00	2013-03-31	Preliminary Tunnel Design Phase II	MBu, AGo	ASr, WSc	AGo
Rev	Date	Status	Prepared	Checked	Approved

CONSULTANT:

3G GRUPPE GEOTECHNIK GRAZ
ZT GmbH
Fasching, Goricki, Klima, Schubert, Semprich, Steidl, Steindorfer

Triester Straße 478a, 8055 Graz-Seiersberg
Tel.: ++43 / 316 / 337799, Fax.: ++43 / 316 / 337799-11
e-mail: office@3-g.at, Internet: http://www.3-g.at

GRUPPE GEOTECHNIK GRAZ ZT GMBH

Vayam Technologies Ltd
(Formerly IBIlt Technologies Limited
Thapar House, 124-Janpath, New Delhi-110 001
Ph.: +91 11 47101223, Mobile: +91 9910034450, Fax: +91 11 23368946
Email: mahenderp@vayamtech.com

CLIENT:

The Chief Engineer
Project BEACON
Border Roads Organization
C/O 56 APO
INDIA

PROJECT:

Consultancy Services for Detailed Feasibility Study and Framing up of Phase-wise proposal (DPR) for construction of two tunnels at Z-Morh and at Zojila for all weather connectivity from Srinagar to Leh in Jammu & Kashmir State

ZOJILA TUNNEL

TITLE:

Phase II: Detailed Project Report - Preliminary Tunnel Design

Volume I: Executive Summary

Prepared by:	Burgstaller, Goricki	Date:	2013-03-31
Checked by:	Steindorfer, Schubert	Date:	2013-03-31
Approved by:	Goricki	Date:	2013-03-31

Contract No.:	CE (P) BCN/05/2009-10	File:	8482B_II-ZOT_rep-01-12-00
Document No.:	8482B_II-ZOT_rep-01-12-00	Rev.No.:	00

Index

Index of Detailed Project Report

1 CONSULTANTS TASK OF WORK

Border Roads Organization (BRO) assigned a consulting contract to Vayam Technologies Ltd (formerly iBilt Technologies Ltd.) for Detailed Feasibility Study and Framing up of Phasewise proposal (DPR) for construction of the Zojila Tunnel. 3G Gruppe Geotechnik Graz ZT GmbH (3G) prepared this Phase II report (DPR) based on the specifications of the consulting contract mentioned above.

Project History

In the following the design phases prior to this Technical Report for the Conceptual Tunnel Design of Phase II are summarized chronologically.

a) Documents of the consultancy contract
b) Conceptual Tunnel Design Phase I, Part I and Part II
c) Update of Conceptual Tunnel Design Phase I, Part I, based on SASE report with separate parallel egress tunnel as per decision of BRO
d) Additional Cost and Time Evaluation for different Scenarios as Requested by the Client
e) Tunnel alignment approval by BRO (letter “40578/Zozila DGBR/12/Brs & Tnls” from 03rd of January 2013)

Ad a) Consultancy Contract

In the tender documents for the consultancy contract a very preliminary tunnel alignment for the Zojila Tunnel was proposed, including locations for both tunnel portals. According to these tender documents, the Zojila Tunnel has a length of approximately 12 km with the western portal (Srinagar) on a tentative elevation of 3150 m and the eastern portal (Leh) with 3250 m.

The horizontal alignment for Zojila Tunnel shall be designed preferably straight. For the vertical alignment a 1.5 % upward gradient towards the tunnel centre from both portal ends shall be designed to facilitate the longitudinal drainage.

Ad b) Phase I report

In Phase I, geological studies and site investigations are carried out to provide the necessary geological and geotechnical information for the design works for all project relevant aspects. Data evaluation and interpretation shall allow the assessment of all necessary geotechnical parameters for design calculations and the prediction of ground conditions and distribution of rock and soil types and classes. As part of Phase I a conceptual design for Zojila Tunnel was prepared and submitted. The conceptual design included the following aspects:

- A study of tunnel alignment alternatives.
- A study of different tunnel systems such as two lane single tube tunnel and bi-directional traffic in comparison with two independent, uni-directional traffic tunnel tubes.
- The design of typical tunnel cross-sections for different tunnel systems.
- A conceptual tunnel design for a proposed (most favourable) tunnel alignment.
- A preliminary design of the tunnel ventilation system based on the preliminary traffic data.
- Excavation methods and preliminary proposals for support systems.
- Construction concepts as well as estimate construction schedule and time.
- A brief summary of technical specifications.

The conceptual tunnel design report of Phase I was submitted in June 2011.

Ad c) Update of Conceptual Tunnel Design Phase I, Part I based on SASE report, with separate parallel egress tunnel

Based on the conceptual tunnel design of Phase I the Snow and Avalanche Study Establishment (SASE) submitted a report with proposals for further alternative tunnel alignments. Based on these additional data concerning avalanche zones in the project area an additional tunnel alignment study report was prepared by 3G.

Various preliminary alignments were compared with respect to the vertical and horizontal alignment, tunnel length, accessibility of portal areas and conceptual ventilation system.

At 9th of March 2012 BRO decided to change the tunnel system to one bidirectional traffic tunnel with one separate, parallel egress tunnel. An updated Conceptual Tunnel Design Phase I, Part I with separate parallel egress tunnel was prepared by 3G based on the Client's decision and submitted in August 2012.

Ad d) Additional Cost and Time Evaluation for different Scenarios as Requested by the Client

Based on the Conceptual Tunnel Design Phase I, Part I with separate parallel egress tunnel the Client requested additional Cost and Time Evaluation with respect to the construction schedule and the accessibility of the eastern and western portal and the duration of winter breaks respectively.

A construction time and cost evaluation was submitted in October 2012 including the scenario with one additional construction shaft and the accessibility of the western portal. An additional construction time and cost evaluation was submitted in November 2013 including the scenario with one additional construction shaft and the accessibility of the eastern portal as requested by the Client.

The Client decided that the general construction concept shall be developed with the assumption of all-year accessibility of the eastern portal only. The supply of the eastern portal shall be guaranteed from Leh during all winter months while all other portals, shafts and site installations (western portal and intermediate construction shafts) are not accessible during winter for five months.

Ad e) Tunnel alignment approval by BRO

Based on the updated Conceptual Tunnel Design and the additional construction cost and time evaluation the Client decided on 03rd of January 2013 (refer to letter "40578/Zozila DGBR/12/Brs & Tnls") that the proposed alignment is approved and shall be further developed in Phase II.

