrete classes T (usually T3 or T4). On the other hand, the fire resistance of traffic tunnels can be increased, i.e. through fire-resistant concrete class BB 2G. For floor slabs in tunnels built by the cut-and-cover method, fibre-reinforced concrete class FS 1 or FS 2 may help to reduce the risk of early shrinkage cracking (addition of PP fibres).

According to the results of recent research projects ([9], ([10]), fibre-reinforced concrete class BB 2G, which largely prevents spalling of near-surface concrete layers in the event of a fire, is achieved through the addition of fine mono-filament polypropylene fibres (e.g. 1.5 – 2.0 kg/m³ PP fibres, 6 mm long, diameter < 20 micrometers). To demonstrate achievement of reinforced-fibre concrete class BB 2G, the fibre may have to be tested for its basic suitability once prior to its use in arch concrete for tunnel inner shells according to Annex 5. Annex 5 will only remain in force until publication of the ÖVBB Guideline on the Increased Fire Resistance of Concrete for Underground Traffic Structures, which contains the final provisions governing fibre-reinforced concrete classes BB 1G and BB 2G.

As regards the constituent materials and the composition, production, placing and testing of the concrete, the provisions of this Guideline as well as those contained in the ÖVBB Guidelines on Fibre-Reinforced Concrete and Increased Fire Resistance of Concrete for Underground Traffic Structures apply.

The material quality, length and geometrical shape of the fibres, both longitudinally and across, as well as their surface have an influence on the workability, strength, deformation behaviour and other properties of the concrete.

As a rule, fibre-reinforced concrete can be produced in pug-mill mixers without special precautions and is easily pumpable. The fibres must be added to and mixed with the concrete so as to ensure a homogeneous distribution. A documented procedures, based on previous tests, must be available, specifying the type, timing and rate of fibre addition as well as the required mixing time after addition of the fibres to ensure their uniform distribution, the required consistency and the specified void content.

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

The addition of fibres results in a stiffer, sticky consistency, which normally can be compensated for through the addition of plasticising admixtures. If the maximum permissible water content according to Table 3/2 is exceeded, reduced shrinkage (RS or RRS) must be demonstrated according to ÖNORM B 3303. Care must be taken to ensure that the required stripping times can be observed, even if the plasticiser dosage is increased. Before concrete placing is begun, a concreting trial is to be performed to establish if the concrete can be properly placed by means of the placing and compaction equipment available on site.

It is important to note that the distribution of fibre-reinforced arch concrete behind the formwork and its compaction between the outer shell and the steel reinforcement are more difficult and therefore demand a special placing and compaction procedure (e.g. more frequent repositioning of the pumping line, adjusted vibration energy, frequency).

As regards the section length of inner shells made of fibre-reinforced concrete, Table 4/1 applies. In the case of tensile force transfer, construction joints need to be secured additionally through reinforcement. For block joints to be sealed by means of expansion joint tapes, fastening of the joint tape in the correct position by means of a supporting structure (e.g. latticed bend) is essential.

9. INTERMEDIATE CEILING AND PARTITION FOR VENTILATION DUCTS IN TRAFFIC TUNNELS

9.1 Intermediate ceiling

9.1.1 Concrete for intermediate ceilings

9.1.1.1 Principles of concrete composition

The composition of concrete for intermediate ceilings has to be determined, above all, with a view to workability, avoidance of early shrinkage cracking, stripping strength and the functional properties of the finished structure.

- For reasons of workability, the concrete must be pumpable and has to permit easy levelling of the intermediate ceiling surface after placing and compaction (usually consistency F45).
- To avoid early shrinkage cracking, the total water content should be $\leq$ 190 l/m³. Curing is to be performed immediately after levelling (spraying with a curing agent suited for fresh concrete).
- In practice, the use of several formwork elements and formwork removal after $\geq$ 36 hours has proved successful. The stripping strength must be demonstrated through testing. As a rule, a stripping strength of $\geq$ 20 N/mm² is required. Heating of the intermediate ceiling concrete is not permitted. The modulus of elasticity must be determined to establish the rate of deformation at the time of formwork removal.
- To ensure compliance with the required functional properties of the finished structure, concrete grade C25/30/XC3/XF3/RS (abbreviated: C25/30/B3/RS) is recommended.
- Increased fire protection requirements must be taken into consideration according to It. 3.1.5.
- To obtain the required concrete properties, the following concrete composition has proved appropriate (Table 9/1):

Table 9/1 Proposed concrete composition for intermediate ceilings

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Mineral aggregates GK 16, GK 11 Range 2/3 (A+B) – B at ϛ =2.700 kg/m^3	1830 – 1900 kg/m^3
Cement WT 38, WT 42	260 – 280 kg/m^3
Additives according to ÖN B 3309 (AHWZ)	0 – 40 kg/m^3
Total water content	≤ 190 l/m^3
Air content	2.5 – 5.0 %
Consistency	F 45
Admixtures BV, FM, LP, LPV	To obtain the required consistency with permissible water content

9.1.1.2 Quality control

- Preconstruction testing is to be performed by an accredited inspection body. The following parameters have to be tested and demonstrated:
  Optimisation of concrete composition with regard to early stripping, fresh concrete properties, stripping strength and modulus of elasticity upon formwork removal at a storage temperature of + 15°C, 28 d compressive strength, water penetration depth according to ÖNORM B 3303 (XC3), XF3, calibration of the rebound hammer, porosity.

- Conformity checks and identity testing are to be performed, by analogy, according to the requirements of Tables 3/7 and 3/8.

- Testing of the structure (to be performed by the user).
  Use of the rebound hammer is recommended for stripping strength testing in each concreting section. The concrete cover of the steel bars is to be tested according to It. 3.4.3.
  To check proper concrete placement and curing, porosity tests are to be performed in three drilled cores from the first three ceiling elements and repeated at intervals of 30 ceiling elements. The results are evaluated by comparison with the porosity established in the preconstruction test.

9.1.2 Design measures

The provisions of RVS – Structural Fire Protection for Road Traffic Structures - apply.

- Deformation under different load conditions (e.g. partition formwork load) and vibration behaviour have to be demonstrated
- Recommended thickness of structural component: 20 cm
- Minimum cover of steel reinforcement: minimum structural dimension 35 mm, minimum design dimension 45 mm (according to Information Sheet RVS 9.35)
- Section length to be adjusted to block division of the arch.

The design assumption for intermediate ceilings is a passenger car on fire, which means that ÖNORM B 3800-4 applies. For security installations, such as air fans, etc., special provisions apply (e.g. proof of deformation under fire load).

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

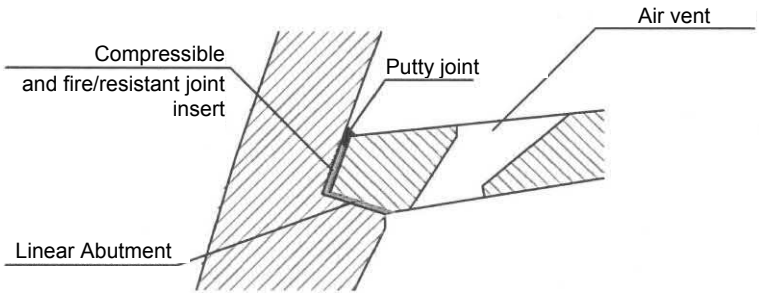


Fig. 9.1 Example of abutment for intermediate ceiling

9.1.3 Concrete production, placing, curing

The provisions of It. 6.1 of this Guideline apply to concrete production. A curing agent suited for use on fresh concrete is to be applied to the finished part of the intermediate ceiling immediately after production (to be sprayed twice).

9.2 Partition

9.2.1 Concrete for partitions

9.2.1.1 Principles of concrete composition

The composition of concrete for partitions is to be optimised with a view to workability, stripping strength, shrinkage and the functional properties of the finished structure.

For reasons of workability, the concrete must be pumpable over short distances and well suited for easy placement in the reinforced, thin (12 – 15 cm) partition without compaction (F 66).

- As a rule, a stripping time of $\geq$ 12 hours at a stripping strength of $\geq$ 1 N/mm² is considered state of the art. As a thin structural component, the partition is extremely sensitive to cooling under the influence of cold air.
- A tight joint between the partition and the arch concrete of the roof is to be provided for (air flows between the fresh-air duct and the waste-air duct are to be avoided). Therefore, low bleeding (BL) and low shrinkage (RS) are essential properties (RS also to avoid crack formation).
- To ensure compliance with the required functional properties of the finished structure, concrete grade C25/30/XC3/XF1/BL/RS/GK16(A) is recommended for partition concrete (XF3 for portal areas).
- Increased fire protection requirements must be taken into consideration according to It. 3.1.5.
- To obtain the required concrete properties, the following concrete composition has proved appropriate (Table 9/2):

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

Table 9/2 Proposed concrete composition for partitions

Mineral aggregates GK 16, GK 11 Range 2/3 (A+B) – B at ϛ =2.700 kg/m^3	1830 – 1900 kg/m^3
Cement WT 38, WT 42	260 – 280 kg/m^3
Additive according to ÖN B 3309 (AHWZ)	120 – 100 kg/m^3
Total water content	≤ 190 l/m^3
Air content [1)]	2.5 – 5.0 %
Consistency	F 66
Admixtures BV, FM, LP, LPV	According to required consistency and LP content

[1)] Recommended for XF1, mandatory for XF3

9.2.1.2 Constituent materials

For the constituent materials, compliance with the requirements of ÖNORM B 4710-1 for the required concrete grade is to be demonstrated.

To obtain the required properties in terms of low bleeding and stripping strength, use of cement grades WT 38 or WT 42 according to ÖNORM B 3327-1 is appropriate.

9.2.1.3. Quality control

- Preconstruction testing is to be performed by an accredited inspection body (inspection report). The following parameters have to be tested and demonstrated in accordance with the tender specifications and/or this Guideline:
  Optimisation of concrete composition, fresh concrete properties, low bleeding, stripping strength > 1 N/mm² at the time of formwork removal and at a storage temperature of + 15°C (average ambient air temperature in the tunnel), 28 d compressive strength (possibly 56 d), water penetration depth according to ÖNORM B 3303 (XC3), XF3 (if required), reduced shrinkage.

- Conformity checks and identity testing are to be performed, by analogy, according to the requirements of Tables 3/7 and 3/8. As regards testing for reduced shrinkage, the frequency is the same as for exposure classes.
  Use of the pendulum hammer, e.g. Schmidt PT, is recommended for stripping strength testing (at the beginning of concreting and at low temperatures). The equipment used is to be calibrated in the course of preconstruction testing.
  The concrete cover of the steel bars is to be verified according to It. 3.4.3.

9.2.2 Design measures

- Thickness of structural component 12 – 15 cm (= diameter of partition suspension plus reinforcement and minimum cover on both sides)
- Minimum concrete cover: design dimension 45 mm, minimum structural dimension 35 mm
- Section length: to be adjusted to block division of the arch
- Design of abutments (recess in arch concrete)
- Joint design: to diminish air resistance, broken edges are not permitted for block joints in the ventilation duct area (no triangular fillet inserts). Deficiencies of up to

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

10% of the corresponding joint length, unavoidable for practical reasons, are to be tolerated.

Special corrosion protection for the suspension system of the intermediate ceiling (suspension rods) is required in the joint between the arch and the partition. Given the dynamic strain acting on the suspension rod., a non-bonded section is to be provided for in the joint area.

9.2.3 Concrete production, placing, curing, concrete surface

- Concrete production has to be in accordance with It. 6.1 of this Guideline.
- As a rule, the stripping cycle is $\geq$ 12 hours. If ambient air temperature is low, the required stripping strength of 1 N/mm² can only be reached through removal of formwork, heating of the section concerned, or insulation of the formwork.
- As a rule, steel formwork is used to obtain as smooth a concrete surface as possible. Class GB 2 according to the ÖVBB Guideline on Formed Concrete Surfaces is required for the concrete surface.
- Immediately after formwork removal, a thixotropic curing agent, according to RVS 11.064, Part II, is to be applied in at least two spraying operations, the total weight corresponding to the value established through qualification testing.
- Horizontal concrete flow must not exceed 7m.
- Given the soft concrete consistency, the increased formwork pressure and the closing pressure upon termination of concreting must be taken into consideration. Joint grouting may be necessary.

