Silkyara Bend – Barkot Road Tunnel
(Executive Summary)

of

2 Lane/ 2 Lane upgradation proposal of Highway between Km 144.00 (Dharasu) and Km 220.00 (Yamunotri) falling along NH - 94 and 123 in the State of Uttarakhand

Submitted to

Ministry of Road Transport & Highways
(Government of India)

By

TASPL
(Committed to resource and energy conservation)

M/s TECHNOCRATS ADVISORY SERVICES PVT.LTD.
(Earlier M/s MC Consulting Engineers Pvt. Ltd.)

JV with

G.E.S. & Association with S.I.P.L.

Contents

1 INTRODUCTION

1.1 General

The Ministry of Road Transport and Highways (MORT&H) is poised to develop all remote and strategically important roads in hilly terrains to perennial routes. In continuation to these developments National Highways And Infrastructure Development Corporation has been appointed by MORT&H, to implement the projects.

NHIDCL have appointed the M/s Technocrats Advisory Services Pvt. Ltd., in Joint Venture with G.E.S. and in association with S.I.P.L, lndia, as consultants to carry out the detailed design, for the Silkyara Bend – Barkot Tunnel of the NH-94, between Dharasu and Barkot section (CH.25.400 to CH.51.00), in the State of Uttarakhand.

1.2 Proposed Silkyara Bend – Barkot Tunnel Alignment

This tunnel is aligned to reduce the distance between Silkyara Bend (CH. 25.400) and Barkot (CH. 51.000) on NH-94, a total of 25.6km to less than 5.0 km. In current scenario this distance through road can be covered by crossing almost 5 hairpin bends with an ascending journey from approx. EL.1720 to EL.2250 and then again a descending journey to EL. 1500. The upper reaches of this ridge receive heavy snowfall during winters and as a result the highway gets blocked for one-two weeks every year.

To overcome this, a tunnel is proposed. The proposed alignment of tunnel is a straight distance of 4.531km with a vertical gradient 4.4%. This tunnel alignment has max. Rock cover of less than 600m under Radi top, not enough as to create any rockburst condition in the tunnel. It has a min. rock cover of approx. 40m, which is more than 3 times of the tunnel dia. Main tunnel direction is Silkyara to Barkot. Tunnel shall be 2-lane, bidirectional tunnel with 1-lane parallel escape. The provision of escape for emergency is kept in view of length of tunnel. They are separated by partition wall/cutoff wall with intermediate openings to connect both passages. An escape tunnel parallel to the main tunnel with intermediate crossways was another alternate. But keeping in view the traffic volume (and corresponding risk probability) which is currently around 1100PCU with projected volume after 5 years less than 2000PCU the option of parallel escape tunnel with crossways linking main tunnel is highly uneconomical .The existing road (2-lane, bidirectional) will be utilized to accommodate the local traffic in the area as well as over-sized and other vehicles non-suitable for tunnel operation. The existing carriageway will be upgraded with minor improvements to both the horizontal and vertical alignment.

1.3 Salient Features

NO	Description	Details
1	Location of Project	Between Silkyara and Barkot (CH.25.4 to CH 51.0)
2	Shape of Tunnel	Modified Horse Shoe

3	Size of Tunnel	13.7 m x 9.9 m
4	Invert Level at Silkayara Portal	EL 1700 m
5	Invert Level at Barkot Portal	EL 1500 m
6	Total Length of Tunnel	4.531 KM
7	Traffic Movement	Bidirectional with Additional Egress Width
8	Cost of Civil Works	879.66 Crore
9	Cost of EM works	193.50 Crore
10	Total Cost (Civil +EM)	1073.16 Crore
11	Estimated Period of Completion	48
12	Forest Diversion for Portal	4.9 Hectare
13	Land Acquisition required for Tunnel	17.85 Hectare
14	Total Land Acquisition required	22.75 Hectare
15	Tunnelling Method	Drill and Blast Method
16	Condition of Rock Mass	Good to Fair
17	Slope of Tunnel	4.40%
18	Clear Width	11.5 m
19	Clear Height of Tunnel	5.5 m
20	Thickness of Lining	400 mm
21	Land Requirement for Dumping	5 Hectare

1.4 Regional Geology

In the Lesser Himalayan domain, the site geology is represented mainly by low-grade quartzitic sandstone, dolomitic limestone and slates with metabasic sills and dykes of undifferentiated Jaunsar- Deoban formations of Garhwal Group overridden by a nappe of older sediments having exceptionally thick flyash sequence of fine grained meta sandstone-siltstone-slate-shales profusely intruded by epidiorite/amphibolite dyke and sills. The northern contact of the nappe with underlying Garhwal Group is identified as Garhwal Thrust which is also named as Srinagar Thrust or North Almora Thrust. The proposed tunnel alignment falls in the inner part of Lesser Himalaya in Uttarkashi District of Uttarakhand. Between Dharasu Bend (EL.960m) in the SSE and Barkot Town (EL.1340m) in the NNW the highway passes across an almost ENE-WSW oriented ridge in the middle part which forms a major water divide through Radi Top (EL.2252m). The terrain displays a highly dissected topography on either slopes of the ridge which are carved by dendritic, torrential rainfed streams originating in the water divide.

1.5 Seismicity

The Himalayas lie within seismic zones IV & V, of the seismic zoning map of India. Earthquakes of sizeable magnitude are not uncommon to the area. In the last 50 years, several major earthquakes with a magnitude in excess of 6 on the Richter scale, have occurred in North-West Himalayas.

1.6 Local Geology and Geomorphology

Barkot Formation: Huge successions of fine grained sandstone-siltstone-slates-shales (which Sometimes appear to be phyllitic) constitute the typical bedrocks. This, largely a turbidite sequence, has been referred in published literature as Damta-Simla slates, Chakrata Formation, Chandpur Formation etc. as an integral part of Dudatoli-Almora nappe. Barkot Formation name has been given by present author to this assemblage as it is prominently exposed around Barkot. The sequence is profusely intruded by thick amphibolite/ epidiorite dykes and sills those almost form more than 40% part of the Group in the present section.

Kuthnor Formation: The rocks exposed within the tectonic window, limited on the north by MCT and south by Garhwal Thrust, are classified under Garhwal Group represented by low-grade quartzitic sandstone/ quartzite, dolomitic limestone and variegated shales/ slates. This sedimentary sequence has pen contemporaneous lava flows in the form of sills and dykes.

1.7 Layout

The tunnel layout is optimized considering various factors; which include length, cross section for sizing, ventilation system to be adopted corresponding to the length and cross-section, traffic volume, vertical rock cover. Overall cost and time of construction are other major factors while fixing the layout of any tunnel.

Three different layouts are studied, refer Figure-1 below.

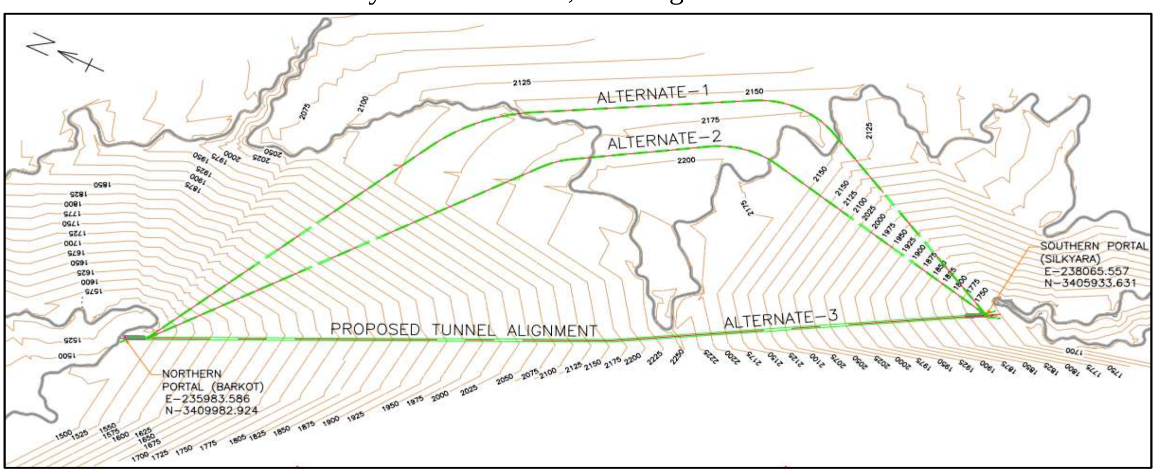

Figure 1

Alternative-I:

In this layout, maximum rock cover above the finished Tunnel is around 485m. The overall length of the tunnel is 5.4 km with two horizontal bends. As the Tunnel length is more than 5kms, Semi-transverse ventilation system is proposed.

Alternative-II:
In this layout, maximum rock cover above the finished Tunnel is around 520m. The overall length of the tunnel is 4.97 km with two bends. As the Tunnel length is more than 1.5kms, longitudinal ventilation system is proposed.

Alternative-III:
In this layout, maximum rock cover above the finished Tunnel is around 585m. The overall length of the tunnel is 4.55 km which is almost straight. As the Tunnel length is more than 1.5kms, longitudinal ventilation system is proposed.

Final Layout:
After comparison of above three alternatives it's clear that no significant reduction in rock cover is achieved but there is considerable increase in the length of tunnel. As the length of the tunnel increases the cost of the ventilation system increases. Hence Alternative-III is considered to be the best in this situation and adopted.

The proposed layout and cross-section arrangement includes all standard operational features. The basic tunnel layout is shown on the Schematic Layout drawing. Spacing of emergency egress openings (4.0m wide) connecting the main tunnel will be 300m. Emergency call niches will have spacing 150m and they will be located on the both sides of the tunnel. Firefighting niches will have spacing of 150m, but they will be located only on one side of tunnel (the side with cross passages). Lay-bays will have the spacing of 1200m (staggered); they will be on both side of the tunnel.

1.8 Cross Section

Similar as the geometric alignment, three cross sections are studied and compared to finalise the best suited cross section. These are as below:

Proposal-I: Single Tunnel (Main Tunnel with No Escape Tunnel/ Passage)
A single tunnel without escape tunnel and having a carriageway width of 7.0 m and clear height of 5.5m. Minimum construction time is required results in less project cost. But as per tunnel guideline any tunnel having length more than 1.5kms must be provided with a escape passage for emergency conditions like accident, fire or other reasons. Hence this proposal is not recommended at all and ignored.

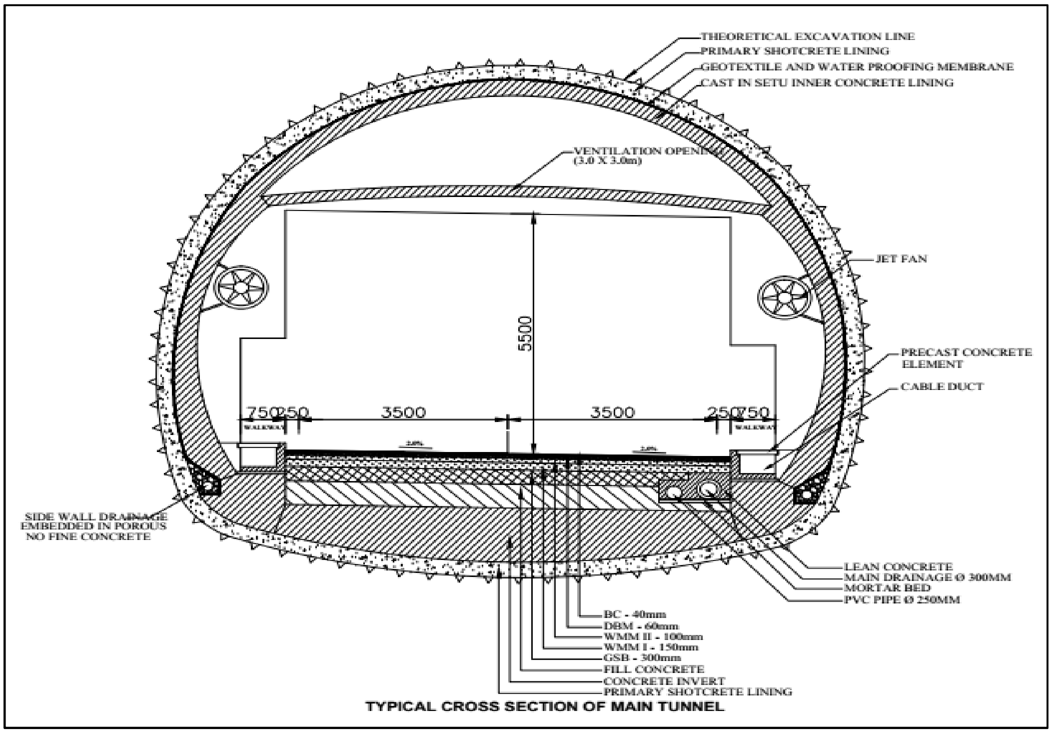

Figure-2: Tunnel Arrangement for Proposal-I

Proposal-II: Twin Tunnel (Main tunnel with parallel Escape tunnel)

In this proposal, two parallel tunnels about 18.0m apart, one main tunnel having carriage way width of 7.0m and other escape tunnel having carriage width of 5.0m are proposed. Both the tunnels are connected with each other at suitable interval by Cross Passage. Escape tunnel can be used in emergency and for future expansion. The construction time and cost required is more for two tunnel, two portals and two set of ventilation system. This system is best suited in case of heavy traffic volume but at current location the traffic volume is only 2000 PCU. Hence this proposal is also not recommended.

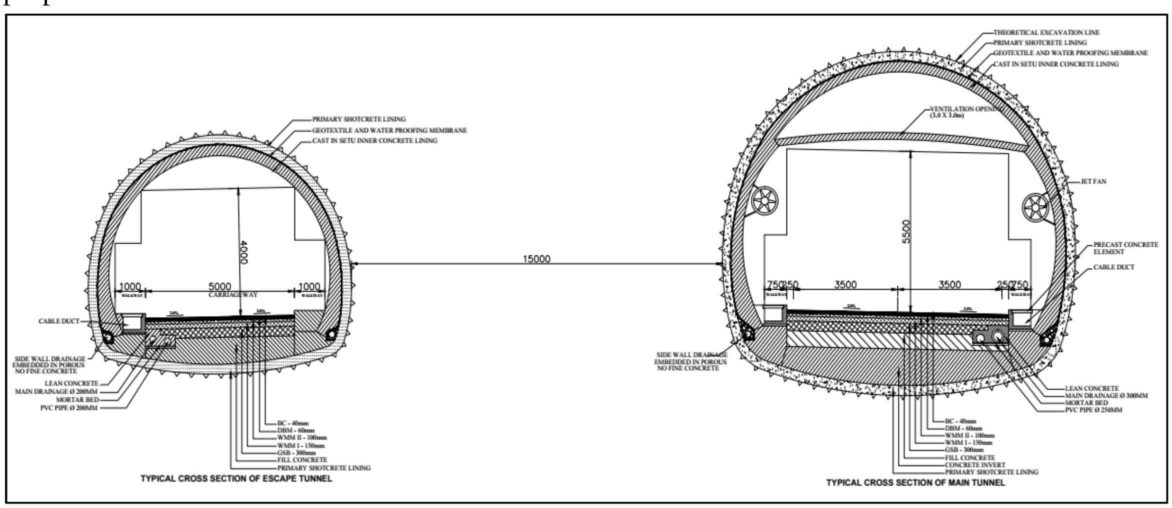

Figure-3: Tunnel Arrangement Proposal-II

Proposal-III: Single Tunnel with an Escape Passage Created using RCC Partition Wall

In this proposal, single tunnel with an escape passage separated by RCC Partition wall having opening at suitable interval is proposed. This proposal has the benefit of both the alternate proposals. This proposal is cost effective as only one single tunnel is to excavate and thus adopted for current situation. Adopted cross section has been attached as Figure -4.