2 GENERAL PROJECT DESCRIPTION

Road: Srinagar to Leh

Object: Single tube road tunnel with two traffic lanes in bi-directional traffic and parallel egress tunnel
Main structure: traffic tunnel, separate egress tunnel, ventilation & construction shafts
Additional structures: portal structures, muck disposal areas

Location: India, Jammu and Kashmir

Client: Border Roads Organization (BRO)

Portals: West Portal in the area of Baltal approx. 60 km east of Kangan
538871.9 m E and 3790008.2 m N (43 S - UTM coordinates)

East Portal approx. 30 km southwest of Dras
549997.8 m E and 3797178.5 m N (43 S - UTM coordinates)

Elevation: West Portal at approx. 2900 m
East Portal at approx. 3310 m
Shaft 1 at approx. 3510 m
Shaft 2 at approx. 3490 m
Shaft 3 at approx. 3430 m

Main tunnel length: approx. 14.1 km

Egress tunnel length: approx. 14.2 km

Ventilation shaft length: Shaft 1 approx. 484 m
Shaft 2 approx. 365 m
Shaft 3 approx. 208 m

Maximum overburden: approx. 660 m

Gradient: continuous approx. +2.9 % (1:35) from the West Portal to the East Portal

The Border Roads Organization (BRO) develops all weather connectivity between Srinagar and Leh in northern India (State of Jammu & Kashmir) which includes the construction of highway tunnels. One of these tunnels is the Zojila Tunnel located north-eastern of the city of Srinagar close to Baltal (see Fig. 1). The Zojila Tunnel is located approx. 10 km from Sonamarg towards Leh with a length of approx. 14.1 km.

Fig. 1 Location of ZojilaTunnel

The design given in this report covers the following parts:

- mined tunnel sections,
- cut & cover tunnel sections in the portal areas,
- ventilation & construction tunnel and ventilation cavern,
- tunnel portals,
- buildings at the portal for tunnel ventilation and power supply and operation,

Not part of this design are the access roads and their structures such as bridges.

3 TUNNEL ALIGNMENT

The alignment is designed according to Indian and International Standards and Guidelines for road tunnels. A detailed description of the alignment design is given in Volume - II Tunnel Design Report.

In the following the main aspects concerning the alignment of the Zojila Tunnel are summarized.

3.1 Horizontal Alignment

The main boundary conditions for the horizontal tunnel alignment are the tunnel portals and the location of the construction & ventilation shafts.

The tunnel length is approximately 14.1 km. The starting point of the horizontal alignment at the western side is approx. 50 m outside the tunnel portal. At the western portal a straight alignment is designed. The alignment is designed with preferable straight sections, which are intercepted by curves with radius from 500 m to 1250 m to keep the straight sections below 1500 m length. At the eastern portal a straight alignment is designed.

The required alignment elements from Indian and Austrian standards are given in Tab. 1 for the key design parameters and compared with the proposed alignment elements.

Tab. 1 Summary of horizontal alignment requirements and proposed horizontal alignment

Alignment element	Indian Standard	Austrian Standard	proposed alignment
Max. length of straight in [m]	1500	no recomm.	1475
Min. curve radius in [m]	230	350	500
Min. length of transition curve	22 (R=1000) 44 (R=500) 30 (change of superelevation)	44	60.5
Max. length of transition curve	no recomm.	88	60.5

The main points of the horizontal alignment are presented in Tab. 2.

Tab. 2 Horizontal alignment points

ID	*Chainage*	*Section length [m]*	*Pos N UTM [m]*	*Pos E UTM [m]*	*RW [gon]*	*Radius [m]*
PS	KM 0.0+ 0.000	0.0	3790016.3	538861.8	142.675	0
TCS	KM 0.1+91.316	191.3	3789897.4	539011.7	142.675	0
CS	KM 0.2+52.566	61.3	3789860.3	539060.5	138.776	-500
CE	KM 0.9+24.963	672.4	3789899.7	539682.1	53.163	-500
TCE	KM 0.9+86.213	61.3	3789942.7	539725.8	49.264	0
TCS	KM 1.8+ 8.979	822.8	3790531.1	540300.8	49.264	0
CS	KM 1.8+69.471	60.5	3790575.0	540342.5	46.697	-750
CE	KM 1.9+88.208	118.7	3790669.1	540414.7	36.618	-750
TCE	KM 2.0+48.700	60.5	3790720.7	540446.2	34.051	0
TCS	KM 2.9+88.638	939.9	3791529.4	540925.3	34.051	0
CS	KM 3.0+49.130	60.5	3791581.0	540956.8	36.618	750
CE	KM 3.3+91.343	342.2	3791816.5	541201.0	65.666	750
TCE	KM 3.4+51.835	60.5	3791846.2	541253.7	68.233	0
TCS	KM 4.7+ 2.395	1250.6	3792444.6	542351.8	68.233	0
CS	KM 4.7+62.887	60.5	3792474.3	542404.5	65.666	-750
CE	KM 5.1+ 3.727	340.8	3792708.7	542647.9	36.735	-750
TCE	KM 5.1+64.219	60.5	3792760.2	542679.5	34.167	0
TCS	KM 6.5+28.062	1363.8	3793932.3	543376.9	34.167	0
CS	KM 6.5+88.562	60.5	3793984.1	543408.2	35.708	1250
CE	KM 6.8+55.331	266.8	3794193.2	543573.1	49.294	1250
TCE	KM 6.9+15.831	60.5	3794235.7	543616.1	50.835	0
TCS	KM 8.3+87.802	1472.0	3795262.8	544670.5	50.835	0
CS	KM 8.4+48.294	60.5	3795304.5	544714.3	53.402	750
CE	KM 8.8+57.217	408.9	3795483.5	545076.4	88.113	750
TCE	KM 8.9+17.709	60.5	3795493.1	545136.1	90.680	0
TCS	KM 10.1+58.162	1240.5	3795674.1	546363.3	90.680	0
CS	KM 10.2+18.654	60.5	3795683.7	546423.0	88.113	-750
CE	KM 10.4+39.801	221.1	3795756.0	546631.1	69.341	-750
TCE	KM 10.5+ 0.293	60.5	3795785.4	546684.0	66.774	0
TCS	KM 11.4+76.808	976.5	3796272.3	547530.5	66.774	0
CS	KM 11.5+37.308	60.5	3796302.0	547583.2	68.314	1250
CE	KM 11.8+71.431	334.1	3796420.6	547894.5	85.331	1250
TCE	KM 11.9+31.931	60.5	3796433.5	547953.6	86.872	0
TCS	KM 13.3+39.472	1407.5	3796721.7	549331.3	86.872	0
CS	KM 13.3+99.964	60.5	3796734.9	549390.3	84.304	-750
CE	KM 13.7+54.737	354.8	3796898.1	549701.6	54.190	-750
TCE	KM 13.8+15.229	60.5	3796939.2	549746.0	51.623	0
PE	KM 14.1+81.967	366.7	3797191.9	550011.8	51.623	0

PS…Project Start PE…Project End
CS…Curve Start CE…Curve End
TCS…Transition Curve Start TCE…Transition Curve End

3.2 Vertical Alignment

A continuous gradient of approx. +2.9 % from West Portal to the East Portal is designed.