9.3 Sealing of ventilation ducts against intermediate ceilings and partitions

Section joints intermediate ceiling	- sealing tape
Section joint partition	- sealing tape facing fresh air duct
Jointing intermediate ceiling – partition	- design according to Fig. 9.2, detail C
Jointing arch – intermediate ceiling	- putty joint facing fresh-air duct (Fig. 9.2, detail B)
Jointing arch – partition	- trapezoidal fillet and putty joint facing fresh-air duct or sealing tape (Fig. 9.2, detail A)
Intersection block joint	- intermediate continuous putty joint topped by sealing tape ceiling

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

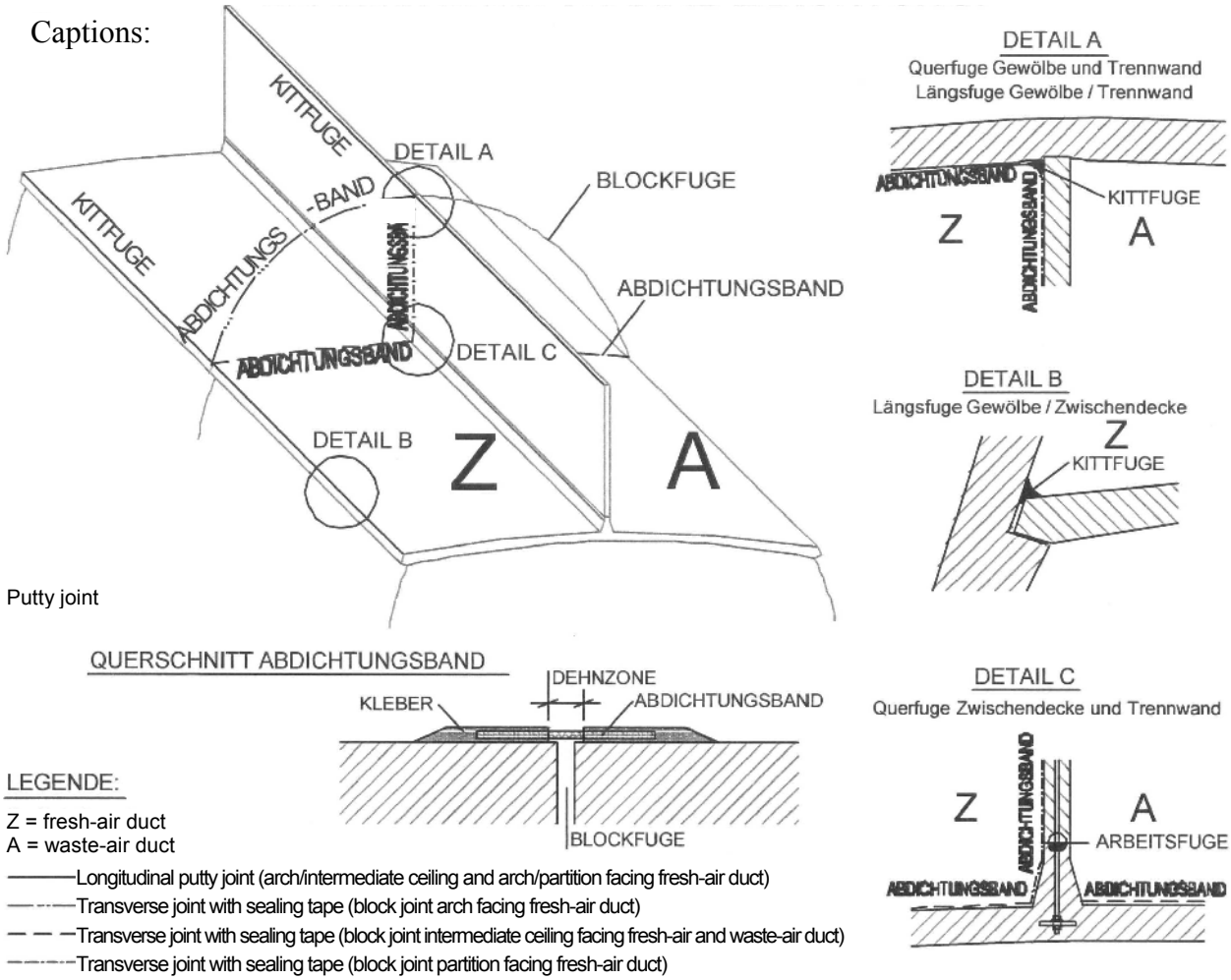


Fig. 9.2 Example of air-duct sealing systems

The durability of the sealing tape and a minimum tensile adhesive strength of 1.5 N/mm² are to be demonstrated.

10. RECOMMENDATIONS FOR TENDERING

Recommendations for tendering are contained in ÖNORM B 2203-1, RVS 7T Performance Specifications for Tunnelling, and RVS 8T Technical Contract Terms for Tunnelling. Examples of concrete grades are specified in Annex 3 of this Guideline.

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

11. NORMEN, RICHTLINIEN, VORSCHRIFTEN UND LITERATUR

11.1 Angeführte Normen

ÖNORM B 2203-1	Untertagebauarbeiten-Werkvertragsnorm, Teil 1: Zyklischer Vortrieb; Ausgabe 12/01.
ÖNORM B 2211	Beton-, Stahlbeton- und Spannbetonarbeiten-Werkvertragsnorm; Ausgabe 04/98.
ÖNORM B 3303	Betonprüfung; Ausgabe 09/02.
ÖNORM B 3308	Güteüberwachung der werksmäßigen Herstellung von Fertigteilen aus Beton, Stahlbeton und Spannbeton; Ausgabe 08/80
ÖNORM B 3309	Aufbereitet hydraulisch wirksame Zusatzstoffe für die Betonherstellung; Ausgabe 09/99.
ÖNORM B 3131	Gesteinskörnung für Beton – Regeln zur Umsetzung von EN 12620; Ausgabe 06/03.
ÖNORM B 3327-1	Zemente gemäß ÖNORM EN 197-1 für besondere Verwendungen, Teil 1: Zusätzliche Anforderungen; Ausgabe 01/02.
ÖNORM B 3800-4	Brandverhalten von Baustoffen und Bauteilen; Baustoffe: Einreihung in die Brandwiderstandsklassen; Ausgabe 05/00.
ÖNORM B 4700	Stahlbetontragwerke - EUROCODE-nahe Berechnung, Bemessung und konstruktive Durchbildung; Ausgabe 06/01.
ÖNORM B 4705	Fertigteile aus Beton, Stahlbeton und Spannbeton und daraus hergestellte Tragwerke für vorwiegend ruhende Belastung; Ausgabe 11/02.
ÖNORM B 4710-1	Beton, Teil 1: Festlegung, Herstellung, Verwendung und Konformitätsnachweis (Regeln zur Umsetzung der ÖNORM EN 206-1); Ausgabe 01/02.
ÖNORM B 4753	Spannbeton – Eisenbahnbrücke; EUROCODE – nahe Berechnung, Bemessung und konstruktive Durchbildung; Ausgabe 06/03
ÖNORM EN 197-1	Zement, Teil 1: Zusammensetzung, Anforderungen und Konformitätskriterien von Normalzement; Ausgabe 12/00.
ÖNORM EN 450	Flugasche für Betondefinitionen, Anforderungen an Güteüberwachung; Ausgabe 09/95
ÖNORM EN 934-2	Zusatzmittel für Beton, Mörtel und Einpressmörtel, Teil 2: Betonzusatzmittel - Definitionen und Anforderungen; Ausgabe 02/02
ÖNORM EN 1363-1	Feuerwiderstandsprüfungen, Teil 1: Allgemeine Anforderungen; Ausgabe 01/00
ÖNORM EN 1363-2	Feuerwiderstandsprüfungen, Teil 2: Alternative und ergänzende Verfahren; Ausgabe 01/00.
ÖNORM EN 13263	Silikastaub für Beton –Definitionen, Anforderungen und Konformitätslenkung; Ausgabe 08/98.
ÖNORM DIN 18202	Toleranzen im Hochbau – Bauwerke; Ausgabe 02/98.

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

11.2 Richtlinien und Vorschriften

RVS 7T	Leistungsbeschreibung für Tunnelbau, Ausgabe xx/03.
RVS 8T	Technische Vertragsbedingungen für Tunnelbau, Ausgabe xx/03.
RVS 9.32	Tunnel; Geschlossene Bauweise im Lockergestein unter Bebauung; Ausgabe 01/93 (Neuauflage in Vorbereitung).
RVS …..	Baulicher Brandschutz für Straßenverkehrsbauwerke (in Vorbereitung)
RVS 9.35 Merkblatt	Tunnel; Statisch–konstruktive Richtlinie; Betondeckung der Stahleinlagen; Ausgabe 06/02.
RVS 11.064; Blatt II	Grundlagen – Prüfverfahren; Beton; Nachbehandlungsmittel Beton; Ausgabe 12/85.
ÖVBB – Richtlinie	„Erhaltung und Instandsetzung von Bauten aus Beton und Stahlbeton“ Anwendung und Prüfverfahren; (Neuauflage in Vorbereitung).
ÖVBB – Richtlinie	„Spritzbeton“; Ausgabe 10/98; (Neuauflage in Vorbereitung).
ÖVBB – Richtlinie	„LPV-Beton“; Ausgabe 09/99.
ÖVBB – Richtlinie	„Faserbeton“; Ausgabe 03/02.
ÖVBB – Richtlinie	„Geschalte Betonflächen“; Ausgabe 06/02.
ÖVBB – Richtlinie	„Wasserundurchlässige Betonbauwerke – Weiße Wannen“; Ausgabe 12/02.
ÖVBB – Richtlinie	„Ausbildung von Tunnelentwässerungen“; Ausgabe 06/03.
ÖVBB – Merkblatt	„Anstriche für Tunnelinnenschalen“; Ausgabe xx/03.
ÖVBB – Merkblatt	„Erhöhte Brandbeständigkeit von Beton für unterirdische Verkehrsbauwerke“ (in Vorbereitung).
ZTV-RISS 00	Zusätzliche Technische Vertragsbedingungen und Richtlinien für das Füllen von Rissen in Betonbauteilen; Ausgabe 07/00.

11.3 Zusätzlich zu beachtende Normen, Richtlinien

ÖNORM B 2221	Bauspenglerarbeiten; Werkvertragsnorm; Ausgabe 01/01.
ÖNORM B 4701	Betontragwerke; EUROCODE–nahe Berechnung, Bemessung und konstruktive Durchbildung; Ausgabe 11/02.
ÖNORM EN 1008	Zugabewasser für Beton-Anforderungen und Prüfung; Ausgabe 10/02.
ÖNORM C 2358	Beschichtungsstoffe - Fassadenbeschichtungen – Mindestanforderungen und Prüfungen; Ausgabe 07/01.
RVS 12.241	Bauprodukte und Bauleistungen; Beton; Qualitätssicherung gemäß ÖNORM B 4710-1; Merkblatt, Ausgabe 12/01.
RVS 13.61	Instandsetzung von Kunstbauten; Anwendung; Ausgabe 07/95.
RVS 13.62	Instandsetzung von Kunstbauten; Prüfverfahren; Ausgabe 07/95.
ÖVBB – Richtlinie	„Frost–Tausalz–beständiger Beton“; Ausgabe 03/89.
ZTV-SIB	Technische Vorschriften und Richtlinien für Schutz und Instandsetzung von Betonbauteilen. (Neuauflage in Vorbereitung).

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11.4 Literatur und Sachstandsberichte

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[2] Brameshuber, W.: Der Altenbergtunnel bei Idar-Oberstein, Beton- und **Stahlbetonbau,** Heft 2/1992.

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[4] ÖVBB- Sachstandsbericht Tübbinge 2003.

[5] Entwurfsrichtlinie „Kontinuierlicher Vortrieb von Eisenbahntunneln mit Tunnelvortriebs-maschinen“ - Stand März 2002.

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[7] Projektierungsrichtlinie RVS 9.2xx „Kontinuierlicher Vortrieb von Straßentunnel mit Tunnelvortriebsmaschinen“ - Stand Dezember 2002.

[8] Richtlinie für die Anwendung der zerstörungsfreien Prüfung von Tunnelinnenschalen - RI-ZEP-TU der deutschen Bundesanstalt für Straßenwesen, Ausgabe 2001.