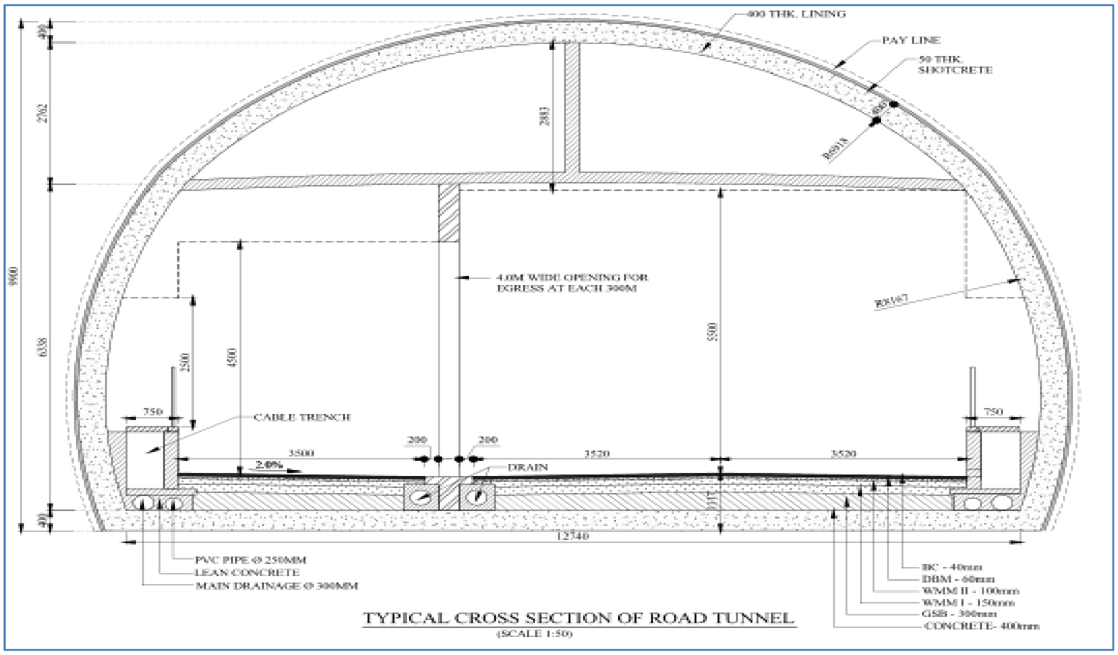

Figure-4: Final Tunnel Arrangement Cross-Section

1.9 Dimensions and Profile

Keeping in view the economics of construction, considering local conditions and construction practice, the standard profile proposed for the tunnel driven by conventional tunneling methods is a Modified horse shoe - shape, rather than the circular shape produced by a tunnel boring machine (TBM). The tunnel dimensions are also based on the requirements to provide a 7.0 m carriageway width and 3.5 escape carriage way, 0.75m wide sidewalks, 5.5 m (minimum) clear headroom and space for ventilation channels for fully transversal system of ventilation.

Feasibility of proposed Silkyara Bend - Barkot Tunnel alignment".

1.10 Structural Analysis of Tunnel Supports

The main model used for discontinuous rock is wedge analysis and can be used in the design to model discrete rock block behavior and examine if the support is sufficient to prevent local block failure. To know the deformational behavior of quasi-homogenous rock mass under specified stress conditions, the assumption of an elasto-plastic rock mass will be used. The selection of realistic parameters for these models is more difficult. Software packages would be used based on FEM/FDM to carry out numerical analysis & study deformation and strength of individual elements. Following sections give brief idea about different numerical modelling approaches that will be carried out for tunnel design.

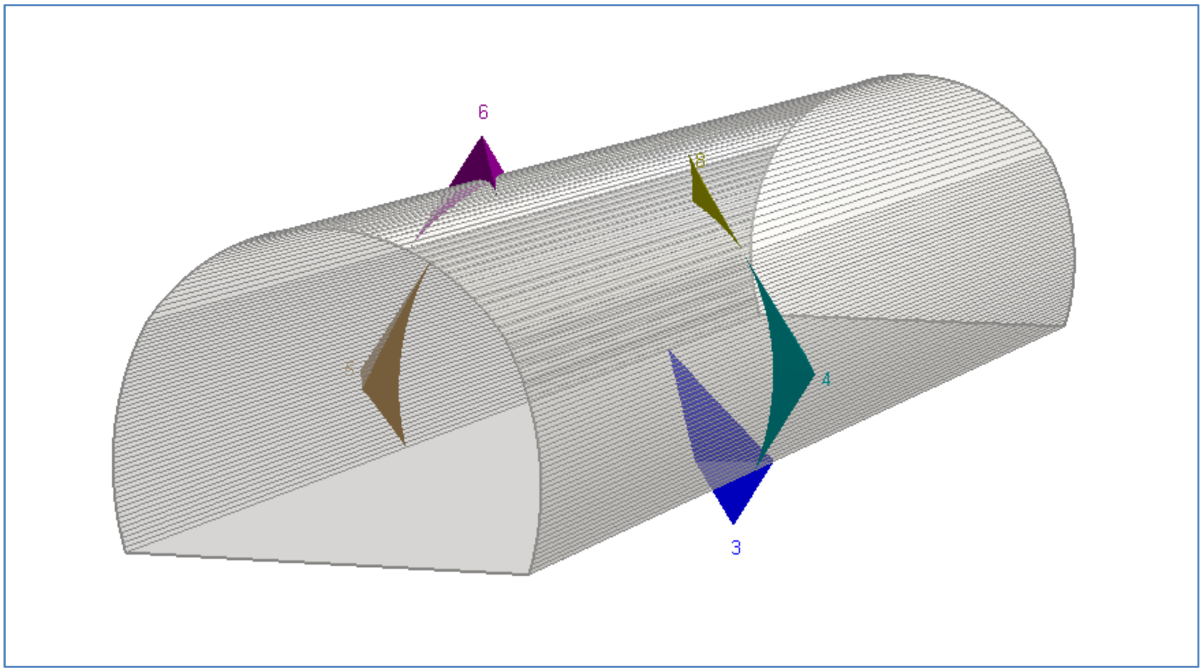

Figure -5: Unwedge Analysis of Tunnel

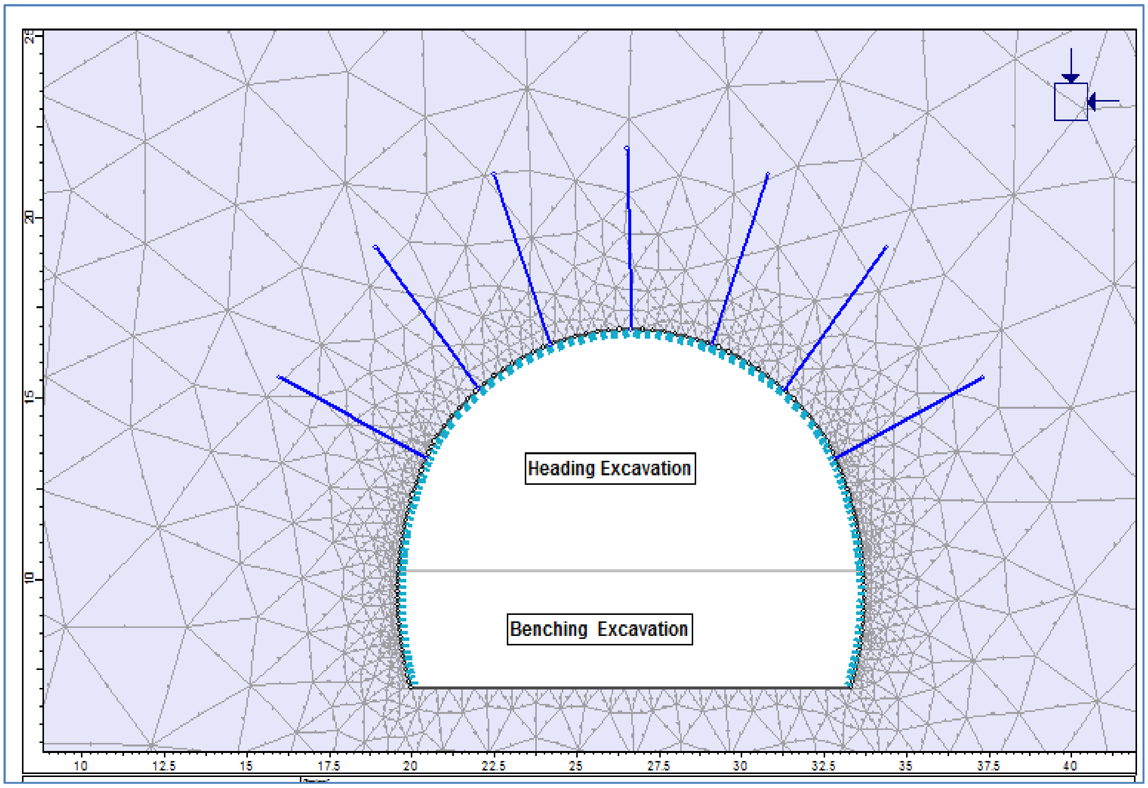

Figure -6: Modelling of Tunnel Excavation

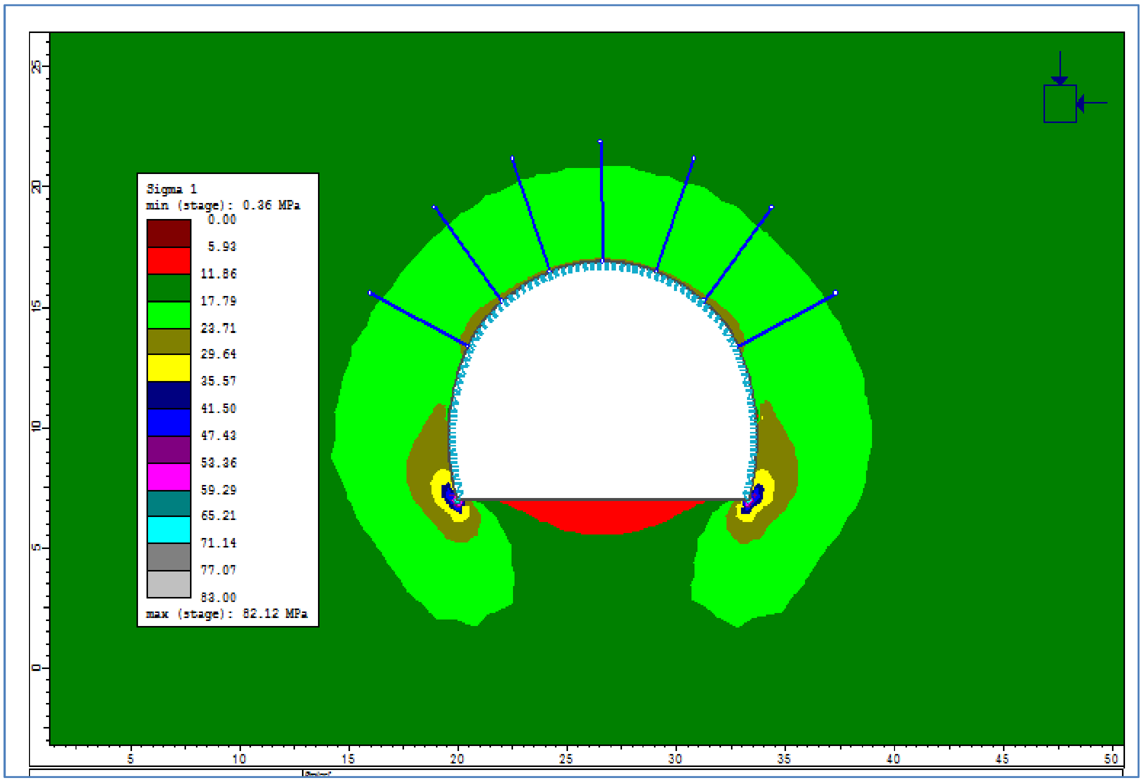

Figure-7: Results and Interpretation

1.11 Final Lining Design

The design of concrete lining is based on the most adverse combination of probable load conditions which have reasonable probability of simultaneous occurrence. The design will be based on normal loading condition and checked for possible different extreme loadings that may occur in life time of project. The design loading incorporates possible adverse combination of following loads.

- External Strata Loads
- Self-Load of Lining
- External Surcharge, if any
- Seismic Loading

The stresses in members under worst loading combination should be within acceptable limits.