As Indian Standards do not provide recommendations for superelevation inside tunnels the recommendations from Austrian Guidelines are considered.

A summary of all required alignment elements from Indian and Austrian Standards are given in Tab. 3 and compared with the proposed alignment elements.

Tab. 3 Summary of vertical alignment requirements and proposed vertical alignment

Alignment element	Indian Standard	Austrian Standard	proposed alignment
Tunnel gradient min./max. in [%]	0.5/3.3	0.5/5.0	0.5/2.9
Min. sag/crest curves radius/length in [m]	no recomm./50	5000/no recomm.	no vert. curve designed
Min. crossfall in tunnel [%]	2.0	2.5	2.5
superelevation in curves in [%]	open roads: R=1250 m 2.3 % R=750 m 3.8 % R=500 m 5.6 %	tunnels: R=1250 m 2.3 % R=750 m 3.2 % R=500 m 4.1 %	tunnels: R=1250 m 2.5 % R=750 m 3.2 % R=500 m 4.1 %
min./max. superelevation in [%]	open roads: 1.7/7	tunnels: 2.5/5	tunnels: 2.5/5

4 TYPICAL CROSS SECTION

The typical cross section is designed according to Indian and International Standards and Guidelines for road tunnels. A detailed description of the cross section design is given in Volume - II Tunnel Design Report.

The proposed typical cross section of the carriage way consists of the following main elements:

- Clearance profile as defined in Fig. 2
- Walkway: width = 1.0 m
- Hard clearance: width = 0.50 m including edge lane marking (0.12 m) with longitudinal ribs (0.20 m x 0.15 m x 0.7 cm) which provides an acoustical signal if vehicles deviate from the driving lane
- Driving lane: width = 3.50 m
- Median mountable strip: An intermediate mountable strip is designed separating the two driving lanes. The strip is 7.5 cm high and 50 cm wide.

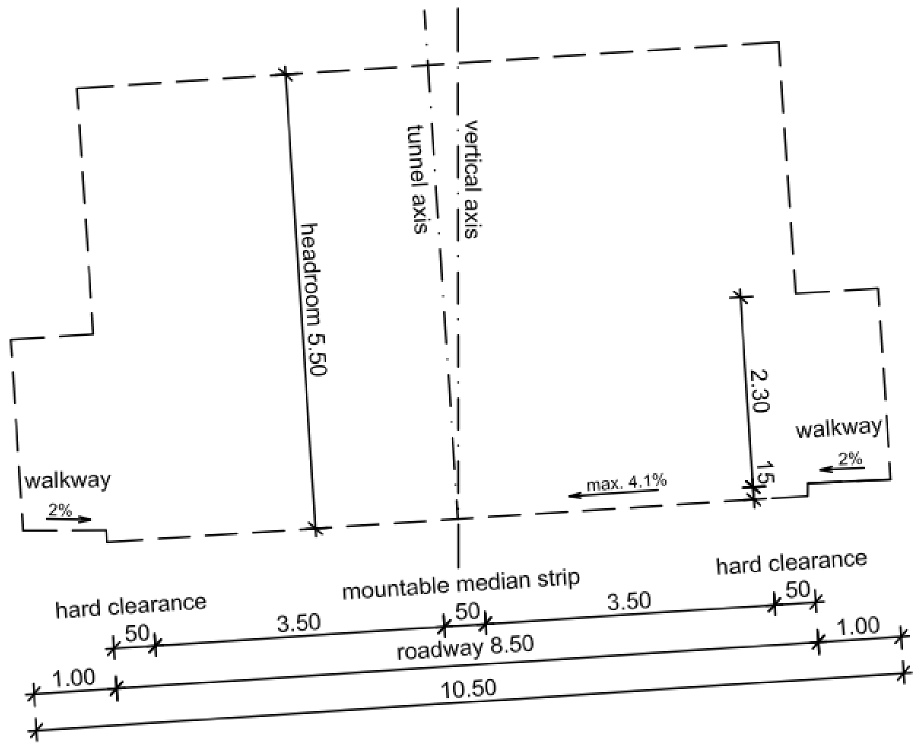

Fig. 2 Proposed clearance profile for bi-directional single tube tunnel

The typical cross sections for the main tunnel with and without invert are given in Fig. 3 and Fig. 4. More details concerning the typical cross sections of the main tunnel and the other tunnel elements are given in the drawings 8482B_II-ZOT_GEOM-01-12-00 to 8482B_II-ZOT_GEOM-21-12-00.