[9] Brandbeständigkeit von Faser-, Stahl- und Spannbeton; Straßenforschung Heft 53 – 2003

[10] Praxisverhalten von erhöht brandbeständigem (Innenschalen-)Beton (EBB); FFF-Projekt Nr.: 806201; Forschungsinstitut der Vereinigung der Österreichischen Zementindustrie – 2003

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ANNEX 1

Concreting PROTOCOL
(Model form)

Date: 11.11.02	Time: 17:37
Plant	1
Construction site	A
Structural member	Floor
Concrete grade	4/ 4/1425008
Concreting date	11.11.02 8:43 a.m. to 11.11.02 17:37 p.m.
Number of mixes	
Total	120
Errors detected	6
Manual switching	0
Mixing time	60 s

Designation	Target	Actual			
		Min.	Max.	Mean	Standard deviation
MINERAL AGGREGATE [1] GK 4-16	547 kg	545 kg	549 kg	547 kg	
GK 0-16	533 kg	529 kg	535 kg	532 kg	
GK 0-4	392 kg	387 kg	395 kg	392 kg	
GK 16-32	487 kg	483 kg	491 kg	488 kg	
CEM II/A 42.5 R/WT38	230 kg	229 kg	232 kg	230 kg	
FLUAL	45 kg	45 kg	46 kg	45 kg	
LPV	0.91 kg	0.91 kg	0.92 kg	0.91 kg	
TOTAL WATER CONTENT [2]					
Concrete temperature		18° C	23° C	20° C	

1) Dosages of mineral aggregates are to be indicated in dry weight.
2) Total water content according to ÖNORM B 4710-1, It. 3.1.29.

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ANNEX 2

EXAMPLE FOR it. 5.7: ESTABLISHMENT OF DIMENSIONAL TOLERANCES FOR TOLERANCE CLASS A2

Assumptions:

- Tunnel length (irrelevant for tolerance calculation): l = 7000 m
- Selected tunnel length to breakthrough: TL = 2500 m
- Clear cross section: 90 m²
- Invert concreted in the course of tunnel driving
- Length of concreting section (L) 12 m
- Clear width (B) 10 m
- Radius of tunnel axis in ground plan (R) 1500 m

Tolerances for the arch:

Tolerance classes	Individual tolerances	
	Position (± mm)	Height (± mm)
Basis A2	20	10
Additional per 1000 m	15	
B 1	15	15
B 2	20	20
B 3	20	20
C	12	
Sum total	**102**	**65**

$$C = 1500 + \frac{10}{2} - \sqrt{(1500 + \frac{10}{2})^2 - (\frac{12}{2})^2} = 12\text{mm}$$

Tolerances for the floor:

Tolerance classes	Individual tolerances	
	Position (± mm)	Height (± mm)
Basis A2	20	10
Additional per 1000 m	15	
B 1	15	15
B 2	50	50
B 3	20	20
C	12	
Sum total	**132**	**95**

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ANNEX 3

EXAMPLES OF CONCRETE GRADES*

	Structure / Structural member	Example of concrete grades indicated in technical specifications
1	Arch concrete for road tunnel, sealed, coated, portal area	C20/25(56)/IGP/GK32
2	Arch concrete for railway tunnel, sealed	C20/25(56)/IG/GK32
3	Arch concrete for road tunnel, reinforced portal sections	C20/25(56)/IGP/GK16
4	Arch concrete for road tunnel, sealed, coated, mountain water containing SO_4^{2-} = 400-1500 mg/l	C20/25(56)/IXAT/GK32
5	Inner shell concrete, e.g. for underground railway, without sealing, ground water containing SO_4^{2-} = 400-1500 mg/l	C25/30(56)/WDI/GK22
6	Floor concrete (invert) for railway tunnel, non-reinforced	C25/30(56)/IXAL/GK45
7	Concrete for floor plates and invert for cut-and-cover railway tunnel, with sealed arch	C25/30(56)/WDI/GK22
8	Floor concrete for road tunnels, with pavement above floor	C20/25(56)/ISP/GK32
9	Inner shell concrete (full round) for bored penstock (d = 15 cm)	C25/30(56)/IGP/GK22
10	Arch concrete for urban location, increased fire resistance requirement	C25/30(56)/WDI/GK16/FaB-BB2 G
11	Arch concrete for cut-and-cover tunnel	C25/30(56)/IGP/GK22
12	Intermediate ceilings	C25/30/B3/RS/GK22
13	Partitions	C25/30/B3/BL/RS/GK16

* The strength classes specified in the Table are examples only and need to be adjusted to specific conditions.

Minimum strength class: C 20/25.

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ANNEX 4

EVENNESS CRITERIA TO BE MET BY THE SUBSTRATE (SPRAYED CONCRETE) FOR THE USE OF SEALING FILM

The surface characteristics and the compressive strength of the substrate must be such as to meet the requirements of the sealing system. In terms of surface geometry, the requirements depend on the specific conditions of the construction site:

1) Tunnel cross section:

As a rule, plastic sealing webs can be placed in tunnel cross sections without any special measures, provided the substrate meets the following conditions:

a) drained tunnel (drained film sealing system, „umbrella sealing“) (see Fig. A4/1):
- Adequate dimensional stability and strength.
- Maximum grain size GK 11.
- Inclination of substrate to target position maximum 45°, if flexible sealing webs, up to 2.5 mm thick, are used to compensate for excavation-related unevenness; for thicker webs, the angle is to be reduced to 30°.
- Curvature radius r of the surface not smaller than 20 cm.

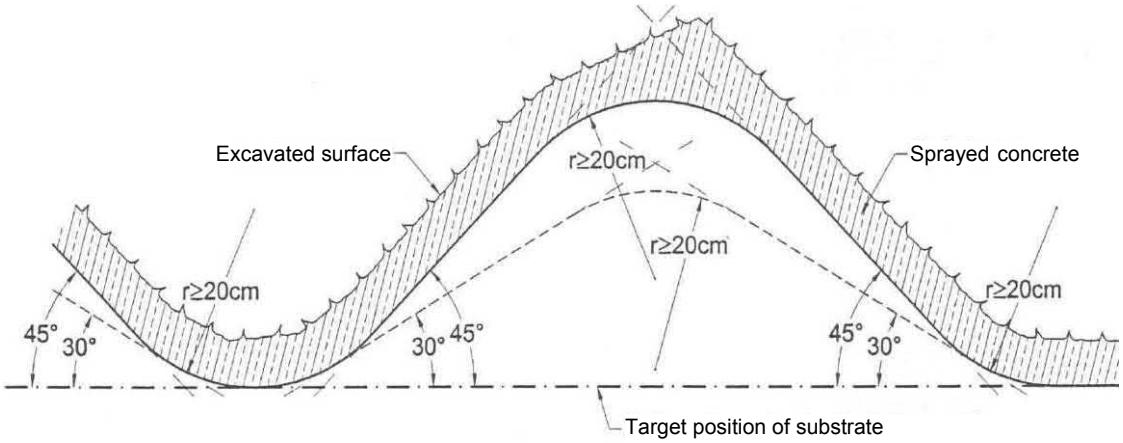
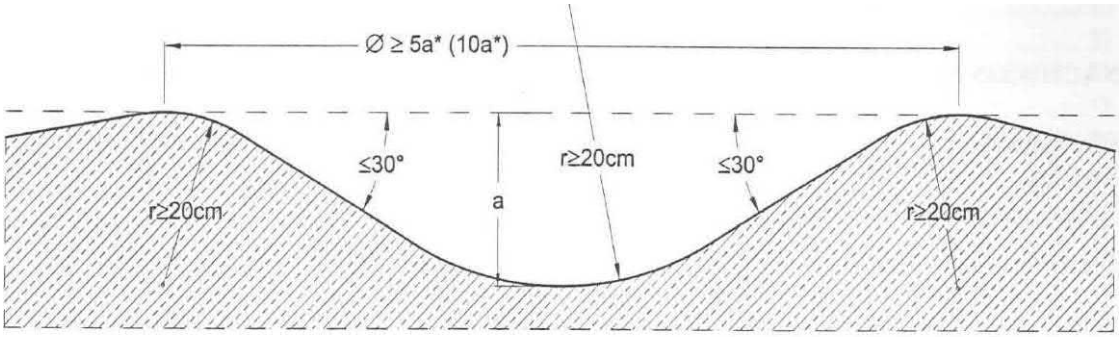


Fig. A4/1: Maximum permissible excavation geometry with rounding radii, depending on angle

b) watertight tunnel (waterproof film sealing system, „submarine“) (see Fig. A4/2)
- Adequate dimensional stability and strength.
- Maximum grain size GK 11.
- Ratio of diameter to height of local excavation-related unevenness in substrate: for flexible sealing webs up to 2 mm thick at least 5:1, for non-flexible webs or webs thicker than 2 mm at least 10:1.
- Inclination of substrate to target position maximum 30°.
- Curvature radius r of surface not smaller than 20 cm.

Basically, these criteria apply regardless of scale. The most stringent criterion has to be observed.

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*) 5a for flexible sealing webs (e.g. soft PVC or ECB) up to 2 mm thick; 10a for non-flexible sealing webs or webs thicker than 2 mm (e.g. PE).

Fig. A4/2: Permissible unevenness of substrate

2) Niches and changes in cross section

Routine laying of plastic sealing webs to offset the unevenness of the substrate is not permitted in these areas. The plastic sealing web has to be cut, fastened and welded to adjust it accurately to the unevenness of the substrate and fix it in its final position.

The criteria listed under 1), applicable to geometrical imperfections of the substrate, need not be observed on a large scale, if edges and grooves are due to niches and changes in cross section provided for in the design.

Edges and grooves of the substrate have to be smoothed as carefully as possible. The radius must not be less than 20 cm. (see Fig. A4/3).

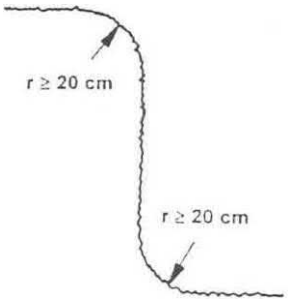


Fig. A4/3: Minimum radii in niches and sections with changes in cross section

Generally speaking, the following applies:

The material properties of the substrate and the method of fastening the plastic sealing web must be adjusted to each other. The fastening elements must not come off the substrate before completion of the inner shell. Nailing must not result in spalling of the substrate.

If the substrate is too wet to permit proper sealing, suitable measures must be taken to capture and drain the ingress of water.

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ANNEX 5

ESTABLISHMENT OF FIBRE-REINFORCED CONCRETE CLASSES BB1G AND BB2G IN LARGE-SCALE TEST SPECIMENS

For inner tunnel shells and tunnels built by the cut-and-cover method, the tests required to establish the fibre-reinforced concrete classes specified in the ÖVBB Guideline on Fibre-Reinforced Concrete have to be performed by a testing body accredited for fire tests on large-scale test specimens according to the following procedure:

The test is performed on two test specimens measuring 180 x 140 x 50 cm (l x w x h).

Formwork:

The lost formwork consists of 4 mm steel plates mounted at the sides, which extend 30 cm into the lower face of the test specimen. For concreting and curing, the test specimen is to be placed flat on the forms (Fig. A5/1 – formwork).

Reinforcement:

The test specimen is reinforced with a steel grid made of BSt 550 steel rods, 14 mm in diameter, 10 cm spacing, with 4 cm concrete cover according to Fig. 5A/2. Spacers (made of fibre cement) are to be positioned outside the area exposed to fire.

Temperature sensor:

Prior to concreting, temperature sensors (iron constantane) are to be attached laterally to the reinforcement rods of the first 2 layers at the centre of the plate and at a corner on every fifth rod. Another sensor is to be positioned at a distance of about 25 cm from the fire compartment, if possible at the centre of the test specimen (for position of temperature sensors see Fig. A5/2).

Constrained thermal expansion:

Not earlier than one day before the fire test, a centric compressive stress of 0.5 MPa and/or 1.16 MPa is to be applied through 2 tendons in longitudinal direction and 4 tendons in transverse direction. Transverse prestressing can also be achieved through a tensioning frame.

Concrete:

The concrete used is either waterproof inner shell concrete according to this Guideline or concrete grade BS 1A according to the ÖVBB Guideline on Waterproof Concrete Structures – White Tanking and/or earlier issues of these Guidelines.

Addition of fibres in the appropriate dosage. The fibres, which have to meet the requirements of the Guideline on Fibre-Reinforced Concrete, are subject to self-inspection and external inspection. Slump is to be maintained, at least, at consistency class F 45 through the addition of a plasticising agent.

Production of reference concrete without fibres is not required. (Comparative value of spalling depth 25 cm, according to *Straßenforschung* 3.269).

Fresh concrete testing and compressive strength testing at the age of 28 days are to be performed. The loss of slump due to the addition of fibres is to be indicated.

Internal vibrators are to be used for compaction.

Storage:

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The test specimens are to remain in the formwork for 14 days. They are to be stored at a temperature of 20±5° C. Water is to be applied to the face of the test specimen exposed to fire in the fire test during the period between production of the test specimen and performance of the test. The fire test has to be performed between the 28th and the 56th day after production.

Fire test:

The fire chamber, internal size 120 x 80 cm, 57 cm high, is to be heated by means of an oil burner from the short side. A flue gas pipe, 21 cm in diameter, is to be fitted on the opposite side. Two temperature sensors (platinum-rhodium-platinum) are to be positioned in the fire chamber approx. 13 cm underneath a horizontal plate to control the temperature in the fire chamber. Ceramic wool is to be used for insulation.