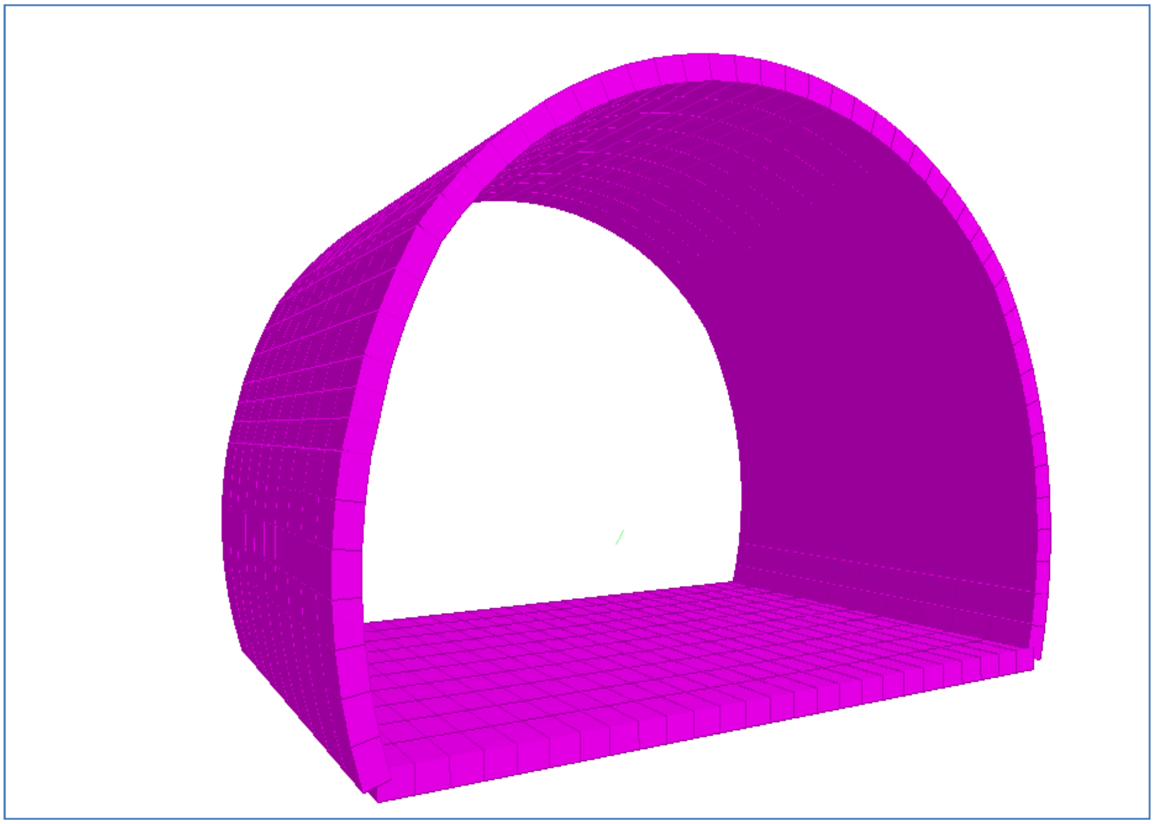

Figure-8: Model for Lining Design in STAAD Pro Software

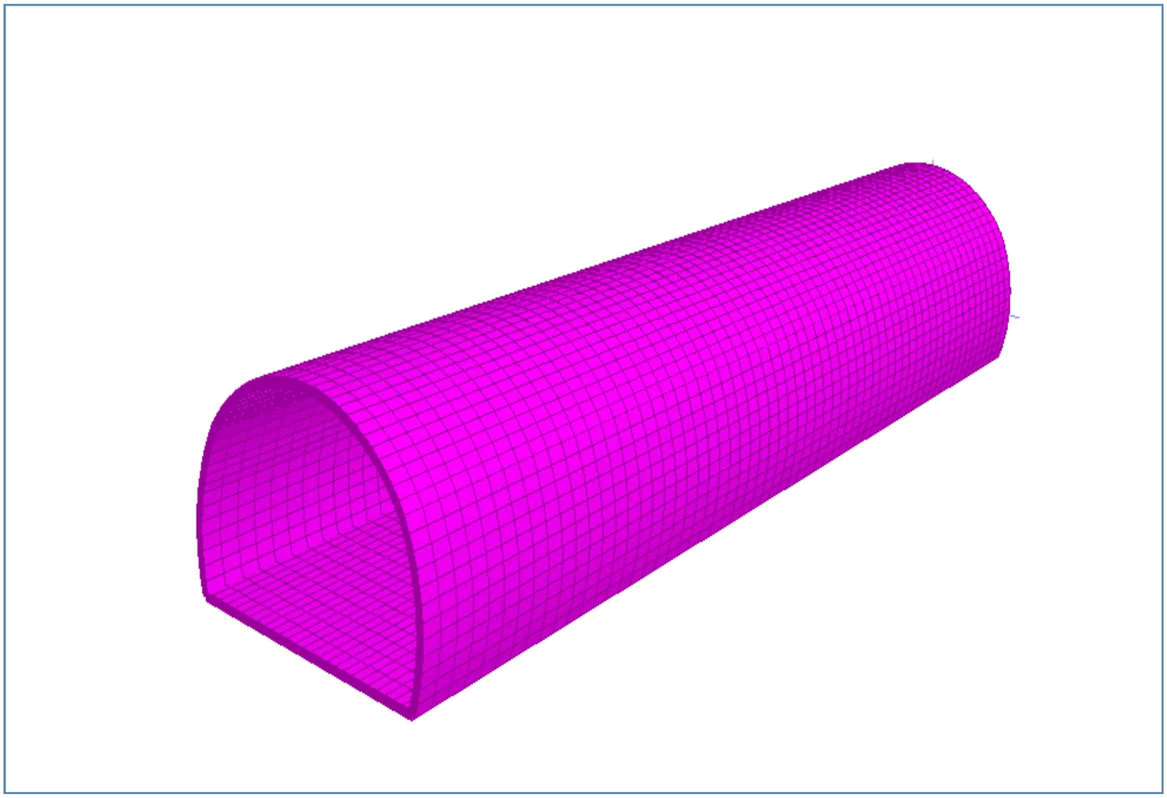

Figure-9: 3D view of Tunnel Model

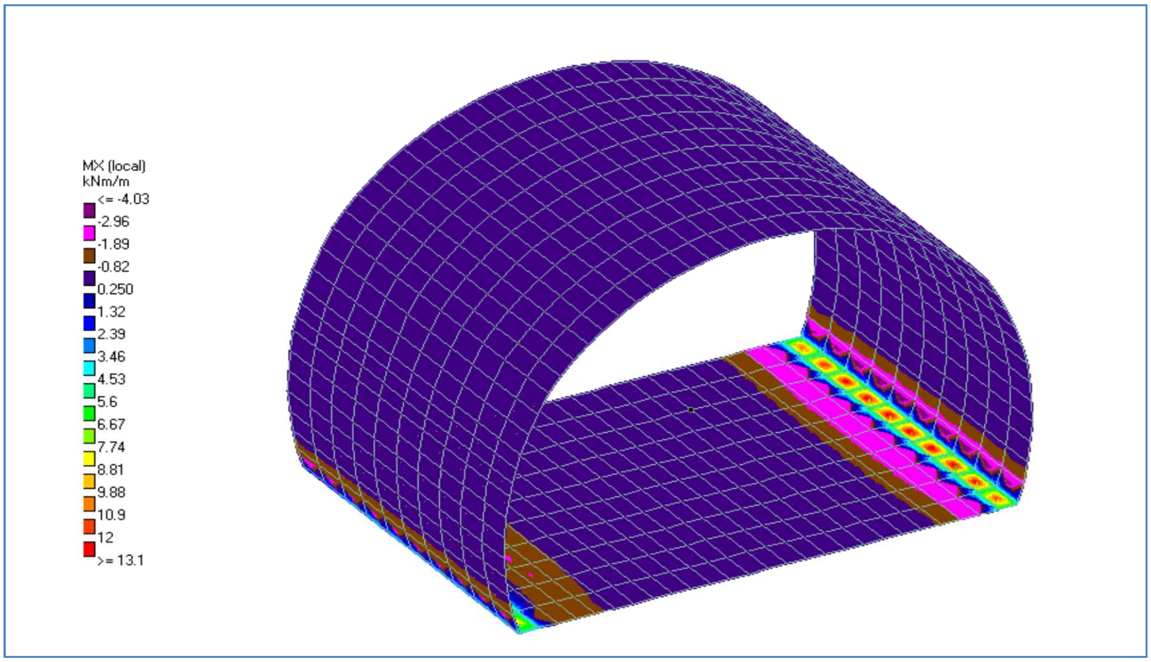

Figure-10: Result Interpretation for Lining Design

1.12 Recommended Support System for Tunnel

Recommended Rock Support System for Tunnel

Rock Class	RMR	Rock Support			
		Shotcrete	**Lattice Girders**	**Rock Bolts**	**Fore Poling**
Class A	81-100	50 mm thick shotcrete mainly above springing line	--	Spot bolting (where ever required)	--
Class B	61-80	75 mm thick shotcrete	--	25mmΦ, 5 m long fully grouted rock bolts @ 2.0 m c/c in crown in staggered pattern	--

Class C	41-60	100 mm thick shotcrete with one layer of wire mesh 100mmx100mmx6 mm	--	Systematic rock bolting, 25mmΦ,5 m long fully grouted rock bolt @ 1.5 m c/c staggered at crown & wall	--
Class D	21-40	100 mm thick shotcrete with one layer of wire mesh 100mmx100mmx6 mm.	Steel Rib ISMB250@ 1 m c/c as shown in drawings	Systematic rock bolting, 25mmΦ, 6 m long fully grouted rock bolts @ 1.5 m c/c staggered at crown & wall	If required
Class E	<20	100 mm thick shotcrete with one layer of wire mesh 100mmx100mmx6 mm.	Steel Rib ISMB250 @ 0.5 m c/c as shown in drawings.	Systematic rock bolting, 25mm Φ, 6 m long fully grouted rock bolts @ 1 m c/c staggered at crown & wall	32 mm 10.0 m long fore poling @ 300 mm c/c

1.13 Tunnel lining

Clearance profile is 13.7 m wide and 9.5 m high. Concrete lining of thickness 400 mm is provide. Rock bolting is applied from spot bolting to all-round the tunnel section at 2.0m c/c respectively from Class A to E. Shotcrete with and without wire mesh is required, the thickness of shotcrete will vary from 50 mm to 100 mm with wire mesh as per the rock class. Tunnel section through Class D and Class E will have lattice girder and steel ribs. Details are shown in the respective rock support drawings.

1.14 Abstract of Equipment

Description of Equipment's			**Quantity**	
2.0 cum Excavator	=		4	nos
2-Boom Drill Jumbo	=		2	nos
Front End Loader	=		4	nos
Wagon Drill	=		8	nos

Compressor 500 cfm	=		2	nos
Compressor 1000 cfm	=		2	nos
25T capacity dumpers	=		14	nos
Jack Hammer (120 cfm capacity)	=		16	nos
90 HP dozer (One dozer against two loaders has been provided at muck disposal site for spreading the muck)	=		4	nos
Gantry shutters	=		4	sets
Concrete pump 40cum/ hr	=		4	nos
Hydraulic Platform/Truck Jumbo	=		4	nos
Concrete Placer	=		8	nos
Transit Mixers (6 cum capacity)	=		4	nos
Needle Vibrators (65 mm dia. Needle)	=		8	nos
Grout Pump	=		4	nos
Shotcrete Machine	=		4	nos
Welding sets	=		4	sets
Blasting Accessories	=		8	nos
Ventilation Blower (One set in front of each Face)	=		4	sets
Rib Bending Machine	=		1	set
Dewatering pumps of different capacity	=		8	sets

1.15 Construction Duration

Duration Calculation for Tunnel Commissioning			
S.No	Activities	Duration	Unit
A	One month for portal formation and road diversion	1	month
Face 1 and 2 (Silkayara and Barnot Side) = 2275 m			
B	Heading Excavation for Tunnel from Both Face	27.00	months

C	Benching Excavation of Tunnel from Both Face	7.00*	months
D	Concreting From Both Face	**16.00**	months
E	Drainage Arrangement	3.00*	months
F	Lighting Arrangement	3.00*	months
G	Ventilation Arrangement	3.00*	months
H	Development of Road surfaces	**4.00***	months
Total Duration of Tunnel Completion		**48**	months

- * Parallel activity that will take place during tunnel excavation.

1.16 Costing

CALCULATION OF CIVIL COST					
Sr. No.	**Description of Items**	**Units**	**Quantity**	**Unit Price in Rs.**	**Sub-Total Price in Lakh**
A	**Underground Excavation**				
a	in Class A, B & C	Cum	4,89,793	4700	23,020
b	in Class D & E	Cum	2,10,125	5100	10,716
c	Extra for haulage of material arising from geologically approved over break	Cum	1,39,984	500	700
B	**Portals (Silkayara +Barkot)**				
a	Surface Excavation	Cum	1,44,500	975	1,409
b	Shotcrete	Cum	580	11,880	69
c	Wiremesh	Sqm	5,800	1,000	58
d	Concrete Portal	Cum	608	9,000	55
e	Concrete Bridge +Retaining Wall	Cum	5,947	9,000	535
f	Reinforcement	MT	528	80,000	423
g	Wearing Coat	Cum	45	50,000	23
h	Rock Anchors	m	8,700	1,877	163

i	Drainage Holes	m	2,960	2,000	59
j	Backfilling	Cum	40,000	5,520	2,208
k	Steel Rib	MT	15	1,20,000	17
l	Tie Rod	MT	1	1,00,000	1
m	Concrete Lagging	cum	15	9,590	1
C	**Shotcrete with wiremesh-Underground**				
b	Shotcrete	Cum	13,739	11,880	1,632
c	Wire mesh	Cum	1,37,392	800	1,099
3	**Fully Grouted Rock Anchor**				
a	Grouted Rock anchors, 25 mm dia; 5 m long	m	2,93,100	1,877	5,501
4	**Steel Ribs**				
a	ISMB250 in Tunnel	MT	2,367	1,12,000	2,651
5	**Tie Rod**	MT	218	1,12,000	244
6	**Pipe Roofing**	m	1,07,640	2,000	2,153
8	**Concreting in**				
a	Concrete Lining (M40A40)	Cum	1,46,724	9,000	13,205
b	Precast Lagging	Cum	3,180	9,590	305
c	Overbreak Backfill (M15A80)	Cum	14,450	5,520	798
d	Invert filling (M40A40)	Cum	22,700	9,000	2,043
e	Lean concrete (M15A40)	Cum	5,300	5,520	293
f	Footpath and cable trench (M25A40)	Cum	4,000	9,000	360
9	**Reinforcement**	MT	4,100	1,06,500	4,367
10	**Drilling Holes for**				
a	Contact Grouting	RM	8,300	2,000	166
b	Consolidation/pregrout Grouting	RM	24,800	2,000	496
d	Placing grout for consolidation/pre grout	Nos	600	2,175	13
e	Fill grouting for temporary drainage system/exploratory holes	Nos	300	2,580	8
f	Water pressure testing	Nos	100	668	1
11	**Grouting Materials**				
	Cement	MT	4,965	12,750	633

	Sand	MT	257	2,001	5
	Bentonite	MT	29	26,846	8
	Admixtures	MT	71	57,321	41
	Super Plasticizer	MT	10	67,299	7
	Embedded mild steel pipes & fittings	MT	239	1,33,581	319
11	**Pressure Relief Holes**				
a	Drilling and washing of 75mm dia holes	RM	30,700	2,000	614
b	Supply & installation of PVC pipes filled with filter material	RM	31,600	338	107
c	Drilling for probe holes / pre-drainage holes up to 20m length	RM	5,000	2,000	100
d	Non core Drilling of exploratory holes NX size for Instrumentation/Check holes	RM	1,000	15,000	150
13	**Supply and installation of PVC Pipe for**				0
a	250mm Dia for Water supply	RM	9,100	500	46
b	300m Dia for Main Drainage	RM	18,200	700	127
14	**RCC M40 for partition wall**	Cum	10,500	9,500	998
15	**Laying of Road Surface**				
a	Constructing Granular Sub-base	Cum	15,000	4,350	653
b	Placing and Constructing wet mix macadam first layer of 150mm thk.	Cum	7,600	3,800	289
c	Placing and Constructing wet mix macadam Second layer of 100mm thk.	Cum	5,100	3,600	184
d	Constructing DBM	Cum	3,100	15,000	465
e	Laying of bituminous primer coat	Sqm	50,100	100	50

16	**Laying and fixing of precast concrete Kerb stone**	Cum	3,700	6,092	225
17	**Fixing of Railing for footpath**	RM	9,100	1,000	91
18	**Instrumentation and monitoring**	lumpsum			1,500
18	**RCC structures for a) Control Room b) HVAC Room C) Water Storage and D) Retaining structures**	lump-sum	250	4	1,000
20	**Dewatering @ 2% cost fo works except lump sum items**				1,598
21	**Contingency and work charged Establishment @ 5% (except L.S. items)**				3,995
Total cost of Civil Works					**87995.5**

Total Cost of E&M (in lakhs)

Sl. No.	Description	INR. Lakh
1	**General**	
1.1	Design works	1000.0
A.	**Tunnel Operation Safety and Traffic Control Section**	
A.2.0	Integrated Tunnel Control System	1500.0
A.3.0	Local Control Centres	400.0
A.4.0	Traffic Control System	1200.0
A.5.0	Acces Control	200.0
A.6.0	Electrical Fire Signalling System	800.0
A.7.0	Emergency Call System	1200.0
A.8.0	Video Surveillance System (Close Circuit TV)	500.0
A.9.0	Fire Fighting System (Automatic High Pressure Water Mist)	6000.0
B.	**Electro-Mechanical Equipment Section**	
B.14.0	Power Supply System	1800.0
B.15.0	Ventilation System	1850.0
B.15.2	Physical Values Measurement	350.0
B.16.0	Tunnel Lighting	600.0
B.17.0	Communication Systems	450.0

C.	Management and coordination	
C.1.0	Contractor works	1250.0
C.2.0	Accessory Documentation	250.0
	Total contract (in lakhs)	**19350.0**

SUMMARY OF TOTAL COST (in lakhs)		
Sl. No.	**Description**	**INR.**
A	**Civil works**	
	Cost of Civil works for tunnel	87995.5
B	**E&M works**	
	Cost of E&M works for tunnel	19350.0
	Total cost (in lakhs)	**107345.5**

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2 FIELD SURVEYS AND SITE INVESTIGATIONS

2.1 Regional Geology

In the Lesser Himalayan domain, the site geology is represented mainly by low-grade quartzitic sandstone, dolomitic limestone and slates with metabasic sills and dykes of undifferentiated Jaunsar- Deoban formations of Garhwal Group overridden by a nappe of older sediments having exceptionally thick flyash sequence of fine grained meta sandstone-siltstone-slate-shales profusely intruded by epidiorite/amphibolite dyke and sills. The northern contact of the nappe with underlying Garhwal Group is identified as Garhwal Thrust which is also named as Srinagar Thrust or North Almora Thrust. The proposed tunnel alignment falls in the inner part of Lesser Himalaya in Uttarkashi District of Uttarakhand. Between Dharasu Bend (EL.960m) in the SSE and Barkot Town (EL.1340m) in the NNW the highway passes across an almost ENE-WSW oriented ridge in the middle part which forms a major water divide through Radi Top (EL.2252m). The terrain displays a highly dissected topography on either slopes of the ridge which are carved by dendritic, torrential rainfed streams originating in the water divide.

2.2 Seismicity

The Himalayas lie within seismic zones IV & V, of the seismic zoning map of India. Earthquakes of sizeable magnitude are not uncommon to the area. In the last 50 years, several major earthquakes with a magnitude in excess of 6 on the Richter scale, have occurred in North-West Himalayas.

2.3 Local Geology and Geomorphology

Barkot Formation: Huge successions of fine grained sandstone-siltstone-slates-shales (which Sometimes appear to be phyllitic) constitute the typical bedrocks. This, largely a turbidite sequence, has been referred in published literature as Damta-Simla slates, Chakrata Formation, Chandpur Formation etc. as an integral part of Dudatoli-Almora nappe. Barkot Formation name has been given by present author to this assemblage as it is prominently exposed around Barkot. The sequence is profusely intruded by thick amphibolite/ epidiorite dykes and sills those almost form more than 40% part of the Group in the present section.

Kuthnor Formation: The rocks exposed within the tectonic window, limited on the north by MCT and south by Garhwal Thrust, are classified under Garhwal Group represented by low-grade quartzitic sandstone/ quartzite, dolomitic limestone and variegated shales/ slates. This sedimentary sequence has pen contemporaneous lava flows in the form of sills and dykes.