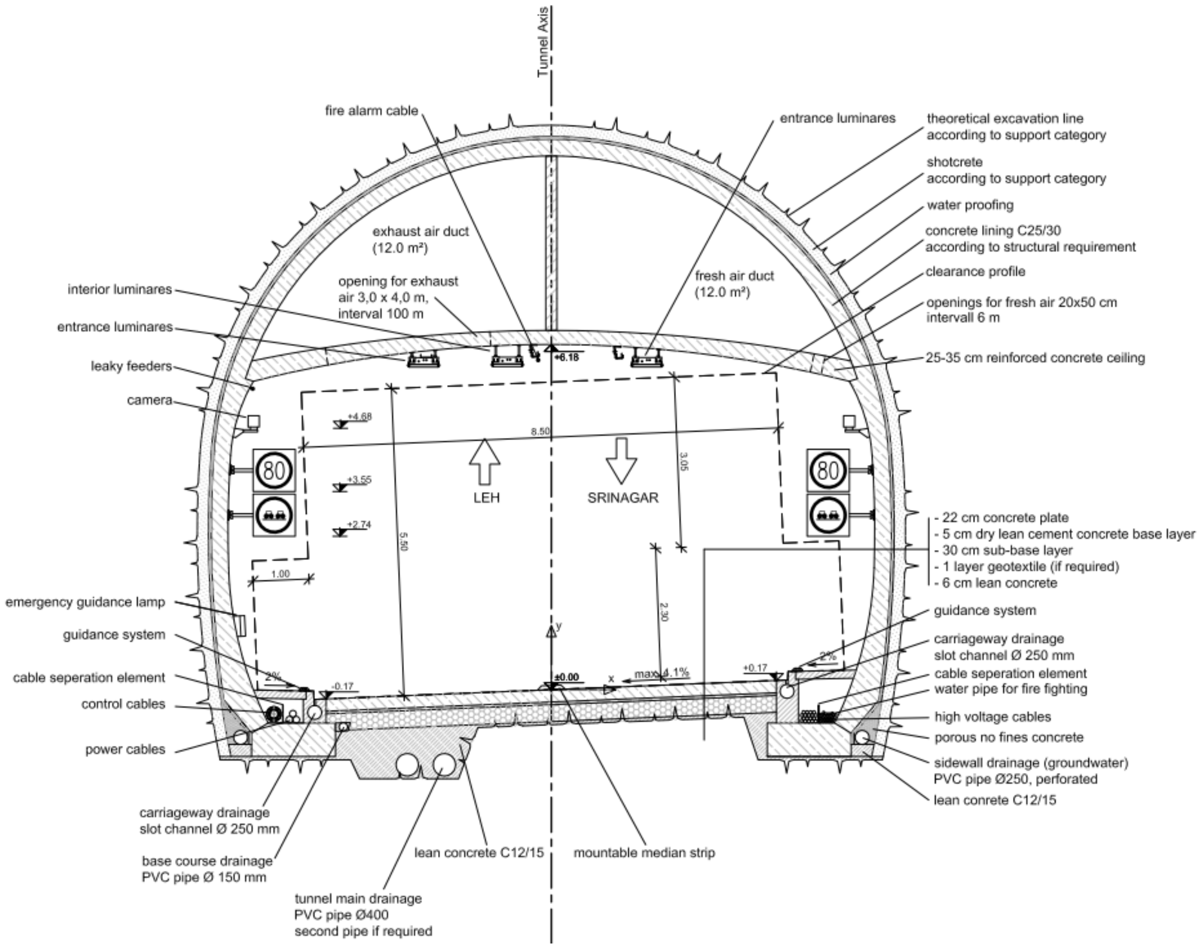

Fig. 3 Typical cross section for bi-directional single tube tunnel without invert

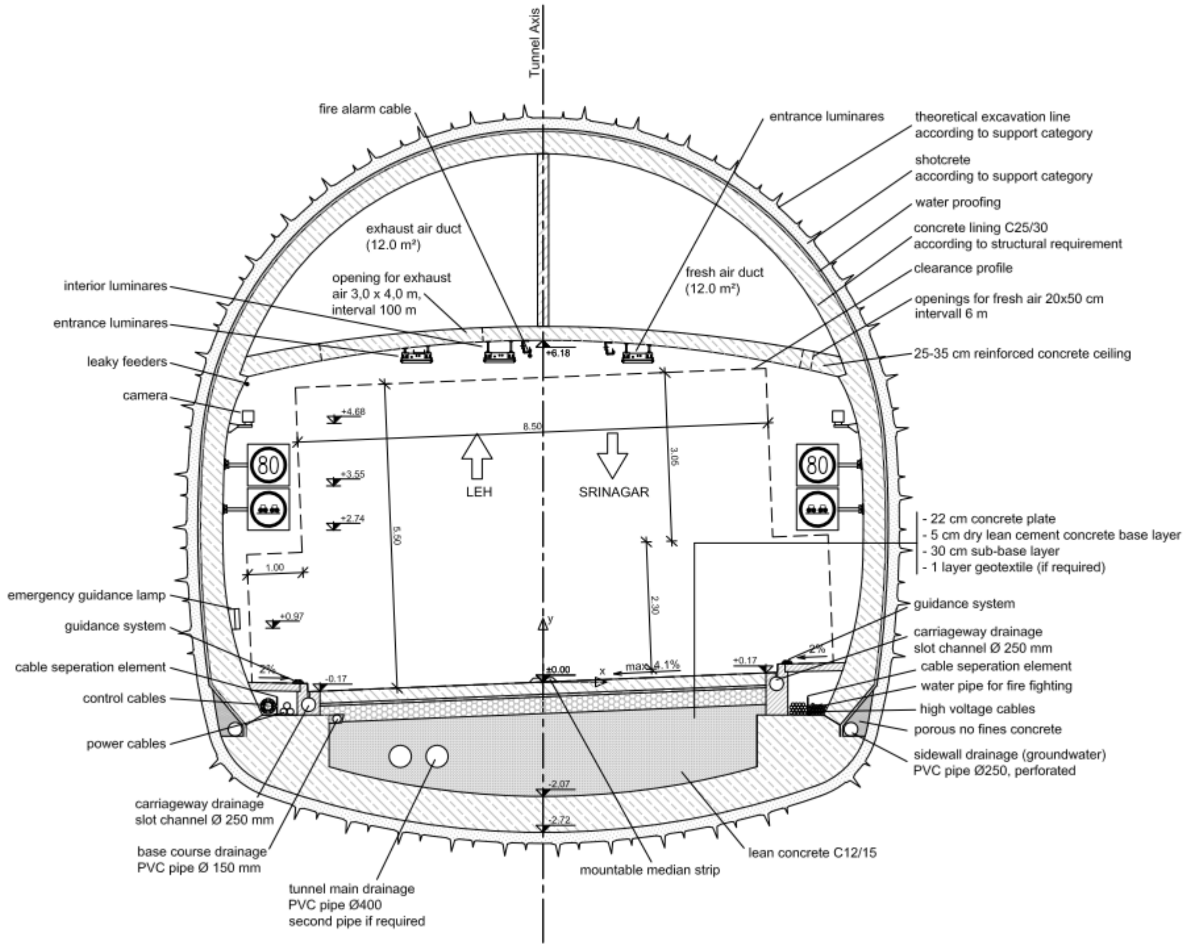

Fig. 4 Typical cross section for bi-directional single tube tunnel with invert

5 PAVEMENT

The preliminary design of the pavement is included in Volume - II: Tunnel Design Report.