The fire chamber temperature is controlled according to the RWS fire curve (see Guideline on Fibre-Reinforced Concrete) and the tolerances of the hydrocarbon curve according to ÖNORM EN 1363-2. The test is to be performed in analogy to ÖNORM EN 1363-1.

Evaluation:

The test specimen is to be removed from the fire chamber 15 minutes after the end of the fire test for immediate inspection and evaluation of the spalling depth. The mean value of the 2 plates is to be used as a basis for concrete classification (fire classes BB). Given a spalling depth of 25 cm in reference concrete, the mean spalling depth for

BB 2 must be less than 1 cm (nowhere as far as the reinforcement),

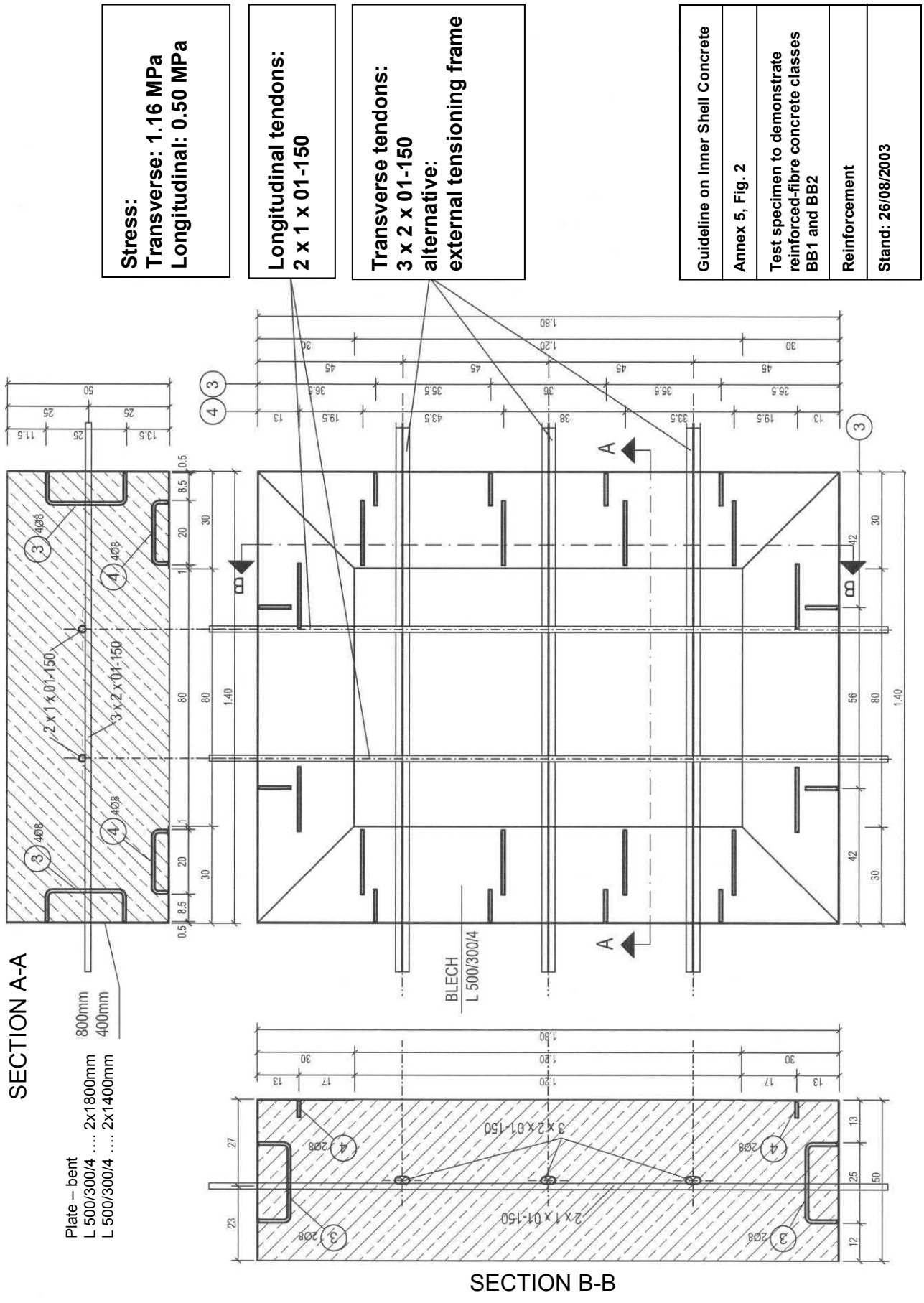
BB 1 must be less than 7.5 cm (2nd reinforcement layer just visible, deep local spalling must not exceed twice the limit value).

Report:

The test report has to contain the following:

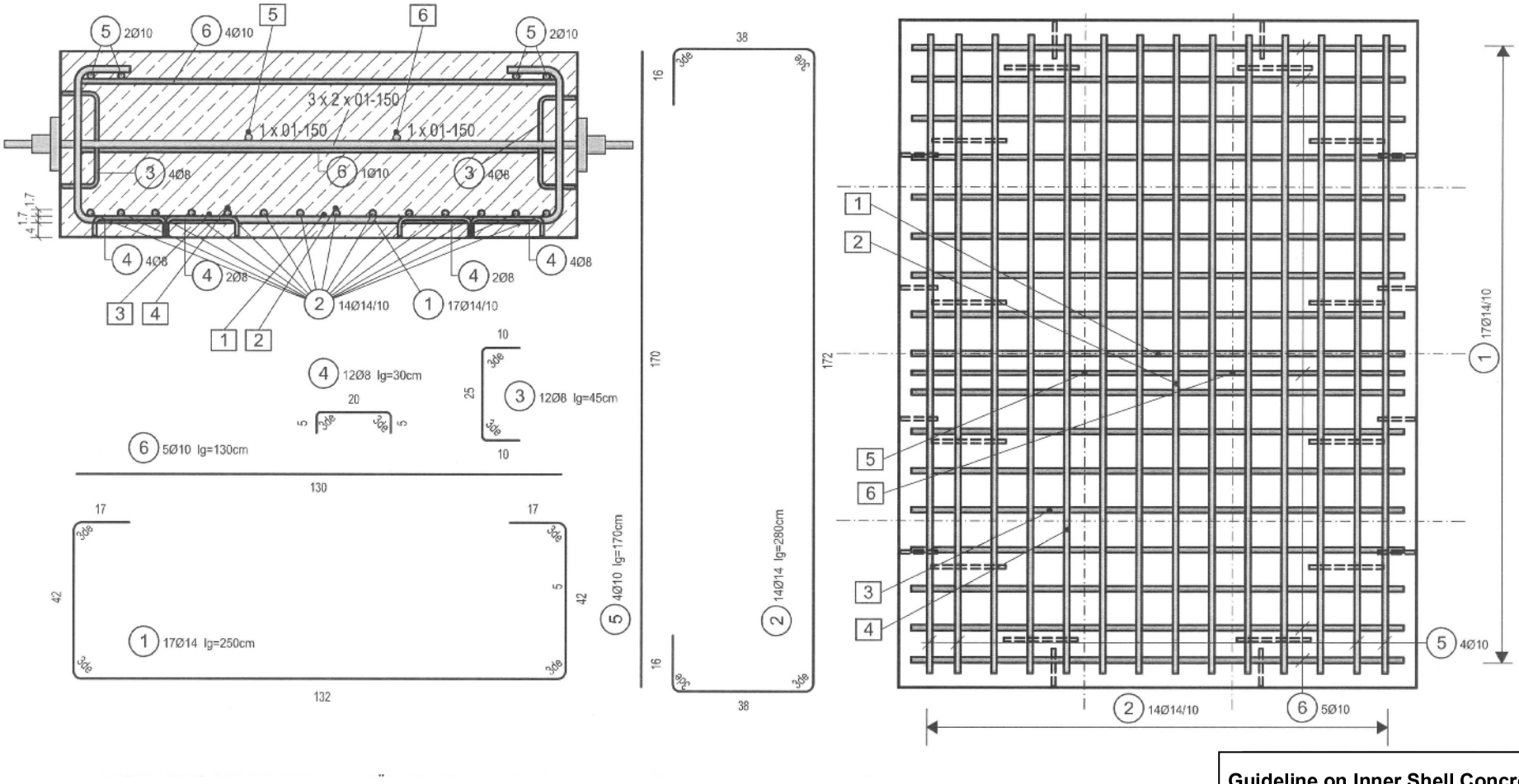
- Reference to this Guideline and to the ÖVBB Guideline on Fibre-Reinforced Concrete
- Concrete used and preconstruction testing data
- Fibres used, dosage and fibre properties according to ÖVBB Guideline on Fibre-Reinforced Concrete
- Fresh-concrete test (w/b value, slump, air, temperature), incl. loss of slump
- 28 d compressive strength
- Production data and storage conditions
- Prestressing protocol
- Total mass of test specimens before and after the test
- Date of fire test and all test observations
- Fire chamber temperature and sensor temperatures
- Spalling depths after the fire
- Concrete classification (classes BB 1 and BB 2)

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Positioning of temperature sensors (assembly of probes on the upper side of the reinforcement rods)

Probe	Position	Probe	Position
[1]	1st reinforcement layer (c = 5.5 cm), centre	[4]	2nd reinforcement layer (c = 7.0 cm), edge
[2]	2nd reinforcement layer (c = 7.0 cm), centre	[5]	tensioning steel (c = 25.0 cm)
[3]	1st reinforcement layer (c = 5.5 cm), edge	[6]	tensioning steel (c = 25.0 cm)

Concrete cover:
4.0 cm (minimum design size)

Guideline on Inner Shell Concrete
Annex 5, Fig. 2
Test specimen to demonstrate reinforced-fibre concrete classes BB1 and BB2
Reinforcement, Position of temperature sensors
Stand: 26/08/2003

VERÖFFENTLICHUNGEN DER ÖSTERREICHISCHEN VEREINIGUNG FÜR BETON- UND BAUTECHNIK

Richtlinien

Richtlinie “Konstruktive Stahleinbauteile in Beton und Stahlbeton” (Ausgabe 2006)

Merkblatt “Schutzschichten für den erhöhten Brandschutz für unterirdische Verkehrsbauwerke” (Ausgabe 2006)

Merkblatt “Kreisverkehre mit Betonfahrbahndecken” (Ausgabe 2006)

Sachstandsbericht “Tübbinge” (Ausgabe 2005)

Richtlinie “Erhöhter Brandschutz mit Beton für unterirdische Verkehrsbauwerke” (Ausgabe 2005)

Merkblatt “Unterwasserbetonsohlen (UWBS)” (Ausgabe 2005)

Richtlinie “Fugenausbildungen im Tunnel und Konstruktionsprinzipien am Übergang offene/geschlossene Bauweise” (Ausgabe 2005)

Richtlinie “Bohrpfähle” (Ausgabe 2005)

Richtlinie “Qualitätssicherung für Instandsetzungsfachbetriebe und Instandsetzungsprodukte” (Ausgabe 2004)

Merkblatt “Anstriche für Tunnelinnenschalen” (Ausgabe 2004)

Richtlinie “Spritzbeton” (Ausgabe 2004)

Richtlinie “Erhaltung und Instandsetzung von Bauten aus Beton und Stahlbeton” (Ausgabe 2003)

Richtlinie “Kathodischer Korrosionsschutz von Stahlbetonbauteilen” (Ausgabe 2003)

Richtlinie “Innenschalenbeton” (Ausgabe 2003)

Richtlinie "Ausbildung von Tunnelentwässerungen“ (Ausgabe 2003)

Richtlinie "Nachträgliche Verstärkung von Betonbauwerken mit geklebter Bewehrung" (Ausgabe 2002)

Merkblatt "Selbstverdichtender Beton“ (SCC) (Ausgabe 2002)

Merkblatt "Beton für Kläranlagen“ (Ausgabe 2002)

Richtlinie "Wasserundurchlässige Betonbauwerke – Weiße Wannen" (Ausgabe 2002)

Richtlinie „Geschalte Betonflächen (‚Sichtbeton’)“ (Ausgabe 2002)

Richtlinie "Faserbeton" (Ausgabe 2002)

Richtlinie "Schmalwände" (Ausgabe 2002)

Richtlinie "Dichte Schlitzwände" (Ausgabe 2002)

Richtlinie "Bewehrungszeichnungen" (Ausgabe 2001)

Richtlinie "LPV-Beton"(Ausgabe 1999)

Merkblatt "Hochleistungsbeton" (Ausgabe 1999)

Richtlinie "Dichtwandmaterialien"(entspricht der ÖNORM B 4452 "Erd- und Grundbau, Dichtwände im Untergrund")