3 TUNNEL LAYOUT, CROSS SECTION AND PROFILE

3.1 Layout

The tunnel layout is optimized considering various factors; which include length, cross section for sizing, ventilation system to be adopted corresponding to the length and cross-section, traffic volume, vertical rock cover. Overall cost and time of construction are other major factors while fixing the layout of any tunnel.

Three different layouts are studied, refer Figure-1 below.

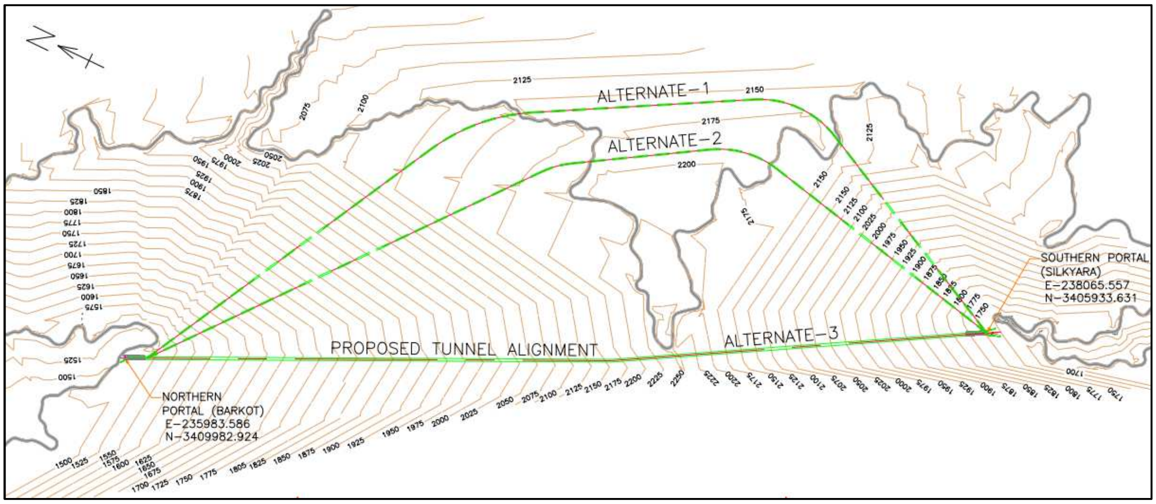


Figure 1

Alternative-I:

In this layout, maximum rock cover above the finished Tunnel is around 485m. The overall length of the tunnel is 5.4 km with two horizontal bends. As the Tunnel length is more than 5kms, Semi-transverse ventilation system is proposed.

Alternative-II:

In this layout, maximum rock cover above the finished Tunnel is around 520m. The overall length of the tunnel is 4.97 km with two bends. As the Tunnel length is more than 1.5kms, longitudinal ventilation system is proposed.

Alternative-III:

In this layout, maximum rock cover above the finished Tunnel is around 585m. The overall length of the tunnel is 4.55 km which is almost straight. As the Tunnel length is more than 1.5kms, longitudinal ventilation system is proposed.

Final Layout:

After comparison of above three alternatives it’s clear that no significant reduction in rock cover is achieved but there is considerable increase in the length of tunnel. As the length of the tunnel increases the cost of the ventilation system increases. Hence Alternative-III is considered to be the best in this situation and adopted.

The proposed layout and cross-section arrangement includes all standard operational features. The basic tunnel layout is shown on the Schematic Layout drawing. Spacing of emergency egress openings (4.0m wide) connecting the main tunnel will be 300m. Emergency call niches will have spacing 150m and they will be located on the both sides of the tunnel. Fire fighting niches will have spacing of 150m, but they will be located only on one side of tunnel (the side with cross passages). Lay-bays will have the spacing of 1200m (staggered); they will be on both side of the tunnel.

3.2 Cross Section

Similar as the geometric alignment, three cross sections are studied and compared to finalise the best suited cross section. These are as below:

Proposal-I: Single Tunnel (Main Tunnel with No Escape Tunnel/ Passage)
A single tunnel without escape tunnel and having a carriageway width of 7.0 m and clear height of 5.5m. Minimum construction time is required results in less project cost. But as per tunnel guideline any tunnel having length more than 1.5kms must be provided with a escape passage for emergency conditions like accident, fire or other reasons. Hence this proposal is not recommended at all and ignored.

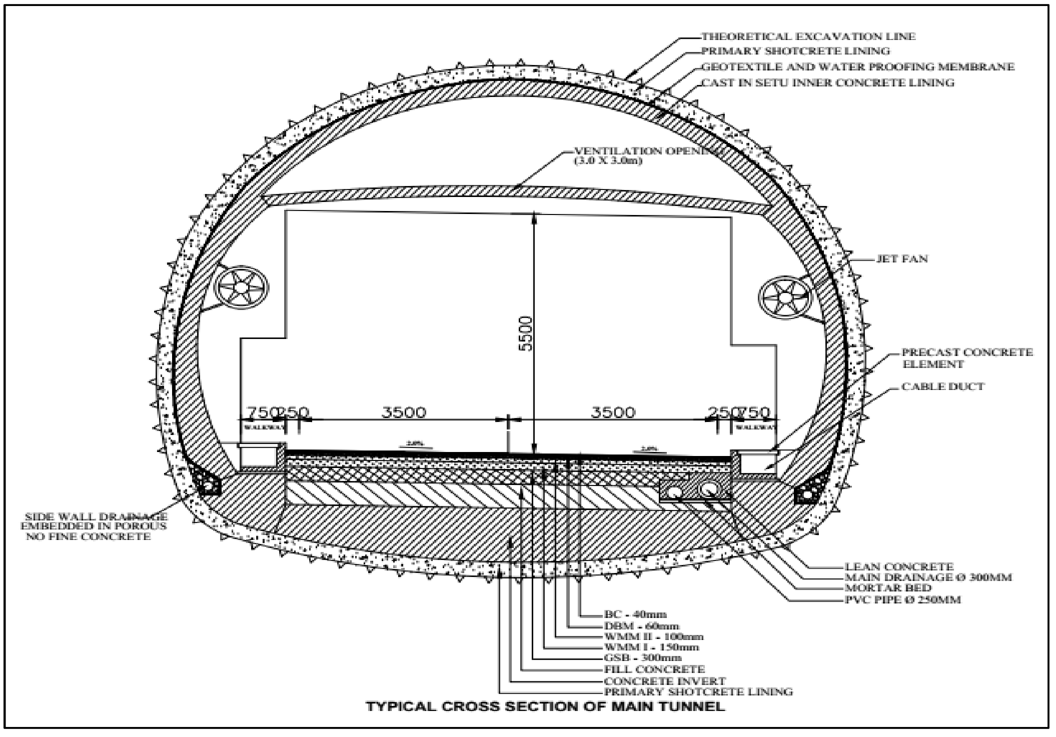


Figure-2: Tunnel Arrangement for Proposal-I

Proposal-II: Twin Tunnel (Main tunnel with parallel Escape tunnel)
In this proposal, two parallel tunnels about 18.0m apart, one main tunnel having carriage way width of 7.0m and other escape tunnel having carriage width of 5.0m are proposed. Both the tunnels are connected with each other at suitable interval by Cross Passage. Escape tunnel can be used in emergency and for future expansion. The construction time and cost required is more for two tunnel, two portals and two set of ventilation system. This system is best suited in case of heavy traffic volume but at current location the traffic volume is only 2000 PCU. Hence this proposal is also not recommended.

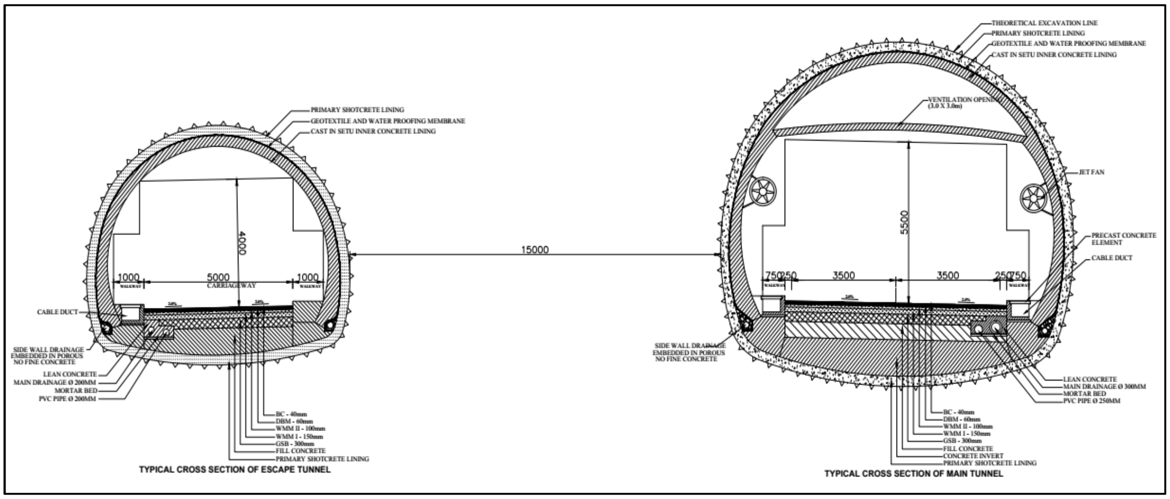


Figure-3: Tunnel Arrangement Proposal-II

Proposal-III: Single Tunnel with an Escape Passage Created using RCC Partition Wall

In this proposal, single tunnel with an escape passage separated by RCC Partition wall having opening at suitable interval is proposed. This proposal has the benefit of both the alternate proposals. This proposal is cost effective as only one single tunnel is to excavate and thus adopted for current situation. Adopted cross section has been attached as Figure -4.

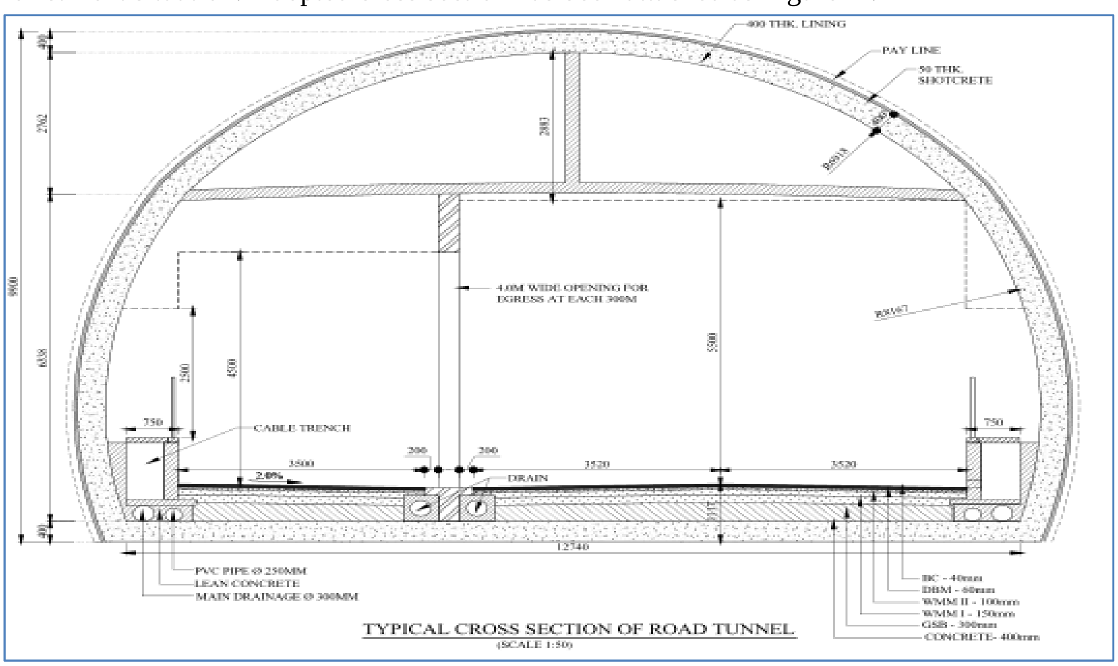


Figure-4: Final Tunnel Arrangement Cross-Section

3.3 Dimensions and Profile

Keeping in view the economics of construction, considering local conditions and construction practice, the standard profile proposed for the tunnel driven by conventional tunneling methods is a D- shape, rather than the circular shape produced by a tunnel boring machine (TBM). The tunnel dimensions are also based on the requirements to provide a 7.0 m carriageway width and

3.5 escape carriage way, 0.75m wide sidewalks, 5.5 m (minimum) clear headroom and space for ventilation channels for fully transversal system of ventilation.

4 PRINCIPLES OF DESIGN AND CONSTRUCTION

4.1 Design

The design for a tunnel usually consists of:

- Drawings
- Specification
- BOQ (for expected conditions and expected distribution of support classes)
- Geotechnical monitoring programe, including expected values
- Contingency measures

The following principles shall be adhered to during design:

- Tunneling involves ground-structure interaction.
- The load to be carried by the composite structure of the ground and lining arises from the insitu stresses and groundwater pressure.
- Deformation of the ground is inevitable and it must be controlled to permit a new state of equilibrium to be reached safely.

The stress in the ground (and therefore the load on the lining) will depend on how much deformation is permitted and how much stress redistribution ("arching") within the ground is possible. The art of tunneling is to maintain as far as possible what inherent strength the ground has so that the amount of load carried by the structure is minimized.

Stand-up time: This is a measure of how long the ground can stand unsupported. If this is less than the time required to install the sprayed concrete lining, additional measures will be required (e.g.: ground improvement, canopy tubes, etc.).

Face stability: The stability of the ground at the face governs the size of the faces in each heading. Various analytical tools can be used to help estimate this.

4.2 Design Approach

Engineering of underground structures has to be based on the assumption that practically nothing is certain about the major input parameters: the geology, the geotechnical and geo-mechanical interpretation of the ground behavior, the assessment of the interaction between the tunnel structure and the surrounding environment, the construction variables and market factors, and the opinion and response of the final users of the infrastructure to be built. Tunneling is generally associated with a high level of risks due to the uncertainties involved in all stages of the work. These risks should be minimized by proper investigations, design based on the results of the investigations and construction practices adopted to tackle residual risks. As such, the risks should be identified and assessed prior to developing the risk mitigation options and residual risks should be clearly identified so that construction measures can be effectively adopted. It can be said that tunneling design is a continuous and iterative process which starts from an initial design based on geological, geotechnical and other inputs and is then fine-tuned gradually by modification of the initial design to cope with the 'evolving' reality revealed by construction, through a dynamic and continuous design process (implementation, monitoring, checking, and optimization of the design) till the completion of the works. The monitoring works are thus an important part of the design process and also construction, especially control of the construction process, should also be seen as an integral part of tunnel engineering (however, the scope of work for this project is limited to the initial design part only and construction support shall be provided separately).The principal concerns for the detailed engineering design and construction for this project can be listed as below: The Himalayas are a tectonically active zone with a complex geological history. The extent and accuracy of the geological and geotechnical investigations would, to a large extent, determine the efficacy of design. It is also to be kept in mind that by proper investigations we can reduce uncertainties and minimize risk but we shall have to tackle the residual risk with proper construction techniques and preparedness. The tunnel alignment, for considerable length is parallel to the hill slopes and wouldbe affected by the stability of the slopes (also vice-versa, the stability of slopes would be affected due to the redistribution of stresses because of tunnel excavation). Extreme caution should be exercised, especially during construction and all efforts should be made to observe the effect of tunneling on the slopes.

4.3 Design of Portals for Tunnels

The tunnel portal location is mainly governed by overall road alignment, the tunnel gradient, geological and geotechnical parameters and the requirement to ensure all construction work remain outside the weak zones. Based on the inputs received for the portal creation, suitable portal design will be done. Portal excavation will be limited avoiding major cutting and disturbance to virgin natural ground. Portals for tunnels will be well defined and also on the other hand will be designed to be as small as possible in order to minimize the environmental impact.