The road pavement consists (from bottom to top) of the following layers:

- 30 cm unbounded sub-base layer
- 5 cm dry lean cement concrete sub-base layer
- 22 cm concrete surface pavement

6 TUNNEL SAFETY CONCEPT

The tunnel safety concept is designed according to International Standards and Guidelines. A detailed description of all safety facilities is given in Volume - II Tunnel Design Report. A description and technical specification of the required electromechanical equipment is given in DPR Volume - X: Technical Specifications Fixed Operating Equipment.

The following safety and operational facilities are designed.

- Egress tunnel parallel to the main tunnel
- Cross passage driveable each 750 m
- Cross passage pedestrian each 250 m
- Lay-bys each 750 m
- Emergency telephone niche each 125 m
- Hydrant niche each 125 m
- Jet fan niche approx. each 750 m
- Electrical supply cabinet each 750 m

The emergency route for passengers in case of an incident in the tunnel leads through cross passages (driveable or for pedestrian only) to the parallel separate egress tunnel, which leads to the outside and is supplied with fresh air and lighting with an independent ventilation and power supply system. Due to the distance of cross passages of max. 250 m, every passenger is able to get to the emergency exits within 4 minutes. A detailed description of the main principles of the self-rescue system is given in DPR Volume - II: Tunnel Design Report, Addendum 3.

7 VENTILATION DESIGN

A detailed description of the preliminary ventilation design is given in Volume - VIII Preliminary Ventilation Design Report. The technical specifications of the ventilation equipment are given in DPR Volume - X: Technical Specifications Fixed Operating Equipment, Addendum 1. A brief summary of the main ventilation elements is given hereafter.

7.1 Ventilation Concept

The ventilation system consists of a fully transverse ventilation system with eight ventilation sections, including three intermediate ventilation shafts and ventilation caverns. The length of the ventilation sections and cross sections of the ventilation ducts are given below. The length of the shafts are not included in the below given values.

Ventilation section length:	Section 1 and 2:	approx. 2245 m
	Section 3 and 4:	approx. 1578 m
	Section 5 and 6:	approx. 1715 m
	Section 7 and 8:	approx. 1543 m
Ventilation cross section:	Exhaust air duct:	minimum 10.6 m²
	Fresh air duct:	minimum 10.6 m²

7.2 Ventilation Cavern

The ventilation caverns are situated perpendicular to the main tunnel at approx. km 4.489, km 7.646 and km 11.076 south of the traffic tunnel, between the main tunnel and the separate egress tunnel, with a length of approx. 30 m. The main characteristics of the ventilation cavern are as follows.

Cavern excavation height:	approx. 15.0 m
Cavern excavation width:	approx. 21.0 m
Cavern length:	approx. 30.0 m
Excavation cross section:	approx. 185 m²

7.3 Ventilation Shaft

Three ventilation shafts are required. The ventilation shafts are located above the caverns and connect the cavern to the ground. The shafts are located at approx. km 4.489, km 7.646 and km 11.076 of the main tunnel alignment. The shafts have a depth of 484 m, 365 m and 208 m. The shafts 1 and 2 are designed to be additionally used as access shaft during the construction period. These shafts are excavated by conventional drill and blast methods top down. The layout of the construction shafts is given in drawing 8482B_II-ZOT_VEN-03-12-00. These ventilation and construction shafts have an excavation diameter of approx. 14 m and an excavation cross section of 154 m^2 depending on the support category. The shaft 3 is only used for ventilation purpose and is constructed with raise boring method with a diameter of approx. 6 m and an excavation cross section of approx. 28 m^2.

8 HYDRAULIC DESIGN

The design of the hydraulic system is given in Volume - II Tunnel Design Report. A summary of the main hydraulic elements is given hereafter.

The tunnel has two separate drainage systems, one to drain the ground water and another to dewater the carriageway. The tunnel high point is equal to the eastern portal, which leads to a drainage to the lower western portal (Srinagar) with a gradient of approx. 2.9 % along the entire tunnel length of approx. 14.1 km.

At the eastern tunnel portal provisions are installed to prevent surface water from flowing into the tunnel.

The tunnel is sealed against ground water inflows (mainly ground water flowing along singular rock mass joints) around the tunnel vault with a water proofing system between the primary and the inner lining. The so called umbrella system consists of a drainage and protection fleece at the outer side and a sealing membrane at the inner side. The fleece and the membrane are fixed on the shotcrete of the primary lining. Splicing of the membrane sheets are welded to guarantee water proofing. The groundwater in the tunnel is collected with two side wall drainages consisting of perforated PCV pipes with a diameter of 250 mm. Base course drainage is installed at the minimum level of the base course to prevent water from ponding. The base course drainage consists of a perforated PCV pipe with a diameter of 150 mm. The main tunnel drainage is designed with PCV pipes and a diameter of 400 mm. If, during tunnel construction, the overall steady state water inflows are observed to be higher than the maximum capacity of the tunnel main drainage, additional drainage pipes shall be designed and installed (sufficient space is available according to the typical cross section). Discharges from the side wall drainage and maintenance accesses are designed every 100 m.

The carriageway water has to be collected and drained separately from the ground water (separate drainage system). Due to the crossfall of the carriageway $\geq$ 2,5 % the carriageway water flows into slot channels (Φ 250 mm) in the area of the kerbs. The carriageway water collected in the slot channels flows from the eastern to the western portal due to the continuous gradient of the alignment.

At the western tunnel portal the collected carriageway water will be diverted into a settling basin with a volume of min 50 m^3 according to Austrian Standard, which secures that dangerous wastewater will not flow directly into the recipient (rivers, etc. next to the tunnel portal) in case of emergency. After sufficient settling of sediments and deleterious material the carriageway water is discharged from the settling basin to the open channel.

9 CONSTRUCTION METHOD

Generally two different construction methods are available for the construction of tunnels according to the construction procedure:

- Continuous tunnel excavation: Excavation by a tunnel boring machine (TBM) with continuous advance of the full tunnel face.
- Cyclic tunnel excavation: New Austrian Tunnelling Method (NATM) with cyclic advance of the tunnel face. When required the tunnel excavation can be subdivided into different excavation sequences.

A qualitative comparison of the conventional and TBM construction method for the application at Zojila Tunnel is given in DPR Volume - II: Portal Design Report, Addendum 2.

Based on this comparison the Zojila Tunnel is designed to be constructed with NATM.