Richtlinie "BETON - Herstellung, Transport, Einbau, Gütenachweis" (Ausgabe 1999)

Sachstandsbericht "Hochfester Beton" (Ausgabe 1993)

Richtlinie "Frost-Tausalz-beständiger Beton" (Ausgabe 1989)

Richtlinie für die Herstellung von Betonfahrbahndecken (Ausgabe 1986)

Richtlinie für Herstellung und Verarbeitung von Fließbeton (Ausgabe 1977)

Richtlinien für Leichtbeton, Teil 1-4 (Ausgabe 1974 - 1978) (Teile 1 und 4a sind durch ÖNORM B 4200-11 ersetzt)

Schriftenreihe

Heft 64/2006
Betontag 2006

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Fortbildungsveranstaltung 2005 Sektion Spannbeton

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Internationale Fachtagung 2005
“Betondecken aus volkswirtschaftlicher Sicht”

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“Fibre Reinforced Concrete in Practice” (inkl. CD)

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30. FB Einführung in die neue Richtlinie Nachträgliche Verstärkung von Betonbauwerken mit geklebter Bewehrung

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Betonstraßen

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Festkolloquium anlässlich der Emeritierung von O.Univ.Prof. Manfred Wicke

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26. FB Externe Vorspannung

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20. FB Einführung in die Richtlinie BETON - Herstellung, Transport, Einbau, Gütenachweis

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19. FB Einführung in die Richtlinie Wasserundurchlässige Betonbauwerke - Weiße Wannen

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18. FB Einführung in die ÖNORM B 4452

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17. FB Einführung in die neue Richtlinie Spritzbeton

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Die auf dem EUROCODE 2 basierenden neuen ÖNORMEN der Reihe B 4700

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Vorstellung der Richtlinie “Spitzbeton” Teil 1 - Anwendung

Heft 10/1988
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Vorträge am Österreichischen Betontag

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Vortrage am Österreichischen Betontag

Heft 5/1986
Flexibilität im Massivbau, Verstärken und Verbreitern von Betontragwerken

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10. Kongreß 1986, New Delhi

Heft 3/1985
Vorspannung im Hochbau, Entwicklung in der Ankertechnik

Heft 2/1984
Eisenbahnbrücken aus Spannbeton, Projektsteuerung im Bauwesen

Heft 1/1984
Aktuelle Fragen des Spritzbetons

Hefte der Schriftenreihe und Richtlinien sind bei der Geschäftsstelle der Österreichischen Vereinigung für Beton- und Bautechnik gegen Kostenersatz erhältlich.

Personalisiert für: 3G Gruppe Geotechnik Graz ZT GmbH, 8055 Graz-Seiersberg, Triester Straße 478a am 15.06.2012

TECHNICAL SPECIFICATIONS

1 The Technical Specifications contained herein shall be read in conjunction with the other Bidding Documents as specified in Volume-IX.

1.1 Site Information

General

1.1.1 The information given hereunder and provided elsewhere in these documents is given in good faith by the Employer, but the Contractor shall satisfy himself regarding all aspects of site conditions and no claim will be entertained on the plea that the information supplied by the Employer is erroneous or insufficient.

1.1.2 The area in which the works are located is in plain terrain, the project road starts from 33° 1.861'N and 75° 21.618'E and ends at 33° 4.203'N and 75° 27.661'E in the state of Jammu & Kashmir.

1.1.3 Climatic Conditions

1.1.3.1 The temperature in this region is as under:

i) During summer months, the temperature varies from 14°C to 30°C.

ii) During winter months, the temperature varies from -2°C to 10°C.

iii) The location receives about 300 mm of rain, with January the wettest month.

1.1.4 Seismic Zone

The stretch lies in Seismic Zone-IV as defined in Fig. 18 of IRC: 6-2017.

2 GENERAL REQUIREMENTS

The Technical Specifications in accordance with which the entire work described hereinafter shall be constructed and completed by the Contractor shall comprise of the following:

2.1 Part-I: General Technical Specifications

The General Technical Specifications shall be the "SPECIFICATIONS FOR ROAD AND BRIDGE WORKS" (Fifth Revision, April 2013), issued by the Ministry of Road Transport and Highways, Government of India and published by the Indian Roads Congress, henceforth called MORT&H Specifications and deemed to be bound into this document.

2.2 Part-II: Supplementary Technical Specifications

The Supplementary Technical Specifications shall comprise of various Amendments/Modifications/ Additions to the "SPECIFICATIONS FOR ROAD AND

BRIDGE WORKS" referred to in Part-I above and Additional Specifications for item of works which are not covered in Part-I.

2.2.1 A clause or a part thereof in "SPECIFICATIONS FOR ROAD AND BRIDGE WORKS (Fifth Revision April 2013",), referred in Part-I above, where Amended/Modified/Added upon, and incorporated in Part-II, referred to above, such Amendment/Modification/ Addition supersedes the relevant Clause or part of the Clause.

2.2.2 The Additional Specifications shall comprise of specifications for item of works which not covered in Part-I.

2.2.3 When an Amended/Modified/Added Clause supersedes a Clause or part thereof in the said Specifications, then any reference to the superseded Clause shall be deemed to refer to the Amended/Modified/Added Clause or part thereof.

2.2.4 In so far as Amended/Modified/Added Clause may come in conflict or be inconsistent with any of the provisions of the said MORT&H Specifications under reference; the Amended/Modified/Added Clause shall alwaysprevail.

2.2.5 The following Clauses in the "SPECIFICATIONS FOR ROAD AND BRIDGE WORKS (Fifth Revision April 2013",) have been Amended/Modified/Added upon

Sr. No.	Section No.	Section Title	Clause No.
1.	100	General	102,106,108,109, 111,112,114,115 and 120
2.	200	Site Clearance	201 and 202
3.	300	Earthwork, Erosion Control and Drainage	301,304,305 and 306
4.	400	Sub-base, Bases (Non- Bituminous) and Shoulder	401and 406
4.	500	Bases and Surface Courses (Bituminous)	501,505 and 507
5.	800	Traffic signs, Markings and other Road Appurtenances	803 and 806
6	1900	Hot-Dip zinc coating in structural steel and other alloyed products-specifications	1903.3
7.	2100	Open Foundations	2104
8	Additional technical specification-1	Wind Tunnel test for long bridges	

2.3 PART-III Specifications for Miscellaneous Works

Technical Specifications for Miscellaneous works shall be the latest "Specifications volume I to VI, 1996 for Civil Works and General Specifications for Electrical Works

PART I – INTERNAL, PART – II, EXTERNAL for electric work 1994 as published by the Central Public Works Department (CPWD), Government of India" and deemed to be bound into this document.

2.4 The latest edition till 28 days before the final date of submission of the bid of all specifications / standard shall be applicable.

SCOPE OF WORKS

The "Works" consist of "Consultancy Services for preparation of Detailed Project Report (DPR) for providing Pre Construction Activities in Sudhmahadev – Dranga Tunnel of approx. length of 4.5 km and its approach roads on Chenani- Sudhmahadev – Goha road position on NH -244 (Old NH-1B) in the state of Jammu & Kashmir. The works shall, inter alias, include the following, as specified or as directed:

A. Road Works

Site clearance; setting-out and layout; widening of existing carriageway and strengthening including camber corrections; construction of new road/ parallel service road; bituminous pavements remodelling/construction of junctions, intersections, bus bays, lay byes; supplying and placing of drainage channels, flumes, guard posts, guard rails and other related items; construction/extension of cross drainage works, bridges, approaches and other related works; road markings, road signs and kilometre/ hectometre stones; protective works for roads/ bridges; all aspects of quality assurance of various components of works; rectification of the defects in the completed works during the Defect Liability Period; submission of "As built" drawings and any other related documents; and other items of work as may be required to be carried out for completing the works in accordance with the drawings and provisions of the Contract to insure safety.

B. Other Items

Execution of any other items of work for the construction and completion of the Works in accordance with the provisions of the Contract including all incidental items as well as preparation and submittal of reports, plans as may be required.

During the period of the Contract the right of way and all existing roads shall be kept open for traffic and maintained in a safe and usable condition. Residents along and adjacent to the works are always to be provided with safe and convenient access to their properties . Traffic control and traffic diversions shall be used as necessary to protect the works and maintenance will be carried out as directed by the Engineer and provided in the Contract.

Any other items as required to fulfil all contractual obligations as per the Bid Documents.

PART II
SUPPLEMENTARY TECHNICAL SPECIFICATION

AMENDMENTS/MODIFICATIONS/ADDITIONS TO EXISTING CLAUSES OF GENERAL TECHNICAL SPECIFICATIONS

SECTION 100 General

CLAUSE 102 DEFINITIONS

The following abbreviations shall be added in this Clause:

"MORT&H"	:	Ministry of Road Transport &Highways (Previously known as 'MOST', Ministry of Surface Transport)
"NHAI"	:	National Highways Authority of India

CLAUSE 106 CONSTRUCTION EQUIPMENT

Add the following sub para (g) and (h) after sub para (f)

- Adequate standby equipment including spare parts shall be available.
- All measuring devices and gauges shall be in good working condition. Measuring devices that can affect product quality shall be calibrated prior to use and at prescribed intervals against certified equipment. Calibration procedures shall be established, maintained and documented and corrective actions taken when results are unsatisfactory. Accuracy and fitness of measuring devices shall be ensured by proper maintenance.

CLAUSE 108 SITE INFORMATION

Sub-Clause 108.4 This clause shall be as follows:

"Identification of quarry sites and borrow areas shall be the responsibility of the Contractor. Materials procured from quarry sites and borrow areas identified by Contractor and to be used in Works must comply with the requirements of quality as stipulated in the Technical Specification for particular items of work."

CLAUSE 109 SETTING OUT

Sub-Clause 109.8 Delete the 2nd and 3rd sentences in Clause 109.8 and substitute the following:
"Setting out of the road alignment and measurement of angles shall be done by using Total Station."

CLAUSE 111 PRECAUTIONS FOR SAFEGUARDING THE ENVIRONMENT

Sub-Clause 111.1 General

Delete the text of Clause 111.1 in its entirety and substitute the following:

"The Contractor shall take all necessary measures and precautions and otherwise ensure that the execution of the Works and all associated operations on site or off-site are carried out in conformity with statutory and regulatory requirements including those prescribed elsewhere in this document.

The Contractor shall take all measures and precautions to avoid any nuisance or disturbance arising for the execution of the Works. This shall wherever possible be achieved by suppression of the nuisance at source rather than abatement of the nuisance once generated. All vehicles deployed for material haulage shall be spillage proof.

Haul roads shall be inspected at least once daily to clear any accidental spillage. In the event of any spoil, debris, wastes or any deleterious substance from the Site being deposited on any adjacent land, the Contractor shall immediately remove all such material at no cost to the Contract and restore the affected area to its original state to the satisfaction of the Engineer."

Sub-Clause 111.2 Borrow Pits for Embankment Construction

Delete the text of Clause 111.2 and substitute the following:

"Prior approval shall be sought from the concerned State Authorities, and the Contractor shall comply with all local environmental regulations. For all borrow areas, the actual extent of area/zones to be excavated shall be demarcated with the signboards and the operational areas shall be access controlled.

In the case of borrow from tank beds, a regrade/improvement of the inlet channels (at least up to 100m stretch) shall be undertaken in consultation with the concerned state government departments (the Minor Irrigation department of the State PWD) and local bodies. The Contractor shall ensure that excavation of tank beds is uniform over the entire area and that the finished profile of the bed is smooth.

In the case of borrow from the dry highlands, all borrow areas shall be reinstated by the formation gentle side slopes, re-vegetated and connected to the nearest drainage channel to avoid the formation of pools during/after the rainy seasons.

Plant and machinery used in the borrow areas shall conform to State noise emission regulations. All operation areas shall be water sprinkled to contain dust levels to the National Ambient Air Quality Standards."

Sub-Clause 111.3 Quarry Operations

Delete the text of Clause 111.3 and substitute the following:

"Aggregates shall be sourced only from quarry sites that comply with the local/state environmental and other applicable regulations. Occupational safety procedures/practices for the work force in all quarries shall be in accordance with applicable laws. Quarry and crushing units shall have adequate dust suppression measures, such as sprinklers, in work areas and along all approach roads to the quarry sites. These shall preferable be located on the upwind side."

Sub-Clause 111.5 Pollution from Hot-Mix Plant and Batching Plants

Delete the 1st sentence of Clause 111.5 and substitute the following:

"Bituminous hot mix plant and concrete batching plants shall be located at least one (1) km away from the sensitive receptors (schools, hospitals, etc.) and at least 500m from urban settlements, unless otherwise required by the statutory requirements."