4.4 Design of Tunnel Primary Support

The tunnel structures has been designed in accordance with the current editions of the codes and standards where these are appropriate. Codes or standards that define loadings on underground construction do not exist either nationally or internationally. In the absence of such documentation, international best practice for the design of such components has been employ precedents, past experiences and the published and unpublished works of prominent authors, workers, researchers and the theoreticians in the field. For present tunnel the design methods used are as follows: Empirical design for derivation of tunnel support the empirical method assesses the needs of the primary support for the tunnel using RMR, and the Q-system chart derived by Barton. The empirically derived support loading is also used as basic input in numerical modelling. Numerical modelling for analyzing the system behavior after application of derived support. Supplementary to the above described design of the tunnel support, numerical modelling and related limit state modelling will be undertaken using computer programs. For design of Tunnel support system refer section covering design of tunnel rock support and tunnel lining.

4.5 Ground Interpretation

For the purpose of designing the tunnel support system, the rock mass along tunnel alignment has been classified into different categories, based on the geological & geotechnical data. The categorization has been done on the basis of rock mass parameters which are likely to be encountered along tunnel alignment as per available geological data. Factors such as weathering, jointing, joint condition, the local hydrogeology and insitu stress will affect the condition of the rock mass and to a large extent will govern parameter allocation. These are briefly explained in the following sections.

4.6 Insitu Field Stress Interpretation

In tectonically active areas such as the Himalayas, tectonic stresses affect the stress regime possibly leading to development of locked-in stresses within rock mass. Also, overlying rock mass strata gives rise to stresses due to its weight which plays important role in local stress field. Due to excavation, redistribution of stresses will take place creating new stress field around the opening. Thus the magnitude and orientation of virgin stress field plays an important role in deciding the stability of an opening. As tunneling projects always have limited information on insitu stress testing, it is proposed to undertake a sensitivity analysis and adopt such stress values which may lead to the development of the critical stress field. Further, in the Himalayan region, it is likely that significant faulting, folding and confinement of the rock has induced high stresses within the rock mass. Thus, derivation of preliminary stress will be done on the basis of the available literature and experience of tunneling in Himalayan geology.

Calculations, in the general case where field test data is absent, will be based on Sheory simplified equation to estimate the horizontal to vertical stress ratio k. This equation is where z (m) is the depth below surface and Eh (GPa) is the average deformation modulus of the upper part of the earth's crust measured in a horizontal direction. Additional data on the unconfined compressive strength for various rock types is required to allow a better prediction of rock mass behavior and more data on the stress state at various locations along the tunnel will help to analyze difficulties during excavation process.

4.6.1 Geological conditions

Although rock is generally considered 'hard' it is a highly varied, discontinuous and complex material. Tunnel may pass through mixed rock mass conditions which vary from massive rock to highly disturbed and fissured material. Rock mass investigation and classification is a very important tool in design stage.

The aim of a tunneling project site investigation is to characterize the rock mass along the alignment into geological units (rock mass types) and to describe and evaluate their geo-mechanical properties and behavior during excavation. These geological / rock mass units form the basis for design of the tunnel excavation and support classes. The following aspects however are fundamental and their implication for the design process is important:

- Rock mass stresses
- Strength & deformation parameters
- Rock structure and discontinuities
- Water conditions

4.6.2 Material behavior of sprayed concrete

Sprayed concrete consists of water, cement and aggregate, together with various additives. In general this leads to a mix (in the wet or dry process), which has more sand, a higher cement content, smaller sized aggregate and more additives compared with conventional cast concrete. Also the water-cement ratio is relatively high. In turn this leads to a faster growth in strength and other properties with age, a lower ultimate strength and more pronounced creep and shrinkage. Since the properties of sprayed concrete change considerably during first hours and days, the response and resistance of the tunnel shotcrete lining to loading varies.

4.6.3 Specification

Specification of all tunneling works describes the function, properties and the way how the different support elements have to be installed and what quality parameters have to be reached. The quality control test regime stipulated in the specification should be appropriate to the scale of the works.

4.6.4 Detailing

Good detailing is essential for good constructability. It is important to form structurally sound joints. Designers should strive for simple joint details. Where reinforcing bars are used, the spacing should not be less than 150 mm. lf the bar arrangement is very dense it will be difficult to spray the concrete around the bars and "shadows" will occur. This reduces the effective bond and increases the risk of corrosion.

4.6.5 Waterproofing

Project specific criteria determine the water tightness to be achieved by the lining. Traditionally sheet membranes are installed where complete water tightness is required. Due to waterproofing system proposed for tunnel, where water is collected in drainage protective layer and diverted to drainage pipes along tunnel foundation beams (umbrella drainage), tunnel lining is not exposed to potential water pressure. The lining does not have to be designed to carry any water pressure.

4.6.6 Durability

Traditionally, a double shell lining system is used. Primary shotcrete lining is supporting tunnel where required and together with rock bolts guarantees stability of excavated opening. Secondary cast in situ concrete inner lining provides additionally structural member for already stabilized tunnel, protects waterproofing membrane and makes uniform smooth surface.

4.7 Construction

4.7.1 Construction Management

Very important part is proper organization of construction and definition of responsibilities and competences. Daily meetings of representatives of the Contractor, Client, Designer and other parties involved (tunnel geotechnical engineer, geo-monitoring expert, etc.) have to agree on rock classification and excavation & support system acc. to designed class or with adjustments. Joint decisions have to be made in writing, possibly on prepared form e.g. Required Excavation and Support Sheet (RESS), which is the basis for further construction and becomes a project document after being signed by all representatives. A copy should be made available to the foreman (shift manager) in the tunnel.

4.7.2 Construction Sequencing

The way how (excavation method, excavation speed, size and shape of opening, time of of the support installation, etc.) a tunnel is constructed has a large influence on distribution of stresses around tunnel and on loading of the lining. Important factors are:

4.7.3 Monitoring

Instrumentation has to be installed to monitor behavior of excavated tunnel and rock mass around the tunnel. Monitoring assists to determine and optimize the required support. For example, advance lengths could be varied or optional additional support measures such as face shotcreting, fore poling/spilling, or rock bolting can be adopted. The normal hierarchy of monitoring is: in-tunnel convergence (shotcrete lining displacement measurement); surface settlement; subsurface instruments (e.g.: inclinometers, extensometers, piezometers); in tunnel stress / strain measurements. For present tunnel only special (3D) optical deformation/displacement measurement of the shotcrete lining after excavation is foreseen, some inclinometers and settlement points are proposed for areas of portals.

Deformation of the tunnel lining and rock mass should be compared to limits and should be used to evaluate the performance of the tunnels. Unexpected behavior should result in a pre-defined sequence of actions to connect the adverse behavior. These countermeasures range from increasing the frequency of monitoring frequency to additional support measures, modification of excavation process and to emergency measures focused on safety of tunnel workers. Complex evaluation of monitoring data is a task for experienced geotechnical engineer. Data gained from ahead-driven pilot tunnel have to be evaluated and prognosis done for the main tunnel drive.

4.7.4 Health and Safety

Health and safety is a very important aspect of all tunneling works and contractor should generate maximum effort to ensure working conditions corresponding to healthy requirements and safety of workers and public.

5 TUNNEL DESIGN - SITE SPECIFICS

5.1 Design Methodology

Initially tunnel excavation shall be provided with primary support to meet the safety need and to maximize the rate of progress of tunnel excavation which is later supported with secondary lining. Both the supports are discussed in brief in subsequent sections. Shotcrete, rock bolts, and steel ribs are used as primary support and concrete lining is used for permanent support. The basic stability requirements for initial support are that all convergences on the roof and walls of the tunnel shall be within permissible limits as prescribed by Sakurai (1993). The supports should not be overstressed. Supports are to be installed in such a way that there is gradual loading of supports. The rock loading imposed on primary supports shall not exceed their structural capacity for particular member.
Based on field observations and measurements, Sakurai (1983) suggested that tunnel strain levels in excess of approximately 1% are associated with the onset of tunnel instability and create difficulties in providing adequate support. With increase in strain level, stability problem increases. Hence, the 1% limit proposed by Sakurai is only an indication of increasing difficulty and shall be adopted in the design.

5.2 Primary Support

Primary support is provided to fulfil the safety for the personnel working under excavated openings. Primary support which acts as initial support mainly comprises of combination of installation of grouted rock bolts in specified patterns and application of appropriate layers of shotcrete in reasonably good quality of rock mass. In case of poor quality rock, steel sets with concrete lagging in combination with spilling bars and shotcrete can be used depending upon passive support reaction required. Such support is mainly recommended in highly sheared ground which may be encountered in thrust zones, fault zones and at portal stretch due to highly weathered ground condition. In all cases the type of initial support arrangement required is primarily dependent on the rock mass characteristics anticipated. Shotcrete is applied directly on exposed excavated face after scaling operation so as to avoid free fall of rock wedges and also provides initial strength to minimize rock mass deformation. Shotcrete produces a full strata-support contact irrespective of the nature of irregularities along the tunnel profile and can be reinforced either through the introduction of wire mesh or steel fibres. Rock bolts act as active support to retain the rock mass forming a reinforced arch around the excavated opening. Rock wedges formed on excavated face are stitched back in sound rock with pattern bolting.

5.3 Permanent Support

To form a permanent robust means of final support, an insitu concrete lining will be cast up against the primary lining. The main function of this lining is to provide long term stability of the excavation, provide aesthetically pleasing finish and, if applicable, achieve the hydraulic performance required for air flow. In design of permanent support, the primary lining and elastic behavior of tunnel support is taken into consideration (i.e., applied primary support in the form of shotcrete and steel support will participate in resisting the forces developed due to different loading conditions).

5.4 Seismic Design

There is a clear distinction between the seismic design of surface structures and underground structures. Surface structures are primarily concerned with the seismic ground acceleration, as this induces large shear forces at the foundation level of the structure, whereas underground structures typically move as part of the rock mass and are primarily concerned with ground deformations induced by the seismic waves. The design methods adopted for the tunnels employ the use of empirical methods to ensure that the tunnel can withstand the shaking effects of an earthquake. These calculations deal with the shaking effects on tunnels where the ground does not fault nor lose its integrity, but imparts a transient shaking to the tunnel. These calculations are based on published information by T. R. Kuesel entitled 'Earthquake design criteria for subways'. This method is suitable for tunnels as the relative stiffness of tunnel lining is negligible compared to the surrounding rock mass. Free-field ground deformations due to a seismic event are estimated, and the underground structure is designed to accommodate these deformations. It provides simple checks to establish whether or not a tunnel will be likely to suffer damage.

5.5 Rock Mass (Ground) Characterization and Determination of Excavation & Support

Limited site investigations (drilling campaign - 2 drill holes) has been performed and accompanied by expert on-site investigation. Review of available information and analyses is carried out. Performed evaluation is based on methodology of Guideline for Geo-mechanical Design by OEGG as shown on following scheme:

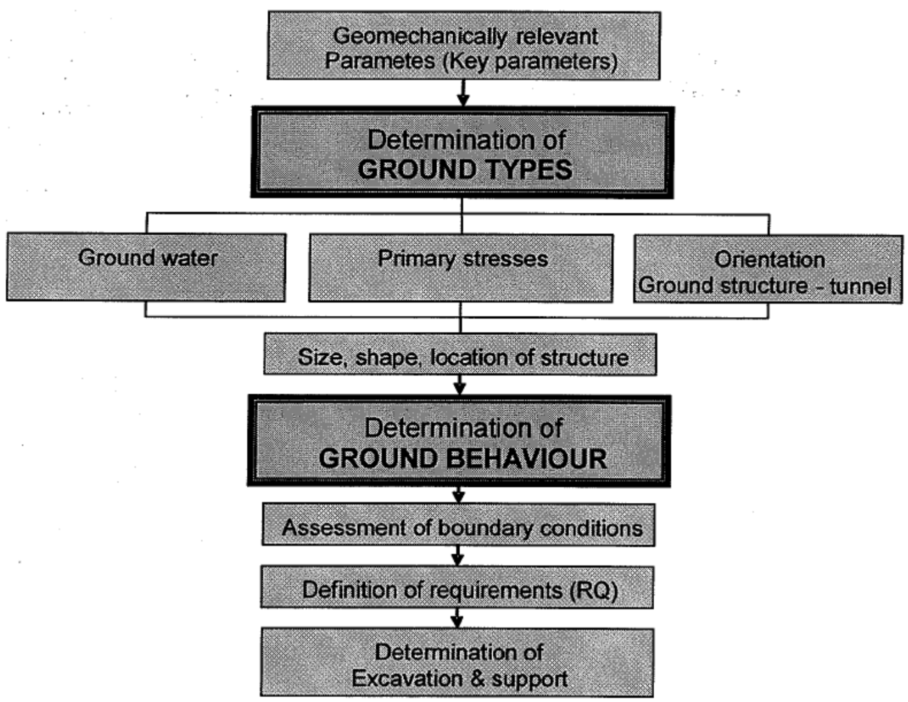


Figure 2

Summary of investigation are tabulated as shown in tables below. For Details of tables 1 to 3 below refer: Geology Report "Geological and Geotechnical Feasibility of proposed Silkyara Bend - Barkot Tunnel alignment".

5.6 Structural Analysis of Tunnel Supports

The main model used for discontinuous rock is wedge analysis and can be used in the design to model discrete rock block behavior and examine if the support is sufficient to prevent local block failure. To know the deformational behavior of quasi-homogenous rock mass under specified stress conditions, the assumption of an elasto-plastic rock mass will be used. The selection of realistic parameters for these models is more difficult. Software packages would be used based on FEM/FDM to carry out numerical analysis & study deformation and strength of individual elements. Following sections give brief idea about different numerical modelling approaches that will be carried out for tunnel design.

5.7 Modelling of Passive Initial Support Arrangements

At the portals, low cover areas and in highly fractured faulted rock masses, full-bodied passive support is required to stabilize the tunnel sections. Passive support normally comprises of the provision for steel ribs/lattice girders embedded in shotcrete. This support will be assumed to act as a monolithic structure that is able to passively support an assumed load of loosened rock. In addition, further support measures can be introduced as part of the excavation sequence. These measures involve the installation of an array of spilling bars or forepoling in the tunnel crown ahead of the excavation. To enable the design of this composite lining (i.e. steel ribs and concrete), a plane frame analysis approach shall be employed to ensure that the proposed arrangement is able to withstand critical assumed ground loading. The theoretical loading applied to the model will be based on the assumption that only a notional head of rock loading will bear onto the tunnel roof. This is because the rock mass will effectively arch around the tunnel opening leaving a zone of loosened rock material above. In this way the inherent strength of the rock mass is taken into account. The height of rock used shall be based on an empirical relationship for rock mass characteristic categories proposed by Terzaghi (1946). In effect, the Terzaghi approach (as modified by Deere et al., 1970) relates rock condition descriptions to a notional height of loosened rock applied to the roof of the tunnel. Note that hydrostatic pressure generated by the surrounding groundwater need not to be considered, as the primary support shall be assumed to be free-draining. Steel sets embedded in shotcrete shall be modelled as composite liner with properties of equivalent material in FEM analysis. Each liner element is a "beam" element which can resist bending moment, axial and shear forces as per Timoshenko or Bernoulli beam formulations. The purpose of undertaking this form of analysis is to determine the magnitude of support deflection for given combinations of loading; as well as calculate the axial forces, bending moments and shear forces that will be applied to the composite arch structure. The resultant forces and bending moment for the component elements can then be compared to their respective moment-thrust failure envelope profiles. Where the capacity of the composite has been exceeded, consideration will be given to the introduction of hinges in the model. These hinges reflect the condition where a plastic hinge is formed and imposed bending moments are redistributed elsewhere within the arch structure.

5.8 Final Lining Design

The design of concrete lining is based on the most adverse combination of probable load conditions which have reasonable probability of simultaneous occurrence. The design will be based on normal loading condition and checked for possible different extreme loadings that may occur in life time of project. The design loading incorporates possible adverse combination of following loads.

- External Strata Loads
- Self-Load of Lining
- External Surcharge, if any
- Seismic Loading

The stresses in members under worst loading combination should be within acceptable limits.

5.9 Extreme Tunneling Conditions

In the Himalayas, high insitu stress are expected in combination with poor quality, weathered rock mass; especially in tectonically active zones. Thus excavation of cavity in such rock mass tends to redistribute stress around the opening which may, in turn, result in squeezing and rock burst phenomena. In areas of high in-situ stress and where the rock masses is competent there may be rock bursting. In the schist, fault zones (which are typically highly anisotropic rock masses, foliated, severely folded and faulted) there may be significant squeezing on the tunnel profile. Extreme condition like Rock Bursting and Squeezing is remote for Silkayara Tunnel but this cannot be completely ruled out.