A brief summary of the general construction methodology is presented in the following. A more detailed description including drilling & blasting, mucking, support elements etc. is given in Volume - IV Geotechnical Tunnel Design Report. The general construction concept is described in Volume - II Tunnel Design Report.

The Zojila Tunnel is designed to be constructed with conventional excavation in accordance with the principles of NATM. The excavation will be carried out by drill and blast or tunnel excavator with a subdivision of the tunnel cross section into top heading, bench and if required with invert. To increase the face stability the tunnel face excavation will be subdivided according to the geotechnical condition. Immediately after excavation of each round the primary support is installed. After finalization of all excavation and support sequences (top heading, bench, invert) the water proofing system and the final concrete lining (plain or reinforced) is installed.

In the following figure the basic construction sequence of a typical NATM tunnel in hard rock is shown schematically.

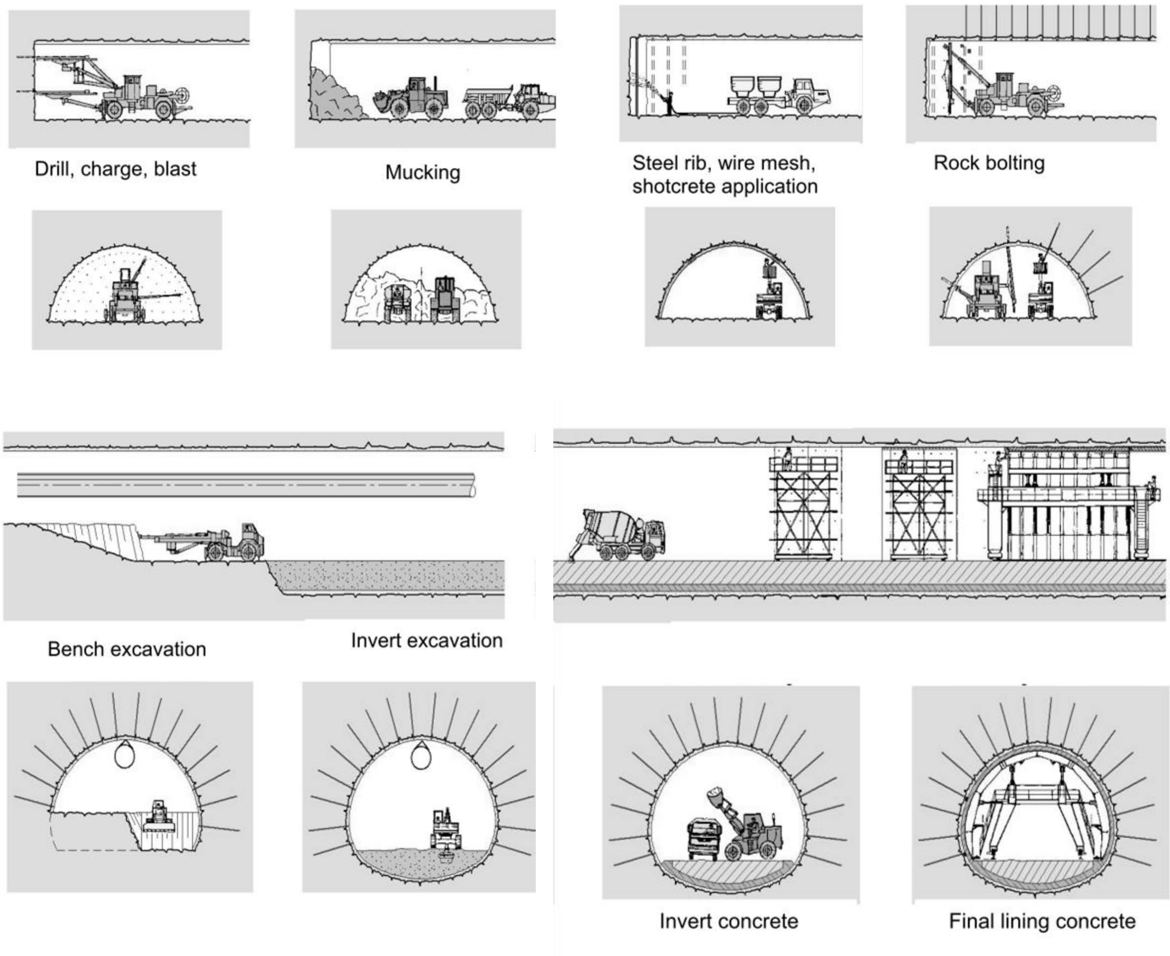

Fig. 5 Schematic construction sequence of a typical NATM tunnel in hard rock, from “Austrian Society for Geomechanics, 2010. NATM, The Austrian Practice of Conventional Tunnelling”

10 GEOLOGICAL/GEOTECHNICAL EVALUATION AND ROCK MASS CLASSIFICATION

10.1 Geological and Geotechnical Evaluation

A detailed geological and geotechnical evaluation of the investigation results is presented in Volume - IV Geotechnical Tunnel Design Report. In the following a summarizing overview is given.

The geological and geotechnical evaluation is based on the available investigation results. The following investigations were performed:

- Remote sensing
- Geological field mapping
- 19 core drillings (total length: approx. 2750 m)
- Laboratory tests

The project area of Zojila Tunnel is located in permo-carboniferous, metamorphic rocks of sedimentary and magmatic origin. The tunnel alignment is in the formations of 'Panjal Trap', 'Zojila formation' and 'Agglomerate Slates' as shown in Fig. 6.