Sub-Clause 111.8.1 Environmental Protection:

Add the following sentences in the first paragraph of Sub Clause 111.8.1:
Water tankers with suitable sprinkling system shall be deployed along the haulage roads and in the work sites. Water shall be sprinkled regularly all along the routes to suppress airborne dusts from truck/dumper movements particularly on unpaved roads. Actual frequency will be agreed with the Engineer to suit site conditions."

Sub-Clause 111.8.2 Air Quality

The Contractor shall device and implement methods of working to minimize dust, gaseous and other air-borne emissions and carry out the Works in such a manner as to minimize adverse impacts on the air quality. Construction camps shall have facilities for LPG fuel. The use of firewood shall not be permitted.

The Contractor shall utilize effective water sprays during delivery, manufacture, processing and handling of materials when dust is likely to be created, and to dampen stored materials during dry and windy weather. Stockpiles of friable materials shall be covered with clean tarpaulins, with applications of sprayed

water during dry and windy weather. Stockpiles of materials or debris shall be dampened prior to their movement, except where this is contrary to the Specification.

Any vehicle with an open load-carrying area used for transporting potentially dust-producing material shall have properly fitting side and tail boards. Materials having the potential to produce dust shall not be loaded to a level higher than the side and tail boards and shall be covered with clean tarpaulins in good condition. The tarpaulin shall be properly secured and extend at least 300mm over the edges of the side of the side and tail boards.

The Contractor shall monitor air-quality once weekly in all operational areas under the project and take the necessary steps to comply with the specified requirements. Air quality parameters will include SPM, RPM, SO_2, NO_X, HC and CO. operational areas include work sites, haulage roads, hot mix plants, quarries, crushing plants, stockpiles, borrow sites and spoil disposal sites.

Sub-Clause 111.8.3 Water Sources and Water Quality

The Contractor shall provide independent sources of water supply, such as bore wells, for use in the Works and for associated storage, workshop and work force compounds.

Prior approval shall be obtained from the relevant State Authorities and all installations shall follow local regulations. Bore wells installed and used for the project shall be left in good operating condition for the use of NHAI and local communities. The Contractor shall prevent any interference with the supply to or abstraction from and prevent any pollution of water resources (including underground percolating water) as a result of the execution of the Works.

Areas where water is regularly or repetitively used for dust suppression purposes shall be laid to fall to specially constructed settlement tanks to permit sedimentation of particulate matter. After settlement, the water may be re-used for dust suppression and rinsing. The Contractor shall protect all watercourses, waterways, ditches, canals, drains, lakes and the likes from pollution as a result of the execution of the Works. All water and other liquid waste products arising on the Site shall be collected and disposed of at a location on or off the Site and in a manner that shall not cause either nuisance or pollution.

The Contractor shall at all times ensure that all existing stream courses and drains within, and adjacent to, the Site are kept safe and free from any debris and any materials arising from the Works. The Contractor shall not discharge or deposit any matter arising from the execution of the Works into any water except with the permission of the Engineer and the regulatory authority concerned.

Work force camps shall have septic tank and soak away pits. Operational areas like POL storage areas/hot mix plant areas shall comply with local/state environmental regulations and safety procedures. Storage and handling areas shall be impervious and surrounded by an impervious lined drain to catch any accidental spills. Storm water shall be stored in lined holding tanks with oil, grease-tapping facility prior to disposal in to nearby watercourses. The trappings and sludge of holding tanks shall be disposed off in accordance with the procedures approved by the local regulatory authority.

Sub-Clause 111.20 Control and Disposal of Wastes

The Contractor shall control the disposal of all forms of waste generated by the construction operations and in all associated activities. No uncontrolled deposition or dumping shall be permitted. Wastes to be so controlled shall include, but shall not be limited to, all forms of fuels and engine oils, all types of bitumen, cement, and surplus aggregates, gravels, bituminous mixtures etc. The Contractor shall make specific provision for the proper disposal of these and any other waste products, conforming to local regulations and acceptable to the Engineer.

Spilling of oil and bituminous products during construction and transport shall be avoided to reduce the chances of contamination of surface as well as ground water.

Degraded materials shall be disposed of in a manner as approved by the Engineer and wastewater shall be disposed into septic tanks and soak pits etc. The Contractor shall make arrangements to cleanup spoil as soon as the work finishes in a stretch. If such sites are located outside the ROW, restoration of the site to a level acceptable to the land owner(s) will be carried out within a time period agreed between landowner(s) and the Contractor. Separators shall be used to separate POL materials from wastewater

prior to discharging to the watercourses or as approved by the Engineer in conformance with directives and guidelines.

Disposal of solid waste materials shall be outlined in a plan for which environmental clearances shall be obtained from State environmental regulatory authorities. Potential locations for solid waste disposal are the natural depressions and borrow areas. The areas used for dumping of uncontaminated debris shall be covered with 300mm soil and shall be planted. Contaminated debris shall be dumped in depressions whose bed must be impervious e.g., stone quarry sites or depressions made impervious with 450mm thick impervious floor apron as per MORT&H Technical Specifications. Each successive 1.0m layers shall be covered with 500mm thick soil layer, and the area will be covered with 300mm thick layer and planted.

After Clause 111.12 add the following new Clauses 111.13 to 111.17

Sub-Clause 111.13 Haulage Roads

Existing roads used for hauling shall be strengthened and/ or widened by the Contractor in accordance with the requirements for normal and construction traffic. Where such roads are not existing, the Contactor shall construct project specific single lane paved roads in settlement areas and gravel roads in open areas conforming to the Ministry of Road Transport and Highways (MORT&H) specifications.

The alignment of the haulage roads shall be fixed to avoid agricultural land to the extent possible. In unavoidable circumstances, suitable compensation shall be paid to the people whose land will be temporarily acquired for the duration of the operations. The compensation shall cover for loss of income for the duration of temporary acquisition and land restoration. Prior to the construction of the haul roads, topsoil shall be stripped and stockpiled for re-use.

Material dumping sites shall be access controlled to prevent the unauthorized entry of the people, grazing cattle and stray animals.

Haulage roads shall be reinstated upon completion of hauling for the use of local communities."

Sub-Clause 111.14 Equipment and Vehicles used for the Works

Equipments and vehicles deployed for the construction activities shall not be older than 5 years. Equipments used for road and bridge works shall be based on new technology and shall generate noise and pollutants not exceeding the limits specified by the relevant State Authorities. Vehicles and machineries used for road and bridge works are to be regularly maintained to conform to the National Air Quality Standards. Blasting, if any, will be carried out using small charges.

Sub-Clause 111.15 Noise Control

The Contractor shall consider noise as an environmental constrain in the planning and execution of the Works.

The Contractor shall take all necessary measures so that the operation of all mechanical equipment and construction processes on and off the site shall not cause any unnecessary or excessive noise, taking in to account applicable environmental requirements. The Contractor shall use all necessary measures and shall maintains all plant and silencing equipment in good conditions so as to minimize the noise emission during construction works.

Any member of the work force likely to be exposed to beyond their threshold noise levels shall be provided with protective equipment, such as earplugs, and shall be rotated every four hours.

Construction operations shall be limited to daytime hours only, particularly in the settlement areas.

Sub-Clause 111.16 Vibration Control

The Contractor shall take measures during construction activities to control the movement of the work force and construction machinery/equipment, and to avoid/ minimize activities, which produce vibrations.

Sub-Clause 111.17 Measurement

Monitoring of Air/Water/Noise and Soil quality shall be paid as per numbers of samples tested. For Compliance of all other provisions made in this Clause 111, it shall be deemed to be incidental to the work and no separate measurement shall be made. The Contractor shall be deemed to have made allowance for such compliance with these provisions in the preparations of his prices for items of work included in the Bills of Quantities and full compensation for such compliance shall be deemed to be covered by them."

CLAUSE 112 ARRANGEMENT FOR TRAFFIC DURING CONSTRUCTION

Sub-Clause 112.4 Traffic Safety and Control

Last line of Para 5 shall be read as under:

"The signs shall be of approved design and of reflector type." **Add**

the following paragraph at the end of the clause:

"Before commencement of any construction, the Contractor shall prepare and submit details of the arrangements for passing traffic during construction, design of barricades, signs, markings, lights, flags etc. conforming and satisfying the requirements of the "Guidelines on Safety in Road Construction Zones" of IRC: SP 55-2001 and get the same approved by the Engineer.

Sub-Clause 112.6 Measurement for Payment and Rates

a) The provision of treated shoulder including construction of temporary cross drainage structures, if required, as described in Clause 112.2 including their maintenance, dismantling and clearing debris, where necessary, shall be considered as incidental to the works and shall be Contractor'sresponsibility.

b) The Construction of temporary diversion including temporary cross drainage structures as described in sub clause 112.3, shall be measured in linear meter and the unit contract rate shall be inclusive of full compensation for construction (including supply of material, labor, tools, etc.), maintenance as per sub clause 112.5, final dismantling, and disposal.

c) All Traffic safety and control devices during construction as per sub clause 112.4 including providing, erecting and maintaining barrier, signs, markings, flags, lights and providing flag men etc. is included in item rate.

CLAUSE 114 SCOPE OF RATES FOR DIFFERENT ITEMS OF WORK

Sub-Clause114.2 Item (ii) of Clause 114.2 shall read as follows:

A detailed resource-based construction programme including resources planning using computerized critical path network method/PERT in a form, which facilitates control of the progress of the works and consequences of any changes in terms of time. The programme shall also include detailed network, activities for the submission and approval of materials, procurement of critical materials and equipment, fabrication of special products/ equipment and their installation and testing and for all activities of the Contractor that are likely to affect the progress of work etc. including updating all such activities on the basis of decisions taken at the periodic site review meetings or as directed by the Engineer. The Contractor shall submit data via electronic media to the Engineer in a form readily compatible with Engineer's planning system.

The first issue of the detailed construction programme including the detailed description of the system and the procedures shall be submitted to the Engineer for acceptance not later than 28 days after the date of receipt of the letter of acceptance.

The contractor shall submit to the Engineer for approval & consent, the updated & revised programme at every three months interval or as such as directed by the Engineer. The updated & revised programme shall be submitted showing the actual progress achieved (physical & financial) and the effects of the progress achieved on the timing of the remaining work including any change to the sequence of the activities

CLAUSE 115 METHODOLOGY AND SEQUENCE OF WORK

The Clause shall be substituted as follows:

Sub-Clause115.1 Submission of Method Statement

The Contractor shall submit methods statement within 28 days after the date of letter of acceptance. The methods statement shall be submitted in two parts.

The General part of the methods statement shall describe the Contractor's proposals regarding preliminary works, common facilities, and items that require consideration at the early stage of the Contract. The General part shall be furnished along with the first issue of the construction programme (refer clause 114.2) and shall include information on:

a) Sources of materials like coarse aggregate and fine aggregate, quantity and quality of materials available in different sources;

b) Sources of manufactured materials like cement, steel, bitumen reinforcement, prestressing strands and bearings. Wherever possible the Contractor shall identify at least two sources for each of the items; he shall also submit test certificates of recently manufactured materials for the consideration of the Engineer.

c) Locations of site facilities like batching plant, hot mix plant, aggregate processing plant, crushing plant etc.

d) Details of facilities/approaches for transportation of men, equipment and materials for construction of pavements, foundations and substructure in riverbed, and plan for free traffic flow and safe drainage.

e) Information on procedures to be adopted by the Contractor for prevention and mitigation of negative environmental impact due to construction activities.

f) Any other information required by the Engineer subsequent to the scrutiny of method statement

The General part of the Q.A. Programme shall accompany the methodsstatement under sub-clause 105.3.

The Special part of the methods statement shall be submitted to the Engineer by the Contractor for each important item of work like construction of embankments and subgrade, pavements, pile/well foundations, concreting, prestressing, repair and rehabilitation of existing structures, concrete superstructure, dismantling of structures and pavement and for any other item as directed by the Engineer.

These statements shall give information on

i) Details of personnel both for execution and quality control of the work.

ii) Equipment deployment with details of number of units, capacity, standby arrangements

iii) Sequence of construction, details of temporary or enabling works like, diversions, cofferdams, formwork including specialized formwork for superstructure, details of borrow areas, method of construction of embankment and subgrade, pavements, piles, wells, concreting procedures,

details of proprietary process and products (e.g. details of prestressing systems, proprietary piling systems, bearings, expansion joints etc.) and details of equipment to be deployed. Wherever necessary, technical literature, design calculations and drawings shall be included in the methods statement.

iv) Testing and acceptance procedures including documentation.

v) Special part of the Q.A. Programme referred in clause 105.3 for the particular item of work shall be submitted along with the methods statement for the concerned activity.

vi) Engineer shall examine and approve the methods statement or direct the Contractor to resubmit the statement with required modifications. The modified statement shall be submitted within 14 days of receipt of Engineer's comments.