5.10 Squeezing

Squeezing stands for large time-dependent convergence during tunnel excavation. It takes place when a particular combination of induced stresses and material properties pushes some zones around the tunnel beyond the limiting shear stress at which creep starts. Various methods are available for prediction of squeezing in tunnels. A simple approach to know the squeezing phenomenon is derived by Goel at. el.(1995). Considering the tunnel depth H, the tunnel span or diameter B, and the rock mass number N, Goel et al. (1995) have plotted the available data on a log-log diagram between N and H The data points lying above the line represent squeezing conditions, whereas those below this line represent non-squeezing conditions.

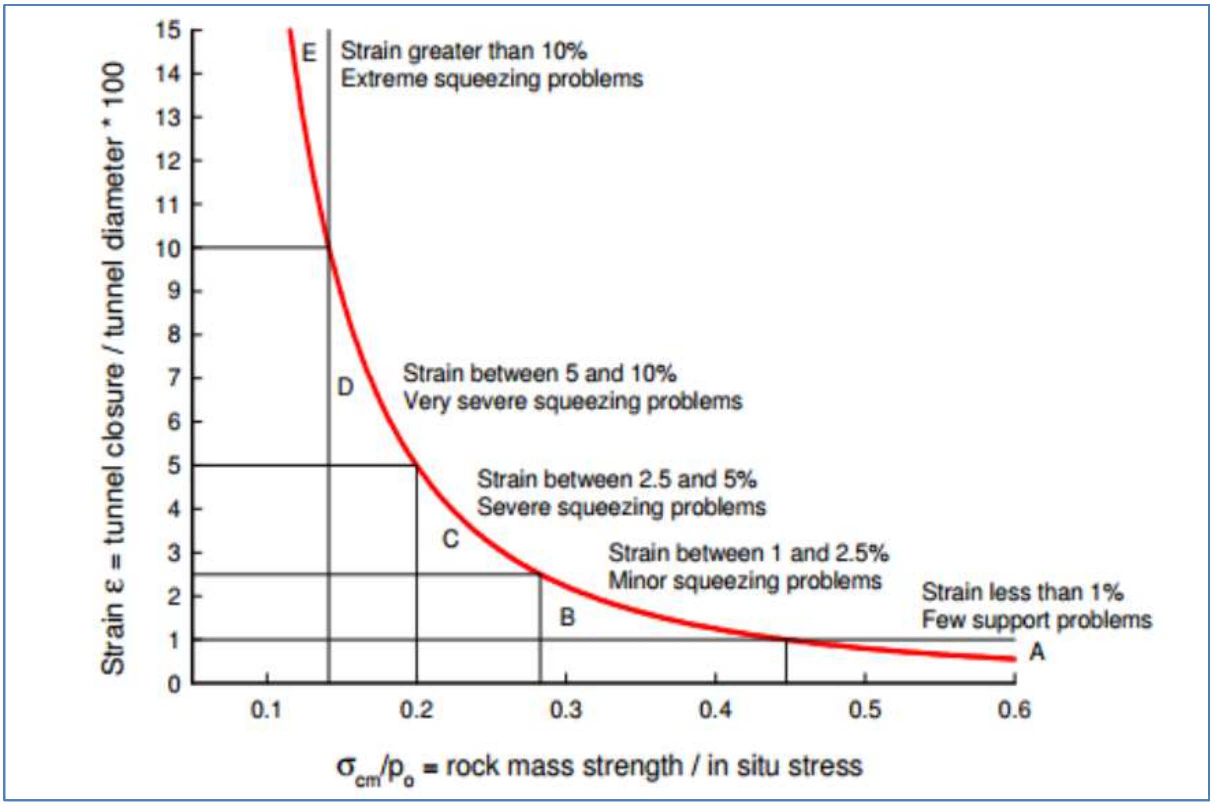
- For squeezing conditions

  $$\mathbf{H >> (275\, N^{0.33})\, B^{-1}}$$

➢ For Non-squeezing conditions

$H \ll (275\, N^{0.33})\, B^{-1}$

Another method for predicting tunnel squeezing is provided by Hoek and Marinos (2000) and can be summarised as below. Measures can be employed to control squeezing conditions. These include sequential excavation and treatment of the tunnel face in combination with full face excavation. Sequential excavation is the adopted method for the tunnel and consists of separate top heading and benching. If the heading and benching arrangement are found to be insufficient to control squeezing the profile could be excavated in numerous smaller headings or reinforcing the face prior to excavation.



5.11 Rock Bursting

Rock bursting is a phenomenon which is related to deep tunnels in hard rock. The rock burst is defined as any sudden and violent expulsion of rock pieces from an apparently (temporarily) stable opening. Experience shows that rock masses which are fractured either naturally or artificially are not prone to rock burst. This is explained by the relatively ductile behavior of jointed rock masses. It is only the massive hard and brittle rocks (Q perhaps greater than 2) which show rock bursting phenomenon. For safety of workers at least no rock burst should occur near working face during excavation process in progress. Some ways to handle rock bursting are to make opening of small size which is directly proportional to strain energy realized per unit area. Thus strain energy released per unit area will reduce considerably. Shape of excavation is selected in such a way that minimum stress concentration is developed around opening leading to stability of opening.

A criterion for estimating degree of difficulty associated with tunneling through overstressed rock (Relative strain is for tunnel with no support, By Hoek and Marinos, 2000)

Difficulty class	Relative strain %	Geotechnical issues	Support types
A	Less than 1	Very simple tunnelling conditions, few stability problems. Tunnel design recommendations based upon rock mass classifications provide an adequate basis.	Rockbolts and shotcrete typically used for support.
B	1 to 2.5	Minor tunnelling problems. Ground Reaction Curve methods are used to predict the formation of a plastic zone surrounding a tunnel and of interactions between the progressive development of this zone and different types of support.	Tunnel support with rockbolts and shotcrete; sometimes light steel sets or lattice girders are added for additional security.
C	2.5 to 5	Problematic tunnelling conditions. Face stability is generally not a major problem. Finite element analyses, incorporating support elements and excavation sequence are normally performed.	Rapid installation of support; careful control of construction quality. Heavy steel sets embedded in shotcrete are generally required.
D	5 to 10	Severe tunnelling and face stability problems. Finite element analyses are generally carried out. Some estimates of the effects of forepoling and face reinforcement are required.	Forepoling and face reinforcement are usually necessary.
E	More than 10	Very severe tunnelling and face stability problems. No effective design methods are currently available. Most solutions are based on experience.	Forepoling and face reinforcement are usually applied and yielding support may be required in extreme cases.

5.12 Tunnel Instrumentation

- **Deformation Measurements**

Instruments are installed in the tunnel roof and at selected points along the tunnel walls to monitor vertical, horizontal, and longitudinal (in tunnel direction) deformation components. The number of points and their detailed location depends on the size of the tunnel and the excavation sequencing in multiple drift applications. As a minimum, the wall of each excavation (including temporary) should be equipped with a device capable of measuring deformations. It is customary to install optical targets for this purpose.

- **Stress Measurements**

If stress information is sought then measurements should be taken with a direct measuring tool that does not rely on any further conversions from say strains to stresses.

For example, instruments based on strain gage principles require the knowledge of the elastic modulus of the material to covert strains to stresses. This introduces an additional parameter that must be estimated thus introducing a secondary uncertainty. Stress measurements within shotcrete linings are frequently carried out using hydraulic pressure cells filled with mercury whereas ground stress measurements are carried out with cells filled with oil. If stress measurements are to be monitored then ground load cells and concrete pressure cells should be grouped in pairs. The primary purpose of geotechnical and structural instrumentation is to monitor the performance of the underground construction process in order to avoid or mitigate problems. If such monitoring also serves a scientific function, or leads to advancement in design procedures, that is a bonus rather than a primary reason for its implementation.

Table 1 : Significant Geological Features

Identified locations of significant geological features on tunnel alignment			
Name	**Tunnel Chainage**	**Width (m)**	**Description**
A. Regional & Local Faults - None			
B. Shear zones (probable!)	300-340	40	The contact could be sheared in case of emplacement of dykes of amphibolite/ epidiorite in the meta siltstones
	4100-4140	40	-do-
C. Jointed & Blocky Rocks	0-300	300	Meta siltstones/fine grained sandstones/phyllites with subordinate amphibolites/epidiorite dyke/sills
	340-4100	3770	Massive amphibolite/epidiorite body with subordinate meta siltstones/fine grained sandstones/phyllites
	4140-4,551	540	Meta siltstones/fine grained sandstones/phyllites with subordinate amphibolites/epidiorite dyke/sills
D. Low Cover Areas	No		
E. Possible water Inflows Dripping and minor flow	All through the tunnel length specially during wet period		
F. Thermal Water Springs	No		

Table 2: RMR and Q ranges of Rock Mass along Proposed Alignment

RMR and Q ranges of rock mass along proposed Tunnel alignment			
Tunnel Chainage (m)	RMR Range	Rock class/ Description	Q Range
0 - 300	62 - 67	B/ Good	4 – 40

300 - 340	21 - 40	D / Poor	0.1 - 1
340 - 2860	81 - 85	A/ Very Good	40 - 1000
2860 - 2900	21 - 40	D / Poor	0.1 - 1
2900 - 4551	61 - 65	B/ Good	4 – 40

Table 3 :Percentage of Rock Mass along Tunnel

Projected values for percentage of length in each formation and class				
Description	Proportion of tunnel excavation	RMR'	GSI	Q
Amphibolite/epidiorite	80.40%	81 - 85	86 - 90	40 - 1000
Meta-sandstone/siltstone/ phyllites	17.89%	61 - 65	66 - 70	Apr-40
Closely fractured phyllites	1.71%	21 - 40	26 - 45	0.1 - 1

Table 4 : Percentage of Rock Class

Description of rock class	**Proportion of tunnel**	**Tunnel Length**
Class A	5%	227.5
Class B	5%	227.5
Class C	50%	2275
Class D	30	1365
Class E	10	455
Total	100%	4550

6 Recommended Support System for Tunnel

Based on the above analysis, the support system recommended for tunnel is as shown in Table 5

Table -5: Recommended Rock Support System for Tunnel

Rock Class	**RMR**	**Rock Support**			
		Shotcrete	**Lattice Girders**	**Rock Bolts**	**Fore Poling**
Class A	81-100	50 mm thick shotcrete mainly above springing line	--	Spot bolting (where ever required)	--
Class B	61-80	75 mm thick shotcrete	--	25mmΦ, 5 m long fully grouted rock bolts @ 2.0 m c/c in crown in staggered pattern	--

Class C	41-60	100 mm thick shotcrete with one layer of wire mesh 100mmx100mmx6 mm	--	Systematic rock bolting, 25mmΦ,5 m long fully grouted rock bolt @ 1.5 m c/c staggered at crown & wall	--
Class D	21-40	100 mm thick shotcrete with one layer of wire mesh 100mmx100mmx6 mm.	Steel Rib ISMB250@ 1 m c/c as shown in drawings	Systematic rock bolting, 25mmΦ, 6 m long fully grouted rock bolts @ 1.5 m c/c staggered at crown & wall	If required
Class E	<20	100 mm thick shotcrete with one layer of wire mesh 100mmx100mmx6 mm.	Steel Rib ISMB250 @ 0.5 m c/c as shown in drawings.	Systematic rock bolting, 25mm Φ, 6 m long fully grouted rock bolts @ 1 m c/c staggered at crown & wall	32 mm 10.0 m long fore poling @ 300 mm c/c

As the variation in lithology in the project area is very limited, only a few parameters allow distinguishing between different Rock types (Ground types). The parameters are:

- Uniaxial compressive strength (UCS)
- Modulus of elasticity
- Joint spacing
- Joint properties
- Rock types

Rock support system is designed for rock classes from A to E based on above data. For details refer rock support drawings for tunnel.

7 TUNNEL PORTALS

7.1 Excavation

Both portals (Silkyara and Barkot) will be excavated in rock.

7.1.1 Silkyara portal:

Quality of rock is good in this area and slope very steep, therefore the portal can be excavated with steep slope (say 6:1). An excavation should not require a systematic rockbolting. Occasional anchoring of loose blocks might be required. But, initial stretch of tunnel (approx.15m length) that is also part of portal shall be strengthened by providing steel ribs as per the drawings.

7.1.2 Barkot portal:

Quality of rock is good in this area and slope very steep, therefore the portal can be excavated with steep slope (say 6:1). An excavation should not require a systematic rockbolting. Occasional anchoring of loose blocks might be required. But, initial stretch of tunnel (approx.15m length) that is also part of portal shall be strengthened by providing steel ribs as per the drawings.

7.1.3 Permanent Solution

Silkyara portal: Open cut transition section and Ventilation building shall be built immediately at the mined portal

Barkot portal: Open cut transition section and Ventilation building shall be built immediately at the mined portal.

7.2 Tunnel lining

Clearance profile is 13.7 m wide and 9.5 m high. Concrete lining of thickness 400 mm is provide. Rock bolting is applied from spot bolting to all-round the tunnel section at 2.0m c/c respectively from Class A to E. Shotcrete with and without wire mesh is required, the thickness of shotcrete will vary from 50 mm to 100 mm with wire mesh as per the rock class. Tunnel section through Class D and Class E will have lattice girder and steel ribs. Details are shown in the respective rock support drawings.

8 CONSTRUCTION METHODOLOGY

Expected work cycle for tunnel excavation and support installation should include the following steps:

- ➢ Excavation
- ➢ Spoil removal
- ➢ Installation of Steel ribs, lattice girder and meshes
- ➢ Shotcreting
- ➢ Installation of rock bolts

8.1 Excavation

The tunnel will be excavated through conventional methods. The rock will probably have to be drilled and blasted. The procedure of drilling and blasting requires experienced staff. In case that rock would be weaker than expected, excavation using excavator should be faster. Depending on excavation classes, further protection measures might be required and should be included into the work cycle (forepolling rockbolting, spiling, canopy tubes, etc. as per drawings).

8.2 Methodology of Heading Excavation in Class B and Class C

The tunnel will have maximum excavated height of around 7 m for Class-B and 7.1 m for Class-C rock. The maximum excavated height for Class-D and Class-E rock shall be 7.5m. Excavation in heading would be taken up by drilling and blasting method. Drilling of holes for blasting would be done by two boom drill jumbos with a man basket. The setting out of the tunnel profile for drilling and other purposes would be achieved by installing three laser beams, one each at the springing level and the third at the crown. The lasers would be kept switched off for safety reasons and would be switched on only when required. Haulage of excavated material shall be done by a combination of 2.3cum. Loader and 25T capacity rear dumpers. As the excavation proceeds, rock support system by way of rock bolts, shotcrete as required shall be provided. To support the face, sealing shotcrete shall also be provided if required. Drilling for rock bolts shall also be carried out with two-boom drill jumbo.

8.3 Methodology of Heading Excavation in Class D & Class E

The heading operation in poor rock will also follow the same methods as detailed in the above paragraph. The pull in this case will be restricted to 1.5m for poor and 1m for very poor rock type. Pre-supporting the rock ahead of excavation with the help of fore poles would invariably be carried out in every round. Here also as the excavation proceeds, rock support system by way of shotcrete, lattice girder, steel ribs and pre-cast lagging and backfill concrete shall be provided, as required. Drilling for rock anchors shall also be carried out with two-boom drill jumbo.

The drilling for tunnel is proposed to be carried out by using two-boom hydraulic drilling jumbo.

In order to limit extra over breaks, profile of tunnel will be marked after each cycle and periphery drilling will be carried out at. The mucking operation will be carried out by using 2.3 cum loader and 25T capacity dumpers. Adequate number of dumpers will be provided to cater for lead involved for mucking.