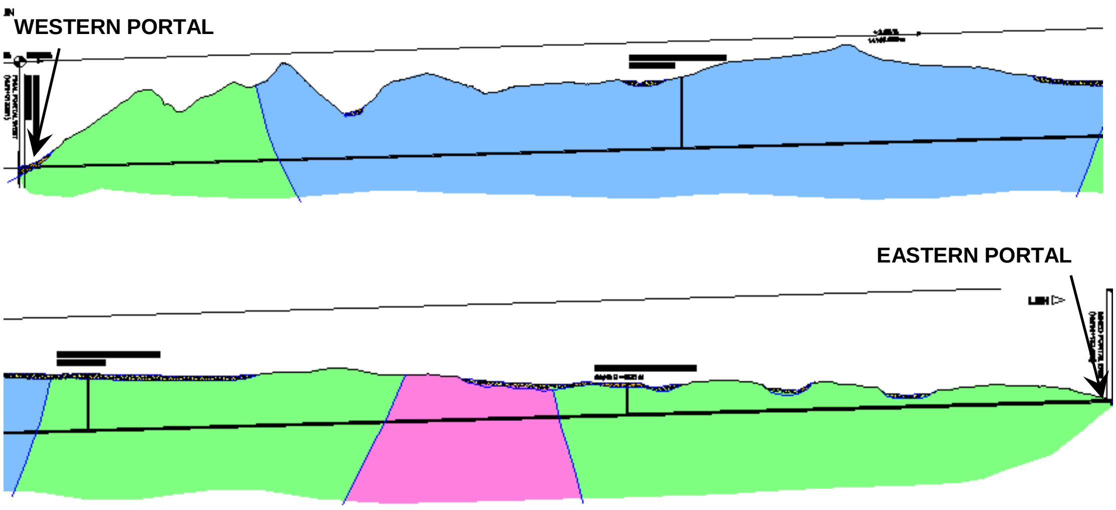

Fig. 6 Geological longitudinal-section of Zojila Tunnel; green…Panjal Trap, blue…Zojila formation, purple… Agglomerate slates

The geotechnical characteristics for the different units are described based on investigation results, mainly data from structural features and laboratory tests.

The project area of Zojila Tunnel is situated in the seismically active mountain range of the Himalaya. Seismic accelerations of 0.23 g and 0.11 g must be considered for the structural designs according to the study of seismologic and seismotectonics. According to Indian Standard seismic accelerations of 0.24 g and 0.12 g must be considered in seismic zone IV.

Based on the topographical and tectonic conditions the vertical stresses are assumed to be higher than the overburden weight (vertical stress = weight x overburden). The increase of the vertical stresses (max. factor 1,5) depends on the topographical condition and is evaluated with numerical analysis. The horizontal stresses are assumed to be 0.75 to 1.0 times the vertical stress (k_0 = 0.75 to 1.0).

10.2 Rock Mass Classification

The rock mass classification is done based on the Austrian Guideline for NATM tunnelling (Austrian Society for Geomechanics, 2001, 2008, 2009; Guideline for the geotechnical design of underground structures with conventional excavation). A detailed description is given in Volume - IV Geotechnical Tunnel Design Report.

According to the procedure for the geotechnical design of NATM tunnels as given in the guideline mentioned above in a first step ground with similar properties is classified into a Ground Type. For the Zojila Tunnel 7 Ground Types are defined based on the geological and geotechnical data and the heterogeneity of the rock mass in the project area. The values for the key parameters of each Ground Type are determined from available information and/or estimated based on experience from tunnel projects in comparable ground conditions.

In the second step project specific Behaviour Types are defined based on the potential behaviour of the ground. These Behaviour Types represents the determined behaviour of the rock mass due to the excavation of the tunnel without any support measures. To determine the ground behaviour the Ground Types are combined with the predicted ground conditions represented by the influencing factors which are the primary stress condition, the water condition and the orientation of discontinuities. For the Zojila Tunnel 7 Behaviour Types are defined, which are the basis for the further support design to achieve stable tunnel conditions.

The following table shows the distribution of the predicted distribution of Ground Types (GT), Behaviour Types (BT) for the Zojila Tunnel.

Tab. 4 Predicted distribution of Ground Types (GT) and Behaviour Types (BT) for mined sections of Zojila tunnel

		Section					
		1	**2**	**3**	**4**	**5**	**6**
Length [m]		76	1640	5551	2217	1112	3487
Ground Types GT [%]	**GT 1**	100	0	0		0	0
	GT 2	0	65-85	0	65-85	0	65-85
	GT 3	0	15-30	0	15-30	0	15-30
	GT 4	0	0-5	0	0-5	0	0-5
	GT 5	0	0	30-50	0	50-70	0
	GT 6	0	0	40-60	0	25-45	0
	GT 7	0	0	5-15	0	0-10	0
Behaviour Types BT [%]	**BT 1**	0	30-45	0	30-45	0	30-45
	BT 2	0	50-60	2-10	50-70	10-20	50-70
	BT 3	0	5-10	25-45	0-5	45-60	0-5
	BT 4	0	0-5	50-70	0-2	25-40	0-2
	BT 7/8/9	100	0	0	0	0	0

11 TUNNEL SUPPORT SYSTEM

The tunnel support system consists of two generally independent lining systems:

- The primary (outer) lining consisting of shotcrete if necessary reinforced with wire mesh, lattice girder and rock bolts. All support measures are installed each round immediately after tunnel excavation. The primary lining is designed to provide immediate support and stability of the excavation until the inner lining is installed.
- The final (inner) lining, constructed of plain or reinforced concrete, is designed to sustain all internal and external forces without considering the bearing capacity of the primary lining.

11.1 Primary Lining Design

The Zojila Tunnel is designed to be constructed with conventional excavation in accordance with the principles of NATM. The excavation will be carried out by drill and blast or tunnel excavator with a subdivision of the tunnel cross section into top heading, bench and if required with invert. To increase the face stability the tunnel face excavation will be subdivided according to the geotechnical situation.

For the Zojila Tunnel 8 Support Categories are designed, which are based on the Behaviour Types representing the predicted ground conditions. The correlation between the Behaviour Types and the Support Categories is given in the following table.

Tab. 5 Basic correlation between the Behaviour Types and the Support Categories

Behaviour Type	Support Category
BT 1 Stable	SC A
BT 2 Gravitational block fall	SC B and SC C
BT 3 Shallow stress induced failure	SC D
BT 4 Voluminous stress induced failure	SC E to SC G
BT 7 Crown failure	SC H
BT 8 Ravelling ground	SC H
BT 9 Flowing ground	SC H

The primary support consists of shotcrete, reinforcement of the shotcrete (steel fibers, wire mesh and lattice girder), rock bolts of various types and length and forepoling if necessary. A detailed description of the primary lining elements is given in Volume - IV Geotechnical Tunnel Design Report. A detailed description of the technical specifications of the support elements is given in Volume - IX Technical Specifications Civil Engineering.

For the structural design of the primary lining numerical analyses were performed. The detailed results of these analyses are given in Volume - V Primary Lining Analysis Report.

The following table shows the distribution of the predicted distribution of Support Categories (SC) for the Zojila Tunnel.