The sole responsibility for the safety and adequacy of the methods adopted by the Contractor shall rest on the Contractor irrespective of any approval given by the Engineer.

Sub-Clause115.2 Approval of Proprietary Product/Process/System

Only proprietary products proven by International usage in comparable projects shall be permitted to be used. Fully authenticated details of licensing and collaboration arrangement shall be submitted by the manufacturer, where relevant.

Within 90 days of award of work the Contractor shall submit the following information for all proprietary products for approval by the Engineer.

i) Name of manufacturer and name of product/ process/ system.

Complete details of the manufacturer of the product/ process/ system shall be furnished. Details of projects where similar product/process/system has been successfully used shall be furnished. Authenticated copies of license/collaboration agreement shall be furnished.

ii) General features of the product/product process/ system.

Detailed write up with methods statements shall be furnished for each product/ process/ system. This shall include complete working drawings & installation drawings, technical specifications covering fabrication, materials, system of corrosion protection etc.,

iii) Details of product development and development testing.

iv) Acceptance test and criteria.

Manufacturer shall submit a quality assurance system document. Details of acceptance test and criteria of acceptance shall be furnished in this document.

v) Installation procedure.

vi) Maintenance procedure and schedule.

vii) Warranty proposal.

The Engineer may instruct any additional tests for the purpose of accepting the product. The charges of these additional tests shall be borne by the Employeronly in case the product satisfies the specifications.

CLAUSE 120 FIELD LABORATORY

Sub-Clause 120.2 Description

Replace the words "indicated in the drawings" in the first sentence of second paragraph of this Clause with the words "per provisions indicated in this Clause and at a location approved by the Engineer."

Replace "electric supply etc." to the second sentence of first paragraph by "including uninterrupted power supply etc.".

Delete the first sentence of second paragraph "The floor space in the drawing" and substitute the following:

"The floor space required for the field laboratory shall be not less than 200 sqm.

"The fourth sentence of second paragraphs"The furnishing.....In Table 100-2" shall read as under.

"A good semi furnished office accommodation shall be provided to the Material Engineers of the Supervision Team as per the direction of the Engineer."

Add the following at the end of this Clause:

"There shall also be provided a concrete paved area, for storing samples adjacent to the laboratory, of about 100 sqm and another 75 sqm shall be suitably roofed with open sides giving protection against sun and rain.

Within 14 (fourteen) days of the commencement date, the Contractor shall prepare and submit a layout plan and details of the laboratory building and make/supplier of the equipment to the Engineer for his approval.

The field laboratory to be provided under the Contract shall be handed over to the Engineer in finished and fully equipped condition not later than 2 months after the receipt of Notice to Commence Work, and the field laboratory with all equipment/ instrument shall be to the entire satisfaction of the Engineer. During the 2-month period starting from the Notice to Commence work, the laboratory tests shall be performed in another laboratory proposed by the Contractor and approved by the Engineer.

Laboratory Equipment

General

The items of laboratory equipment shall be provided in the field laboratory depending upon the items to be executed as per Table mentioned below instead of Table 100-2 shown in MORTH:

The following items of laboratory equipment shall be provided in the field laboratory:

The equipment and instruments shall be new and shall be quality certified by Bureau of Indian Standards (BIS).

Sr. No.	Sub No.	Item, Specifications	Nos. required
A: General			
(i)	**Balance**		
	(a)	7 kg to 10 kg capacity semi -self indicating Electronic Type –Accuracy 1 gm	2
	(b)	500 gm capacity semi-self-indicating Electronic Type – Accuracy 0.01 gm	2
	(c)	Chemical balance 100gm capacity - Accuracy 0.0001gm	1
	(d)	Pan balance 5 kg capacity - Accuracy 0.5 gm	2
	(e)	Platform Scale – 300 kg capacity	1
	(f)	Triple Beam balance-25kg capacity Accuracy 1gm	2
(ii)	**Ovens – Electrically operated, thermostatically controlled**		
	(a)	From 100°C to 220°C – Sensitivity	2
(iii)	**Sieves, as per IS 460-1962**		
	(a)	IS Sieves 450 mm internal dia. of sieve sets as per BIS of required sieve sizes complete with lid and pan	2 set
	(b)	IS sieve 200 mm internal dia. (brass frame and steel or brass wire cloth mesh) consisting of sieve sets of required sieve sizes complete with lid and pan	2 set
(iv)	Sieve shaker capable of taking 200 mm and 450 mm dia. Sieves electrically operated with time switch assembly (As per BIS)		1
(v)	200 tones compression testing machine		1
(vi)	Stop watches 1/5 sec. Accuracy		2
(vii)	Glassware comprising of Beakers, Pipettes, dishes, measuring cylinders (100 to 1000 cc capacity) glass rods and funnels, glass thermometers range 0°C to 100°C and metallic thermometers range 300°C		1 Dozen each
(viii)	Hot plates 200 mm dia (1500 watt)		6
(ix)	**Enamel trays**		

Sr. No.	Sub No.	Item, Specifications	Nos. required
	(a)	600 mm x 450 mm x 50 mm	10
	(b)	450 mm x 300 mm x 40 mm	10
	(c)	300 mm x 250 mm x 40 mm	6
	(d)	Circular plates of 250 mm dia.	6
(x)	Water Testing Kit		1
(xi)	First Aid Box		1
(xii)	Spatula Set of 100 and 200 long		3
(xiii)	Digging Tools (pixels, shovel, fork etc.)		As reqd.
(xiv)	Miscellaneous tools (sledge hammer, lump hammer, wooden pegs etc.)		As reqd.
(xv)	Maximum and Minimum Thermometer		2 Set
(xvi)	Rain Gauge		1 Set
(xvii)	Timer 0-60 minutes with alarm & 1/5 sec accuracy.		3 Sets

B: For Soils and Aggregates			
(i)	Water still, 3 liter/hr with fittings and accessories		1
(ii)	Liquid limit device with Casagrande and ASTM grooving tools as per IS: 2720		1
(iii)	Sampling pipettes fitted with pressure and suction inlets, 10 ml Capacity		2 set
(iv)	Compaction apparatus (Proctor) as per IS: 2720 (Part 8) complete with collar, base plate and hammer		1 set
(v)	Modified AASHTO compaction apparatus as per IS. 2720 (Part 7) 1980 or Heavy Compaction Apparatus as per IS complete with collar, base plate and hammer		1 set
(vi)	Sand pouring cylinder with conical funnel and tap and complete as per IS 2720 (Part 28) 1980 including modified equipment		4
(vii)	Sampling tins with lids 100 mm dia x 75 mm ht ½ kg capacity and miscellaneous items like moisture, tins with lid (50 grams) etc		12
(viii)	Lab CBR testing equipment for conducting CBR testing, load frame with 5 Ton capacity, electrically operated with speed control as per IS: 2720 (Part 16), and consisting of following:		**1 set**
	(a)	CBR moulds 150-mm dia – 175-mm ht complete with collar, base plate etc.	**24**
	(b)	Tripod stands for holding dial gauge holder	**24**
	(c)	CBR plunger with settlement dial gauge holder	**1**
	(d)	Surcharge weight 147-mm dia 2.5 kg weight with central hole	48
	(e)	Spacer disc 148-mm dia, 47.7-mm ht. With handle	3
	(f)	Perforated plate (Brass)	24
	(g)	Soaking tank for accommodating 24 CBR moulds	1 each
	(h)	Proving rings of 1000 kg, 2500 kg and 5000 kg capacity	10

B: For Soils and Aggregates			
	(i)	Dial gauges, 25 mm travel- 0.01 mm/division	
	(j)	**Aluminium Tis**	
	50x30m		36 nos
	55x35m		36 nos
	70x45m		36 nos
	70x50m		36 nos
	80x50m		36 nos
(ix)	Standard Penetration test equipment		1
(x)	Nuclear Moisture Density Meter or equivalent		2
(xi)	Speedy moisture meter complete with chemicals		2
(xii)	Unconfined compression test apparatus		1 set
(xiii)	Aggregate Impact Test Apparatus		1
(xiv)	Aggregate Impact Test Apparatus as per IS 2386 (Part 4) 1963		1
(xv)	Los Angeles abrasion Test Apparatus as per IS 2386 (Part 4) 1963		1
(xvi)	Riffle Box of Slot size of 50mm as per ASTM C-136		1

C: For Bitumen and Bituminous Mixes		
(i)	Constant temperature bath for accommodating bitumen	2
	test specimen electrically operated and thermostatically controlled, 50-liter capacity temp. range ambient 80o C	
(ii)	Penetrometer automatic type, adjustable weight arrangement and needles as per IS. 1203 – 1978	2
(iii)	Solvent extraction or centrifuge type apparatus complete (AASHTO, T-164) with extraction thimbles with stocks of solvent and filter paper	1
(iv)	Laboratory mixer including required accessories about .02 cum capacity electrically operated fitted with heating jacket	1
(v)	Marshall compaction apparatus automatically operated as per ASTM 1559-62 T and complete with electrically operated loading unit, compaction pedestal heating head assembly, dial micrometer and bracket for flow measurement, load transfer bar, specimen mould 100 mm dia. (4 in) with base plate, collars, specimen extractor, compaction hammer 4.53 kg (10 lb.) x457 mm (18 in) fall	1 set
(vi)	Distant Reading Digital Thermometer for Measuring Temperatures in Asphaltic Mixes	As required
(vii)	Riffle Box	1
(viii)	Automatic Asphalt Content Gauge [Nuclear are equivalent]	1
(ix)	Thin film Oven test apparatus to the requirement of AASHTO T 179, including accessories	1
(x)	Ring Ball Apparatus as per IS 1205- 1978	1
(xi)	Asphalt Institute Vacuum Viscometer as per IS 1206(part II) – 1978	1
(xii)	BS U- Tube Modified Reverse Floro Viscometer IS 1206(Part III) – 1978	1

C: For Bitumen and Bituminous Mixes		
(xiii)	Apparatus for Determination of Ductility Test as per IS 1208 – 1978	1
(xiv)	Pen Sky – Martars closed Tester for testing flashand fire point as per IS 1209 – 1978.	1
(xv)	Apparatus for Float Test – IS – 1210 – 1978	1
(xvi)	Apparatus for Determination of water content (Dean and Shark Method) IS – 1211 – 1978	1
(xvii)	Apparatus for Determination of Loss on Heading IS – 1212-1978.	1
(xviii)	Apparatus of Determination of specified Gravity IS- 1202-1978	1
(xix)	Core cutting machine with 100mm dia. Diamond cutting Edge	1
(xx)	Apparatus for Elastic Recovery test for Modified Bitumen	1
(xxi)	Apparatus for Storage Stability test for Modified Bitumen	1
(xxii)	Apparatus for Separation test for modified bitumen	1

D: For Cement, Cement Concrete and Materials			
(i)	Water still		1
(ii)	Vicat needle apparatus for setting time with plungers, as per IS. 269-1967		1
(iii)	Moulds		
	(a)	150 mm x 300 mm ht cylinder with capping component	As required
	(b)	150mmx150 mm x150mm cubical for compressive strength	As required
	(c)	150mmx100 mm x600mm beam for flexural strength	As required
(iv)	Concrete permeability apparatus		1
(v)	High frequency mortar cube vibrator for cement testing		1
(vi)	Concrete mixer power driven, 1 cu ft capacity		1
(vii)	Variable frequency and amplitude vibrating table size 1 metre x 1 metre, as per the relevant British Standard		1
(viii)	Flakiness & Elongation test apparatus		2each
(ix)	Aggregate impact test apparatus as per IS 2386 (Part 4) 1963		2
(x)	Los Angeles abrasion apparatus as per IS. 2386 (Part 4) 1963		1
(xi)	Flow table as per IS 712-1973		1
(xii)	(a)	Equipment for slump test	2
	(b)	Compaction factor test equipment	1
(xiii)	Equipment for determination of specific gravity for fine and coarse aggregate as per IS 2386 (Part 3) 1963		2

D: For Cement, Cement Concrete and Materials		
(xiv)	Flexural attachment to compression testing machine	1
(xv)	Core cutting machine with 150 mm dia. Diamond cutting edge	1
(xvi)	Needle vibrator	1
(xvii)	Vibrating hammer as per BS specification	1
(xviii)	Air entrainment meter ASTM C - 231	1
(xix)	0.5 Cft, 1 Cft cylinder for checking bulk density of aggregate with tamping rod	1
(xx)	Soundness testing apparatus for cement	1
(xxi)	Flexural Beam testing machine with accessories	1
(xxii)	Chemicals solutions and consumable	As reqd.
(xxiii)	Chloride Testing kit for chemical analysis of chloride content.	1
(xxiv)	ION Exchange kit for rapid determination of sulphate content.	1

E: For Control of Profile and Surface Evenness			
(i)	Digital Level complete with all accessories		2 sets
(ii)	Distomat or equivalent		2 Nos.
(iii)	Theodolite – Electronically operated with computerized output attachment		2 sets
(iv)	Total Station with all accessories		2 sets
(v)	Towed Fifth Wheel Bump Indicator		1 set
(vi)	3meter straight edge and measuring wedge		2 sets
	Camber templates 2 lane		
(vii)	String line Arrangement with paver and sensor powers		1
	(a)	Crown type cross-section	2 sets
	(b)	Straight run cross-section	2 sets
(viii)	Steel tape		
	(a)	5 m long	as reqd
	(b)	10 m long	as reqd
	(c)	20 m long	as reqd
	(d)	30 m long	as reqd
	(e)	50 m long	As reqd
	(e)	50 m long	As reqd
(ix)	Precision Staff		3 Sets

Note: The laboratory set-up must be complete including a set of reference standards, adequately staffed and operational to the satisfaction of the Engineer not later than 2 months from the date of receipt of Notice to commence theworks.