The excavation of heading will be carried out in following operations:

i) Survey and marking of profile

ii) Drilling

Drilling will be done by using two-boom hydraulic drilling jumbo, which can theoretically drill up to 100m/hr. This progress can however be achieved under ideal conditions and continuous drilling operations. Since the drilling is to be carried out for large number of holes of limited depth, each time the location of booms will have to be changed which takes lot of time. As such, practically a progress of not more than 100m of drilling can be achieved in one hour with the help of two booms. Periphery holes at 500mm c/c will be provided to minimize over excavation of rock and to maintain correct profile. The periphery holes will be charged only to an extent of 25%.

iii) Charging and Blasting

The holes drilled will be loaded by power-gel or equivalent. Non-electric detonators with millisecond delay are proposed to be used. Non-electric detonators will enable to carry out charging and drilling in simultaneous operations. After loading of explosive of the entire face is completed, the equipment and personnel will be withdrawn and blasting will be done.

iv) Defuming

Adequate ventilation is essential during excavation of tunnels. The headrace tunnels, during excavation, will be provided with two (2) exhaust fans in series with a ventilation duct of 1.4m diameter. The ventilation system will not be required once the tunnel heading excavation has been completed.

v) Scaling

After excavation of the face, scaling of roof and sides will be carried out. The scaling is proposed to be carried out manually with the help of scissors platform. All loose rock fragments shall be removed during scaling operation. Local drilling and blasting will be done, if required, to remove any undercut.

vi) Mucking

In fair to good rock conditions, mucking operations shall be carried out immediately after scaling of face whereas in poor rock conditions a layer of shotcrete shall be provided first to avoid any loose rock from falling, and mucking shall be carried out thereafter.

vii) Rock Support Measures

Shotcreting shall be carried out upto excavated face after each blast whereas rock bolting shall be provided about 2 pulls behind the excavated face. Both the operations, however, are to be carried out after each blast. The excavated tunnel will be supported by steel ribs in the reaches which are geologically weak. Special tunneling techniques like multiple drift method will be deployed in shear zones and flowing strata reaches, if encountered. The cycle time for excavation of tunnel both for normal reaches without ribs and with ribs has been worked out. However, cycle time in shear zones and flowing strata reaches will be as per actual site conditions encountered and cannot be predicted. Sufficient time margins have been kept as average rate of progress of tunnel taken will be less than anticipated.

8.4 Methodology for Benching for All Classes of Rock

The benching of 3.2 m will be carried out by conventional bench blasting method.

There are two alternatives for excavating the bench, as below:

By first completing the entire heading excavation and then doing the benching, or

By excavating the heading for, say, 50m and then completing the benching up to that length, of course, leaving an approach ramp up to the heading.

The advantage in the first method is that the heading excavation would advance at an optimum rate without any disturbance or interruption, as the cycle would have been well established. Once the heading is completed, the drilling jumbo would be spared for other jobs. Also, when the heading is through, the ventilation situation would improve due to cross-ventilation. The three laser beams deployed for profile marking would also be spared for use elsewhere.

Regarding the other alternative, one advantage would be to simultaneously lay the kerbs for the concreting gantry track after the bench is completed up to a certain length. However, the first alternative has been adopted for framing the construction schedule to ensure uninterrupted working with the established heading excavation cycle time and availability of equipment for other works.

8.5 Spoil Removal

Spoil removal can be done either by dumpers, trucks or using belt conveyor.

8.6 Installation of Steel ribs, Lattice Girder and Meshes

Installation of Steel ribs, Lattice girder and wire-meshes depends on rock class. They are provided for rock class D and E, as shown in drawings. More than one layer of shotcrete may be required from poor to very poor rock class. Thickness of one shotcrete layer should not exceed 50mm. Thicker lining should be applied in several layers (to avoid falls of green shotcrete). Surveyor should be present during lattice girder installation to determine connect locations of the rib.

8.7 Shotcrete

Shotcrete should be applied either by wet process or dry process. Dry shotcrete components, shall be slightly pre-dampened to reduce dust and are fed into a hopper with continuous agitation. Compressed air is introduced through a rotating barrel or feed bowl to convey the materials in a continuous stream through the delivery hose. Water is added to the mix at the nozzle. In case wet process, shotcrete components and the water are mixed before delivery into a positive displacement pumping unit, which then delivers the mix hydraulically to the nozzle where air is added to project the material onto the rock surface. The final product of either the dry or wet shotcrete process is very similar. Decisions to use the dry or wet mix shotcrete process are usually made on a site-by-site basis. The wet mix process seems to be more appropriate for the proposed tunnel, as shotcrete mix will be required regularly.

The quality of the final shotcrete product is closely related to the application procedures used. These procedures include: surface preparation, nozzling technique, lighting, ventilation, communications, and crew training. Shotcrete should not be applied directly to a dry, dusty or frozen rock surface. The work area is usually sprayed with an air-water jet to remove loose rock and dust from the surface to be shot. The damp rock will create a good surface on which to bond the initial layer of shotcrete paste. The nozzleman commonly starts low on the wall and moves the nozzle in small circles working his way up towards the back, or roof. Care must be taken to avoid applying fresh materials on top of rebound or over sprayed shotcrete. It is essential that the air supply is consistent and has sufficient capacity to ensure the delivery of a steady stream of high velocity shotcrete to the rock face. Shooting distances are ideally about 1 to 1.5 metres. Holding the nozzle further from the rock face will result in a lower velocity flow of materials which leads to poor compaction and a higher proportion of rebound. A well-trained operator can produce excellent quality shotcrete manually, when the work area is well-lit and well ventilated, and when the crew members are in good communication with each other. Spraying over lattice girders should be done carefully to avoid shadowing and to assure proper bound of steel and shotcrete. Shotcrete should be applied either manually or using automatic robot. Manual spraying is more physically demanding; moreover it would be problem for sprayer to reach the tunnel crown. Therefore robotic spraying should be preferred in case of proposed tunnel.

Strength and thickness of the lining should be regularly tested (hilti penetration tests, core samples, thickness drills). Lining, which does not reach prescribed strength, should be replaced. Deformations of the tunnel lining should be regularly monitored. Regular convergency readings are essential to assure safety of excavation. Additional monitoring (extensometers, inclinometers, levelling, piezometers, etc.) might be required in problematic areas (namely in areas of portals).

8.8 Concrete Lining

After the excavation is completed, concrete lining of tunnel will begin. The lining of the tunnel comprises of 40cm thick plain cement concrete. Concrete lining operation consists of overt lining to be followed by invert lining. The overt lining shall be done using a 12m long hydraulically operated collapsible gantry shutter moving on rails. The concreting of invert portion will be done after the overt lining is completed.

The average quantity of concrete required for one block of 12m in the overt would be 348 cum. Concrete pump of capacity 40cum. /hr. would be utilized for placement of concrete. Considering an average efficiency of 80% and placement rate of 32cum /hr, placement activity would take about 10.9 hours, say 11 hours.

Cycle time for concreting one block of 12m length would be as follows:

Releasing gantry from earlier block, cleaning and oiling and shifting to next block	=6 hours
Setting to desired line and location and checking	= 5 hours
Bulkhead erection	=2 hours
Concrete placement @ 32cum./hr	= 11 hours
Setting time for concrete	= 24 hours

Total time for one cycle = 48 hours

Thus time for placement and setting of one block of 12m would take 48 hours.

Progress in one month of 25/2 days = 12.5 cycles (pours) = 12.5x12

= 150m/month

8.9 Equipment Planning

SILKAYARA TUNNEL -UTTARAKHAND (5.45 KM Long)							
				Type of Rock			
				CL B	**CL C**	**CL D**	**CL E**
	Lining thickness	m	=	**0.40**	**0.40**	**0.40**	**0.40**
	Pay line thickness	m	=	**0.10**	**0.10**	**0.10**	**0.10**
	Shotcrete thickness	m	=	**0.075**	**0.10**	**0.10**	**0.10**
	Maximum working hours assumed in 24hrs in 3 shift allowing 2hrs for shift change	hrs	=	20.00	20.00	20.00	20.00
	Progress per cycle	m	=	**3.00**	**3.00**	**1.50**	**1.00**
i)	**Drilling and Blasting**						
	Depth of holes to be drilled.	m	=	3.25	3.25	1.75	1.25
	Cross sectional area of tunnel	m^2	=	**77.67**	**78.22**	**79.90**	**79.90**
	Assuming spacing of holes @0.85m c/c	m^2	=	0.72	0.72	0.72	0.72
	No. of holes required per face	nos.	=	108	109	111	111
	Additional hole for line drilling/ burn hole	nos.	=	10	10	10	10
	Total no. of holes		=	118	119	121	121
	Total depth of drilling	m	=	383.50	386.75	211.75	151.25
	Output of two boom drill jumbo	m/hr	=	**100.00**	**100.00**	**100.00**	**100.00**
	2 boom drill jumbo	no	=	1.00	1.00	1.00	1.00
	Profile Marking & Setting of Operation	hr	=	0.50	0.50	0.50	0.50
	Drilling Time	hr	=	3.84	3.87	2.12	1.51

	Loading and blasting	hr	=	1.00	1.00	1.00	1.00
	Defuming	hr	=	1.00	1.00	1.00	1.00
	Scaling and cleaning	hr	=	1.00	1.00	1.50	2.00
	Total time for drilling and blasting	hr	=	7.34	7.37	6.12	6.01
ii)	**Mucking**						
	Quantity of muck (bank)	cum	=	233.01	234.67	119.85	79.90
	Out put of 2.3 cum Loader (Loose)	cum/hr	=	**140.00**	**140.00**	**140.00**	**140.00**
	Loose density of excavated muck	T/m^3	=	**1.58**	**1.58**	**1.58**	**1.58**
	Capacity of 25 T Dumper	cum	=	15.81	15.81	15.81	15.81
	Swell factor		=	0.63	0.63	0.63	0.63
	Total Loose muck per pull	cum	=	369.6	372.0	190.3	126.2
	Mucking hours required	hr	=	2.64	2.66	1.36	0.91
iii)	**Cycle Time**		=				
	Drilling and Blasting	hr	=	7.34	7.37	6.12	6.01
	Mucking time	hr	=	2.64	2.66	1.36	0.91
	Time for rock bolt and shotcrete	hr	=	6.00	6.00	-	-
	Time for rock bolt, shotcrete, Erection of steel ribs,lattice girder, lagging and backfilling	hr	=	-	-	8.00	15.00
	Fore poling & grouting					3.00	4.00
	Total time required	**hr**	**=**	**15.98**	**16.03**	**18.48**	**25.92**
	No of cycle	nos	=	1.25	1.25	1.08	0.77
	Total progress per day	m	=	3.75	3.74	1.62	0.77
	Total progress per month of 25 days	m	=	93.87	93.57	40.58	19.29
	Percentage of Rock Classification		=	30%	55%	10%	5%
	Average Progress per month	m	=		85		
	Say	m	=		85		
iv)	**Requirement Dumpers**						
	Average Lead	km	=		**5.03**		
	Loading Time	min	=		6.78		
	Spotting Time	min	=		0.50		
	Turning and Dumping time	min	=		2.00		
	Empty haul @ 20 Km/hr	min	=		15.09		
	Loading haul @ 15 Km/hr	min	=		20.12		
	Total cycle time	min	=		44.49		

	No. of Trips per working hour of 50 minutes	nos	=		1.12		
	Output of Tipper per 50 minutes	cum	=		17.77		
	Total nos of dumpers required	**nos**	=		**8**		
B	**Benching**						
i)	**Drilling and Blasting**						
	Width of Head Race Tunnel for benching	m	=	**14.00**	**14.00**	**14.00**	**14.000**
	Pay line thickness	m	=	**0.15**	**0.15**	**0.15**	**0.15**
	Shotcrete thickness	m	=	**0.08**	**0.20**	**0.35**	**0.35**
	Maximum working hours assumed in 24hrs in 3 shift allowing 2hrs for shift change	hrs	=	20.00	20.00	20.00	20.00
	Progress in horizontal direction	m	=	**15.00**	**15.00**	**15.00**	**15.00**
	Progress in vertical direction	m	=	**3.00**	**3.00**	**3.00**	**3.00**
	Depth of holes to be drilled.	m	=	3.50	3.50	3.50	3.50
	Plan area for drilling	m^2	=	210.00	210.00	210.00	210.00
	Assuming spacing of holes @1.25m c/c	m^2	=	1.56	1.56	1.56	1.56
	No. of holes required per face	nos.	=	135.00	135.00	135.00	135.00
	Additional holes for line drilling/ burn hole	nos.	=	10.00	10.00	10.00	10.00
	Total no. of holes	nos.	=	145.00	145.00	145.00	145.00
	Total depth of drilling	m	=	507.50	507.50	507.50	507.50
	Output of Wagon Drill	m/hr	=	**15.00**	**15.00**	**15.00**	**15.00**
	No. of wagon drill	nos.	=	4.0	4.0	4.0	4.0
	Drilling time	hr	=	8.46	8.46	8.46	8.46
	Loading and blasting	hr	=	1.00	1.00	1.00	1.00
	Defuming	hr	=	0.50	0.50	0.50	0.50
	Scaling and cleaning	hr	=	1.00	1.00	1.50	2.00
	Total time for drilling and blasting	hr	=	10.96	10.96	11.46	11.96
ii)	**Mucking**						
	Quantity of muck (bank)	cum	=	309.60	309.60	309.60	483.90
	Out put of 2.3 cum Loader	T/m^3	=	**140.00**	**140.00**	**140.00**	**140.00**
	Loose density of muck		=	**1.58**	**1.58**	**1.58**	**1.58**
	Capacity of 25 T Dumper	cum	=	15.81	15.81	15.81	15.81
	Swell factor		=	0.63	0.63	0.63	0.63

	Total Loose muck per pull	Cum	=	491.43	491.43	491.43	768.10
	Mucking hours required	hr	=	3.51	3.51	3.51	5.49
iii)	**Cycle Time**						
	Drilling and Blasting	hr	=	10.96	10.96	11.46	11.96
	Mucking time	hr	=	3.51	3.51	3.51	5.49
	Time for rock bolt and shotcrete	hr	=	3.00	3.00	3.00	3.00
	Total time required for 15 m horizontal advance	hr	=	17.47	17.47	17.97	20.45
	No of cycle	nos	=	0.86	0.86	0.83	0.98
	Progress per day	m	=	12.88	12.88	12.52	14.67
	Progress per month	m	=	322.1	322.1	313.5	366.8
	Percentage of Rock Classification		=	27%	44%	19%	10%
		m	=		325		
	Say				325		325
iv)	**Requirement Dumpers**						
	Average Lead	km	=		**5.03**		
	Loading Time	min	=		6.78		
	Spotting Time	min	=		0.50		
	Turning and Dumping time	min	=		2.00		
	Empty haul @ 20 Km/hr	min	=		15.09		
	Loading haul @ 15 Km/hr	min	=		20.12		
	Total cycle time	min	=		44.49		
	No. of Trips per working hour of 50 minutes	nos	=		1.12		
	Output of Tipper per 50 minutes	cum	=		17.77		
	Total nos of dumpers required	**nos**	=		**8**		
A	**Concreting**						
	Volume of Concrete	cum	=		36432		
	Concrete Pump	cum/hr	=		40.00		
	Out put of concrete pump @80% efficiency	cum/hr	=		32.00		
	Working hrs/day for concreting	Hrs	=		8.00		
	Working days/month for concreting	days	=		10.00		

	Working Months required	hrs	=		3.5578		
	Working Months provided for concreting	**months**	=		**4.00**		
	Total Concreting in One Face		=				
B	**Requirement of 6 cum Transit Mixer for one 40cum/hr Concreting Pump**						
	Capacity of Concreting pump		=		40.00	cum/hr	
	Output of concrete pump @80% efficiency		=		32.00	cum/hr	
	Number of pumps		=		1.00	no	
	BM plant capacity		=		**45.00**	cum/hr	
	Output of B&M Plant @ 70% efficiency		=		31.50	cum/hr	
	Capacity of Transit Mixers		=		**6.00**	cum	
	Output of transit mixer @80% efficiency		=		4.80	cum	
	Time per working hour		=		50.00	min	
	Lead Distances		=		**1.37**	km.	
	Loading (=4.8 x 60/31.5)		=		9.14	min.	
	Spotting time		=		1.50	min.	
	Turning		=		2.00	min.	
	Unloading (=4.8 x 60/32)		=		9.00	min.	
	Empty haul @ 20 Km/hr		=		4.11	min	
	Loading haul @ 15 Km/hr		=		5.48	min	
	Total cycle time		=		31.23	min.	
	No. of trips/working hour		=		1.60	nos.	
	Output/working hour		=		7.68	cum	
	No. of Transit Mixers required		=		**5**	nos.	