Tab. 6 Predicted distribution of Support Categories (SC) for mined Zojila Tunnel

		Section					
		1	2	3	4	5	6
Length [m]		76	1640	5551	2217	1112	3487
Support Categories [%]	**SC A**	-	30 - 45 %	-	30 - 45 %	-	30 - 45 %
	SC B	-	30 - 45 %	-	30 - 45 %	-	30 - 45 %
	SC C	-	10 - 25 %	2 - 10 %	15 - 30 %	10 - 20 %	15 - 30 %
	SC D	-	2 - 8 %	25 - 45 %	0 - 5 %	45 - 60 %	0 - 5 %
	SC E	-	0 - 5 %	20 - 40 %	0 - 2 %	20 - 35 %	0 - 2 %
	SC F	-	-	15 - 25 %	-	0 -10 %	-
	SC G	-	-	5 - 15 %	-	-	-
	SC H	100 %	-	-	-	-	-

11.2 Final Lining Design

The lining consists of plain concrete as well as reinforced concrete according to the structural requirements.

- In tunnel sections with general stable hard rock mass plain concrete C25/30 with a minimum thickness of 30 cm in the vault is designed.
- In tunnel sections with unstable or weak rock mass plain or reinforced concrete C25/30 with a minimum thickness of 40 cm in the vault is designed. Additionally an invert slab with a thickness of 60 cm is designed. Detailed definition of the lining thickness will be done according to structural analysis.

The inner lining is constructed independent to the excavation and primary support of the tunnel in blocks with a length of 12.5 m in two general construction steps, strip foundations or invert and vault.

The structural analyses are done according to the state of the art including structural requirements due to fire load. A detailed description of the final lining design is given in Volume - VI Final Lining Design Report.

These analyses are based on the preliminary design phase and shall be updated in the detail design phase due to variation of tunnel layout, geometry, lining type, ground conditions etc.

Three different final lining types are designed and analysed as described below:

- Final lining without invert
- Final lining with invert
- Final cut & cover lining

The final lining without invert is constructed in Support Category A to C with a minimum thickness of 30 cm and shall be of plain concrete. The lining is founded on strip foundations. The lining is constructed with unreinforced concrete and withstands all loads considered (as per Volume - VI Final Lining Design Report).

The final lining with invert is constructed in Support Category D to G with a minimum thickness of 40 cm. The invert lining has a thickness of 65 cm. The lining shall be unreinforced for Support Category D and reinforced for Support Category E to G. In Volume - VI Final Lining Design Report it is shown that the lining withstands all considered loads.

The final lining of the cut & cover tunnel has a minimum thickness of 60 cm and shall be of reinforced concrete. In Volume - VI Final Lining Design Report it is shown that the cut & cover tunnel withstands all considered loads.

For the reinforced concrete ceilings in the tunnel the following load cases are considered.

- *Permanent load cases*: Dead weight of construction, rock load, water pressure, creeps etc.
- *Variable load cases*: Load cases due to construction sequences, temperature load, air pressure and air suction due to movement of vehicles and ventilation operation, maintenance loads etc.
- *Exceptional load cases:* Exceptional air pressure and suction due to malfunction of ventilation shutters, malfunction of suspensions, loads due to earthquake, loads due to fire incident etc.

12 PORTAL DESIGN

The cuts and embankments of the temporary and permanent portal layout are analysed and described in Volume - III: Portal Design Report.

The following external loads are considered in the design of the portal cuts and embankments:

- *Permanent load cases*: Dead weight of construction and water pressure
- *Exceptional load cases:* additional loads due to earthquake

The analyses of the cuts and embankments are conducted with different slope failure models after Janbu and Bishop. The overall factors of safety are defined with respect to the load combination for each cut and embankment as following:

- General load combination 1.35
- Exceptional load combination (with earthquake) 1.00

The designed cuts have different inclinations with various support measures as given in Tab. 7 for the eastern portal and Tab. 8 for the western portal.

Tab. 7 Support elements for cut at tunnel portal East

5:1 Cut	reinforced shotcrete:	thickness = 20 cm 2 layers wire mesh Q377 (a_s = 3.77 cm²/m)
	ground anchors:	yield strength: 970 kN free length: 8 m bond length: 4 m pattern: 3 m x 3 m inclination: 10°
2:1 Cut	reinforced shotcrete:	thickness = 10 cm 1 layer wire mesh Q377 (a_s = 3.77 cm²/m)
	rock bolts:	yield strength: 200 kN length: 6 m pattern: 2 m x 2 m inclination: 10°
	or soil nails:	yield strength: 200 kN length: 8 m pattern: 2 m x 2 m inclination: 10°

Tab. 8 Support elements for cuts at tunnel portal West

5:1 Cut	reinforced shotcrete:	thickness = 20 cm 2 layers wire mesh Q377 (a_s = 3.77 cm²/m)
	rock anchors:	yield strength: 970 kN pre-stressing force: 840 kN free length: 20 m bond length: 5 m pattern: 3 m x 3 m inclination: 10°
2:1 Cut	reinforced shotcrete:	thickness = 10 cm 1 layer wire mesh Q377 (a_s = 3.77 cm²/m)
	soil nails:	yield strength: 200 kN length: 6 m pattern: 2 m x 2 m inclination: 10°
4:5 Cut	reinforced shotcrete:	thickness = 5 cm 1 layer wire mesh Q377 (a_s = 3.77 cm²/m)

The designed embankments are constructed and compacted in layers. Rip-rap layers are placed on the surface of embankments to prevent surface erosion. No additional support measures are required for embankments when the required angle of internal friction is achieved.

13 CONSTRUCTION TIME AND CONSTRUCTION COST

The overall construction time is based on the assumptions and calculations given in Volume - II Tunnel Design Report. The construction time of Zojila Tunnel is estimated to approx. 84 working month. The estimation of the construction time is based on the assumption of four independent site installations at both tunnel portals and at two construction & ventilation shafts. The construction time is estimated based on the assumption, proposed and decided by the Client, that the eastern portal of Zojila Tunnel is accessible during the entire year and the supply can be done from Leh even during the winter months. It is also assumed that full independent construction works can be done minimum 7 months per year at all other construction faces (West portal and both shafts). Details of the construction time estimation are given in Volume - II Tunnel Design Report and drawing 8482B_II-ZOT_GEN-06-12-00.

The construction cost evaluation is based on the unit rates and quantities determined in Volume - VII - Cost Estimation. The overall costs are determined with 4538.8 Crores INR. These costs are only the basic construction costs as per detailed description in Volume - VII Cost Estimation.