Sub-Clause 120.3 Ownership

This Clause shall read as under:

"Land for the laboratory shall be provided by the Contractor."

Sub-Clause 120.4 Maintenance

This Clause shall read as under:

"The Contractor shall arrange to maintain the field laboratory including sample store yards in a satisfactory manner until the issue of Taking over Certificate for the whole work. Maintenance includes all activities described in Clause 120.4 and maintenance of equipment and running of the same including chemicals and consumables."

Sub-Clause 120.5 Rate

The construction, supply, installation, maintenance, and operation including all consumables like chemicals & reagents etc., and all other expenses involved in connection thereto for the field laboratory shall be incidental to the work, and shall not be paid for separately.

SECTION 200 Site Clearance

CLAUSE 201 CLEARING AND GRUBBING

Sub-Clause 201.1 Scope

Replace with following Para:

This work shall consist of cutting, excavating, removing, and disposing of all materials such as trees of girth up to 300 mm, bushes, shrubs, stumps, roots, grass weeds, rubbish etc. and top soil up to 150 mm, which in the opinion of Engineer is unsuitable for incorporation in the work including draining out stagnant water if any from the area of road land, drain, cross drainage structure and other area as specified in the drawing or instructed by Engineer. It shall include necessary excavation by harrow discs or any other suitable equipment, backfilling of the pits by suitable soil, resulting from uprooting of trees & stumps and making the surface in proper grade by suitable equipment and compacted by power roller to required compaction as per Clause 305.3.4. The work also includes handling, salvaging and disposal of cleared material. Clearing and grubbing shall be performed less than one month in advance of earthwork operation and in accordance with requirement of these specifications.

CLAUSE 202 DISMANTLING CULVERTS, BRIDGES AND OTHER STRUCTURES/ PAVEMENTS

Sub-Clause 202.5 Disposal of Materials

The first paragraph of the sub clause shall read as below:

All materials obtained of dismantling/milling shall be the property of the Contractor for which he shall quote a rate for rebate in BOQ Bill No. 1, and the Contractor shall be free to use this material in work, or he may sell/dispose the material to as desired / deemed fit by him.

The existing pavement crust shall be reused as indicated below:

Contractor shall be free to use dismantled / milled material, as is where is basis, or by suitably modifying the material, or by crushing the material, or by breaking the material, and screening the same, provided it meets the specifications and is approved by the Engineer.

SECTION 300 Earthwork, Erosion Control and Drainage

CLAUSE 301 EXCAVATION FOR ROADWAY ANDDRAINS

Sub-Clause 301.1 Scope

Add the following as second paragraph under this clause:

"The work shall also include excavation for channel training at culverts/bridges, excavation of existing shoulders and medians for purposes of widening the pavement and excavation of existing embankment for reconstruction to specification."

CLAUSE 304 EXCAVATION FOR STRUCTURES

Sub-Clause 304.3.2 Excavation

At the end of 1st paragraph of Clause 304.3.2 inserts the following additional sentences:

"The Contractor shall ensure the stability and structural integrity of adjacent existing foundations and structures and if necessary shall, at his own expense, install temporary or permanent sheet piles, coffer dams, shoring or similar as support or protection to the satisfaction of theEngineer."

CLAUSE 305 EMBANKMENT CONSTRUCTION

Sub-Clause 305.2 Material and General Requirements

Sub-Clause 305.2.1 Physical Requirements:

Sub-Clause 305.2.1.2 Add the following after second paragraph:

"Soils having medium and high swelling potential shall be defined based on Liquid Limit, Plastic Limit, Shrinkage Limit, Gradation, Free swelling Index, Field dry Density and Field Moisture Content and types of Clay minerals present in the soil and as directed by the Engineer. The location and the extent of these soils with medium to high swelling potential should be defined as directed by the Engineer."

Sub-Clause 305.2.2.2 Borrow Materials

Para 1 of this Clause shall read as under:

" No borrow area shall be made available by the Employer for this work. The arrangement for the source of supply of the material for embankment and sub-grade as well as compliance to the different environmental requirements in respect of excavation and borrow areas as stipulated, from time to time, by the Ministry of Environmental and Forest, Government of India and the local bodies, as applicable, shall be the sole responsibility of the Contractor."

Sub-Clause 305.2.2.4 Compaction Requirements

In Clause 305.2.2.4 delete Table 300-2 and substitute the following:

Table 300-2
Compaction Requirements of Embankment and Subgrade

Sr. No.	Type of Work/Material	Relative Compaction as %age of maximum laboratory dry density as per IS 2720 (Part 8)
1	Subgrade and earthen shoulders	Not less than 97%
2	Embankment	Not less than 95%
3	Expansive clays	Not allowed
4	Design CBR of Subgrade & Shoulder has been taken 8. The borrow earth used for subgrade material must satisfied the requirement of the design CBR of 8 %	

Para 2 of this Clause given below Table 300-2 shall read as under:

The contractor shall at least 21 working days before commencement of construction of embankment and the subgrade; submit the following to the Engineer for approval:

(i) The values of maximum dry density and optimum moisture content obtained in accordance with IS: 2720 (Part 8) for each fill material proposed to be used in the construction of embankment and subgrade.

(ii) The graphs of Density plotted against moisture content from which each of the values in (i) above of maximum dry density and optimum moisture content were determined.

(iii) The dry density-moisture content-CBR relationships, heavy compactive efforts conforming to the IS 2770 (part 8) for each of the fill material proposed to be used in the subgrade.

The above information shall form the basis for compaction only upon its approval by the Engineer."

Sub-Clause 305.3 Construction Operations

Sub-Clause 305.3.4 Compacting Ground Supporting Embankment/Subgrade

Para 1 of this clause shall be read as

"Where necessary the original ground shall be levelled, scarified, mixed with water and then compacted by rolling to facilitate placement of first layer of embankment so as to achieve minimum dry density as given in Table 300-2.

Sub-Clause 305.8 Measurement for Payment

Substitute Clause 305.8.1 shall be read as

"Earth embankment/sub-grade construction shall be measured separately by taking cross sections at intervals after clearing and grubbing and if necessary compaction of original ground before the embankment work starts and after its completion and computing the volumes of earthwork in cubic metres by the method of average and areas."

CLAUSE 306 SOIL EROSION AND SEDIMENTATION CONTROL

Sub-Clause 306.4 Measurements for Payment

Substitute Clause 306.4 as follows:

"All temporary sedimentation and pollution control works shall be deemed as incidental to the earthwork and other items of work and as such no separate payment shall be made for thesame."

SECTION 400 Sub-Bases, Bases (Non-Bituminous) and Shoulders

CLAUSE 401 GRANULAR SUB BASE

Sub-Clause 401.1 Scope

Add the following at the end of this Clause:

"A site trial shall be performed in accordance with Clause 901.16."

Sub-Clause 401.2.2 Physical Requirements

Add at the end of this clause as under:

The Contractor shall, at least 21 working days before the commencement of the construction of the sub-base course, submit to the Engineer, the results for approval of the laboratory testing on the physical properties defined above. The construction of the sub-base course shall be taken up only upon the Engineer's approval of the material.

Grading I of table 400-1 shall be adopted at site.

CLAUSE 406 WET MIX MACADAM SUB BASE/BASE

Sub-Clause 406.4 Opening to Traffic

The Clause shall be read as follows:

No vehicular traffic of any kind shall be allowed on the finished wet mix macadam surface.

SECTION 500 Base and Surface Courses (Bituminous)

Sub-Clause 501.2 Materials

Sub clause 501.2.1 Binder

Binder of VG-30 grade shall be used or if available viscosity grade of bitumen shall be used in accordance with IS:73

Sub-Clause 501.2.2 Delete "Crushed gravel or other hard material" from first Line of Para 1."
Para 3 isdeleted.

CLAUSE 505 DENSE BITUMINOUS MACADAM

Sub-Clause 505.2.1 Bitumen

Binder of VG-30 grade shall be used or if available viscosity grade of bitumen shall be used in accordance with IS:73.

CLAUSE 507 BITUMINOUS CONCRETE

Sub-Clause 507.2.1 Bitumen

Binder of CRMB-60 grade shall be used.

SECTION 800 Traffic Signs, Markings and Other Road Appurtenances

CLAUSE 803 ROAD MARKINGS

Sub-Clause 803.2 Materials

This clause shall read as under:
"Road markings shall be hot applied thermoplastic compound and the materials shall meet the requirements as specified in Clause 803.4.

The road markings shall be laid in one layer with appropriate road marking machine approved by the Engineer. Before the road-marking machine is used on the permanent works, the satisfactory working of the machine shall be demonstrated on a suitable site, which is not part of the permanent works. The rate of application shall be checked and adjusted as necessary before application on a large scale is commenced, and thereafter daily."

CLAUSE 806 ROAD DELINATORS

Sub-Clause 806.2 This clause shall read as follows:

a) Triangular Object Marker shall be 300mm side with four red reflectors, made out of 2mm thick aluminum sheet, face to be fully covered by high intensity grade white retro reflective sheeting of encapsulated lens type as per clause 801. The background/ border/ symbols shall be made by screen-printing of desired colour as per sign details. The sign plate shall be fixed with 6mm dia. aluminium rivets on MS angle iron frame. The angle iron frame shall be made with angle of size 40mmx40mmx5mm. The sign shall be fixed with nut-bolts & welding on MS pipe 50mm dia (NB-MW) and 500mm high.

b) Rectangular hazard marker 600mm x 300mm made out of 2mm thick aluminum sheet, face to be fully covered by high intensity grade white retro reflective sheeting of encapsulated lens type. The background/ border/ symbols shall be made by screen-printing of desired colour as per sign details. The sign plate shall be fixed with 6mm dia aluminium rivets on MS angle iron frame. The angle iron frame shall be made with angle of size 40mmx40mmx5mm. The sign shall be fixed to 80mm dia (NB-MW) MS pipe.

c) Roadway Indicators shall be 1000mm high made with 100 mm dia. NB medium weight MS pipe. One reflector of high intensity grade retro reflective sheeting with encapsulated lens shall be provided on top of the reflector. The white & red reflector shall be provided alternatively of 40mm width, so that total width of reflector shall be 120mm. A wire mesh cover of 150mm height shall be provided on top.

d) All components of signs & supports shall be throughly descaled, cleaned, primed and painted with two coats of epoxy paint. The sign backside shall be with grey colour and post shall be white colour/ alternate white & black bands. The post below ground shall be painted with three coats of red lead.

Clause 1900 Corrosion resistant steel

Sub-Clause 1903.3 Corrosion resistant steel

Please add the following sub clause -

Sub-Clause 1903.3a

To make the steel corrosion free hot dipped zinc coating of the structure shall be done as per code "IS: 4759:1996 Hot dipped Zinc coating on structural steel and Other alloyed products -specifications".

Clause 2100 Open Foundation

Sub-Clause 2104.1 Preparation of Foundation

Please add the following as a last para-

Considering the soil SBC as per Geotechnical report, 1 m of depth below the founding level of bridges shall be removed and replaced with granular sand. The cost of the excavation and sand shall be made from respective items.

Additional Technical specification -1 Wind tunnel test for the structure

Wind tunnel test shall be done as per the specification and manual as given below

"ASCE (1999) Wind tunnel studies of building and other structures, ASCE manual of practice 67".

"ASCE (2012) Wind Tunnel Testing for buildings and other structures, Wind Tunnel Testing Standards Committee, Standards 49-12".