8.10 Abstract of Equipment

Description of Equipment's			**Quantity**	
2.0 cum Excavator	=		4	nos
2-Boom Drill Jumbo	=		2	nos
Front End Loader	=		4	nos
Wagon Drill	=		8	nos
Compressor 500 cfm	=		2	nos
Compressor 1000 cfm	=		2	nos

25T capacity dumpers	=		14	nos
Jack Hammer (120 cfm capacity)	=		16	nos
90 HP dozer (One dozer against two loaders has been provided at muck disposal site for spreading the muck)	=		4	nos
Gantry shutters	=		4	sets
Concrete pump 40cum/ hr	=		4	nos
Hydraulic Platform/Truck Jumbo	=		4	nos
Concrete Placer	=		8	nos
Transit Mixers (6 cum capacity)	=		4	nos
Needle Vibrators (65 mm dia. Needle)	=		8	nos
Grout Pump	=		4	nos
Shotcrete Machine	=		4	nos
Welding sets	=		4	sets
Blasting Accessories	=		8	nos
Ventilation Blower (One set in front of each Face)	=		4	sets
Rib Bending Machine	=		1	set
Dewatering pumps of different capacity	=		8	sets

8.11 Construction Duration

Duration Calculation for Tunnel Commissioning			
S.No	Activities	Duration	Unit
A	One month for portal formation and road diversion	1	month
Face 1 and 2 (Silkayara and Barnot Side) = 2275 m			
B	Heading Excavation for Tunnel from Both Face	27.00	months
C	Benching Excavation of Tunnel from Both Face	7.00	months
D	Concreting From Both Face	**16.00**	months

E	Drainage Arrangement	3.00*	months
F	Lighting Arrangement	3.00*	months
G	Ventilation Arrangement	3.00*	months
H	Development of Road surfaces	**4.00***	months
Total Duration of Tunnel Completion		**48.00**	months

- * Parallel activity that will take place during tunnel excavation.

8.12 Grouting

8.12.1 Contact Grouting

Contact grouting in the tunnel is proposed to be carried out after 30 days of placement of concrete overt. Subsequently, the contact grouting will progress simultaneously with lining activity of tunnel. Contact grouting is provided to fill any gap between rock and concrete lining, especially at crown level, which has been left during concreting activity. For this purpose grout holes of 38 mm diameter will be drilled 600 mm inside the rock and grouting will be done at a low pressure of about 2 to 2.5 kg/cm2. The water-cement ratio in the will be kept leaner in the beginning and will be thickened as grouting progresses. The grouting will be carried out till refusal. Grout pumps will be utilized to carry out the grouting operations. The grouting operations will be finished one month after the last activity of concreting.

8.12.2 Consolidating Grouting

Consolidation grouting shall be done at locations having poor geology, as decided by the Engineer-in-Charge. The length of drill hole for consolidation grouting in general shall be 6 m deep in to the rock. Consolidation grouting would be carried out through these holes at a pressure ranging from 5 to 7 kg/cm^2. The grouting in this case is also to be carried out till refusal. Grouting shall be done using grout pumps.

8.12.3 Cleaning of Tunnel and Road Formation

After completion of all activities the tunnel will be thoroughly inspected for any foreign material left inside during construction. The cleaning operation will be carried out simultaneously when lining is completed in some stretches. Road development will be carried out as parallel activity and will be completed just one month after completion of concreting.

SUMMARY OF TOTAL COST (in lakhs)		
Sl. No.	**Description**	**INR.**
a	**Preconstruction Work**	
i	**Cost for Preparation of DPR**	**700**
ii	**DPR Level Investigation**	
A	**Land (Forest and Private Lands)**	
I	**Land for Tunnel construction (22.75 Hectare)**	**500.5**
II	**Land for Dumping (5 Hectare)**	**110**
B	**Civil works**	
I	Cost of Civil works for tunnel	87966.0
II	Contigencies at 2.8% of Civil Cost	2463.0
III	Supervision Consultancy Charges at 2% of Civil cost	1759.3
IV	Administrative Charges at 1%	879.7
V	Quality Control Charges at 1%	879.7
VI	Road safety audit charges at 0.5%	439.8
VII	Escalation at 5% for four years	17593.2
VIII	Maintenance Charges at 5% for 4 Years	4398.3
IX	Total Cost Including Centages	**116379.0**
C	**E&M works**	
	Cost of E&M works for tunnel	**19350.0**
	Total cost (in lakhs)	**137039.5**

	Sl. No.		Item		
	1		2		3
	Investigation and Design				
	A-1: Investigation				
	Drilling of Boreholes	m	1000	50000	500
	Laboatory Test	LS			200
	Hydrofracture Test	Nos	4	2500000	100
	Total Cost in Lakh for Investgation				**800**
	A-2: Detailed Design (Project Layout, Service Buildings, E&M Works, Drainage works etc.)				
1	**North Portal -Barkot**				
	A-1 Temporary Dewatering Arrangement				**35**
	A2- Open Excavation and Earthwork (Loose excavation, rock excavation, rip rap layer on embankment, Gabion etc.)				**704**
	A3- Primary support measures (Bolts & Anchors, Shotcrete & Wire Mesh)				**155**
	A-4(PVC pipes, perforated PVC pipes, precast concrete slots channel elements, dimpled sheets between permanent lines of C&C tunnel length and backfill material, water-proofing membrane etc,)				**140**
	A5-Concrete Works (PVC water stop serrated with Central bulb, etc.)				**506**
	A6- Pavement				**11**
	A7- Construction of Buildings				**1948**
	Total North Portal -Barkot				**3500**

2	**South Portal -Silkyara**	
	B-1 Temporary Dewatering Arrangement	**35**
	B2- Open Excavation and Earthwork (Loose excavation, rock excavation, rip rap layer on embankment, Gabion etc.)	**704**
	B3- Primary support measures (Bolts & Anchors, Shotcrete & Wire Mesh)	**155**
	B-4(PVC pipes, perforated PVC pipes, precast concrete slots channel elements, dimpled sheets between permanent lines of C&C tunnel length and backfill material, water-proofing membrane etc,)	**140**
	B5-Concrete Works (PVC water stop serrated with Central bulb, etc.)	**506**
	B6- Pavement	**11**
	B7- Construction of Buildings	**1948**
	Total South Portal -Silkyara	**3500**
3	**Main Tunnel with escape passage**	
	A1- Temporary Dewatering Arrangement	**971**
	A2- Underground Excavation for tunnel in Support Category dominating the Face Area including Drilling and Grouting	**36272**
	A3- Permanent DewateringArrangement	**1948**
	A4- Primary Support Measures (Bolts & Anchors, Shotcrete & Wire Mesh)	**12455**
	A5-Concrete Works	**22367**
	A6-Instrumentation and Monitoring	**2000**
	A7-Pavement	**2720**
4	**Site Facility and Time Dependent Costs**	
	S&T:A- Site Facility*	**1400**
	S&T:B- Time Dependent Costs**	**28413**
5	**Electro and Mechanical Equipment ofTunnels**	**17500**
6	**Ventilation System**	**1850**
7	**Approach Roads including Construction of Culverts,**	**33**
TOTAL COST OF THE PROJECT		***135729***

CALCULATION OF CIVIL COST

Sr. No.	Description of Items	Units	Quantity	Unit Price in Rs.	Sub-Total Price in Lakh
I	**Geotechnical Invetigation**				
	Drilling of Boreholes	m	1000	50000	**500**
	Laboatory Test	LS			**200**
	Hydrofracture Test	Nos	4	2500000	**100**
A	**Underground Excavation**				
a	in Class I, II & III	Cum	4,89,793	4700	23,020
b	in Class IV & V	Cum	2,10,125	5100	10,716
c	Extra for haulage of material arising from geologically approved overbreak	Cum	1,39,984	600	840
B	**Portals (Silkayara +Barkot)**				
a	**Approach Road Silkyara Side**	m	248	LS	**25**
b	**Approach Road Barkot Side**	m	80	LS	**8**
c	**Draiange Works Silkyara**			LS	**5**
d	**Draiange Works Barkot**			LS	**5**
e	Surface Excavation	Cum	1,44,500	975	**1,409**
f	Shotcrete	Cum	580	11,880	**69**
g	Wiremesh	Sqm	5,800	1,000	**58**
h	Concrete Portal	Cum	608	9,000	55
i	Concrete Bridge +Retaining Wall	Cum	5,947	9,000	535
j	Reinforcement	MT	528	80,000	423
k	Wearing Coat	Cum	45	50,000	23
l	Rock Anchors	m	8,700	1,877	**163**
m	Drainage Holes	m	2,960	2,000	**59**
n	Backfilling	Cum	40,000	700	**280**
o	Steel Rib	MT	15	1,20,000	**17**
p	Tie Rod	MT	1	1,00,000	**1**
q	Concrete Lagging	cum	15	9,590	**1**
C	**Shotcrete with wiremesh-Underground**				
b	Shotcrete	Cum	13,739	11,880	1,632
c	Wiremesh	Cum	1,37,392	800	273
3	**Fully Grouted Rock Anchor**				
a	Grouted Rock anchors, 25 mm dia; 5 m long	m	2,93,100	1,877	5,501
4	**Steel Ribs**				
a	ISMB250 in Tunnel	MT	2,367	1,12,000	2,651
5	**Tie Rod**	MT	218	1,12,000	244
6	**Pipe Roofing**	m	1,07,640	2,000	2,153

8	**Concreting in**				
a	Concrete Lining (M40A40)	Cum	1,46,724	9,000	13,205
b	Precast Lagging	Cum	3,180	9,590	305
c	Overbreak Backfill (M15A80)	Cum	14,450	5,520	798
d	Invert filling (M40A40)	Cum	22,700	9,000	2,043
e	Lean concrete (M15A40)	Cum	5,300	5,520	293
f	Footpath and cable trench (M25A40)	Cum	4,000	9,000	360
9	**Reinforcement**	MT	4,100	1,06,500	4,367
10	**Drilling Holes for**				
a	Contact Grouting	RM	8,300	2,000	166
b	Consolidation/pregrout Grouting	RM	24,800	2,000	496
d	Placing grout for consolidation/pre grout	Nos	600	2,175	13
e	Fill grouting for temporary drainage system/exploratory holes	Nos	300	2,580	8
f	Water pressure testing	Nos	100	668	1
11	**Grouting Materials**				
	Cement	MT	4,965	12,750	633
	Sand	MT	257	2,001	5
	Bentonite	MT	29	26,846	8
	Admixtures	MT	71	57,321	41
	Super Plasticizer	MT	10	67,299	7
	Embeded mild steel pipes & fittings	MT	239	1,33,581	319
11	**Pressure Relief Holes**				
a	Drilling and washing of 75mm dia holes	RM	30,700	2,000	614
b	Supply & installation of PVC pipes filled with filter material	RM	31,600	338	107
c	Drilling for probe holes / pre-drainage holes up to 20m length	RM	5,000	2,000	100
d	Non core Drilling of exploratory holes NX size for Instrumentation/Check holes	RM	1,000	15,000	150
13	**Supply and installation of PVC Pipe for**				0
a	250mm Dia for Water supply	RM	9,100	1,000	91
b	300m Dia for Main Drainage	RM	18,200	1,000	182
14	**RCC M40 for partition wall**	Cum	10,500	9,500	998
15	**Laying of Road Surface**				
a	Constructing Granular Sub-base	Cum	15,000	4,350	653
b	Placing and Constructing wet mix macadam first layer of 150mm thk.	Cum	7,600	3,800	289
c	Placing and Constructing wet mix macadam Second layer of 100mm thk.	Cum	5,100	5,000	255
d	Constructing DBM	Cum	3,100	15,000	465
e	Laying of bituminous primer coat	Sqm	50,100	500	251
16	**Laying and fixing of precast concrete Kerb stone**	Cum	3,700	9,550	353
17	**Fixing of Railing for footpath**	RM	9,100	2,000	182
18	**Instrumentation and monitoring**	lumpsum			**2,000**

18	**RCC structures for a) Control Room b) HVAC Room C) Water Storage and D) Retaining structures**	lump-sum	350	4	**1,400**
20	**Dewatering @ 2.5% cost fo works except lumpsum items**				**1,948**
21	**work charged Establishment @ 5% (except L.S. items)**				**3,896**
Total cost of Civil Works					**87966.0**

EL

Estimation of Quantities for Tunnel

Total Length length of the tunnel = **4550** m INPUT

Shape of tunnel = HSS

Sr. No.	Description	Units	Class I	Class II	Class III	Class IV		Class V	Total
						Steel rib	L. girder		
	%age of Rock Class		**0.0**	**10.0**	**60.0**	**15.0**	**0.0**	**15.0**	
	Length of Tunnel in each class	m	0	455	2730	682.5	0	682.5	4550.0
	Thickness of Lining	m	0.4	0.4	0.4	0.4	0.4	0.4	
	Thickness of Shotcrete	m	0.05	0.075		0.1		0.1	
	Thickness of Shotcrete + Wire mesh	m			0.1		0.1		
	Area of excavated Section including payline	Sqm	151.75	152.84	153.94	153.938	153.94	153.94	
	Perimeter of Excavated Section	m	30.668	30.825	30.982	30.9823	30.982	30.982	
1	**Excavation**								
a	Excavation Quantity	Cum		69542	420251	105062.7		105063	699919
b	Overbreak @ 10.00%	Cum		6967	42025	10526		10506	70024
c	M40 backfilling due to overbreak	Cum		6967	42025	10526		10506	70024
d	Excavation of Laybay niches	Cum	0.0	50.4		75.6	0.0		504.0
e	Excavation of Emergency/fire fighting niche	Cum	0.0	80.0		120.0	0.0		800.0
2	**Support System**								
a	**Lining and Shotcrete**								
i	Quantity of Concrete lining	Cum		7662	45970	11493	0	11493	76617
ii	Area of shotcrete	Cum	0	1052		2115		2115	5281
iii	Area of shotcrete + wiremesh	Cum			8458		0		8458
	Reinforcement								
	Kg per Cum of Concrete Lining	Kg/m^3	50	50	50	50	50	50	
	Weight of reinforcement	MT		383.09	2298.5	574.6287		575	3830.9
b	**Rockbolt/ Anchor**								
	Diameter	mm	25	25	25	25	25	25	
	Length	m	5	5	5	5	5	5	
	Spacing	m	2	2	1.5	1.5	1.5	1.5	
	Nos. in X-section	Nos	6	14	19	19	19	19	
	Nos. along length	Nos		229	1821	456		456	
	Total Length	m		16030	172995	43320		43320	275665.0
c	**Steel Ribs**								
	Type					ISMB250		ISMB250	
	Weight	Kg/m				37.3		37.3	
	Spacing	m				1		0.5	
	Nos. of ribs along Length	Nos				683		1365	
	Total length	m				21160.91		42291	63451.7
	Total Weight	MT				789.3		1577.4	2366.8
d	**Conrete Lagging**								
	Thickness of lagging	m				0.075		0.075	
	Width of lagging	m				0.15		0.15	
	nos. of lagging per section	Nos				207		207	
	Volume of One Lagging	Cum				0.01125		0.0056	
	Total Volume	Cum				1590.536		1589.4	3179.9
e	**Tie Rod**								
	Weight	Kg/m				3.8465		3.84	
	Dia of rod	mm				25		25	

EL

	Longitudinal Spacing	m				1		1	
	Length of Rod	m				1.2		0.7	
	Nos per section	Nos				32		32	
	Total Lengthof Rod	m				26227.2		30576	
	Total Weight of Rod	MT				100.9		117.4	218.3
f	**Lattice Girder**								
	Length of rod in Lattice girder	m					30.982		
	Length of connecting rings	m					0.62		
	spacing of rings	m					0.25		
	spacing of lattice girder	m					1		
	Nos of Lattice girder along length	Nos					0		
	Total volume of main rod (16mm dia)	MT					0.0		0.0
	Total volume of connecting rings (12mm dia	MT					0.0		0.0
g	**Pipe Roofing**								
	Diameter	m				0.114	0.114	0.114	
	Length	m				10	10	10	
	Spacing along								
	Perimter	m				0.2	0.2	0.2	
	Length	m				10	10	10	
	Nos of Forepoles	Nos				0	0	10764	
	Total Length	m				0	0	107640	
	Total Weight of Forepoles	MT				0.0	0.0	8624.7	8624.7
3	**Drlling of Holes**								
a	**For contact grouting throughout tunnel**								
	Dia of the holes	m	0.045	0.045	0.045	0.045	0.045	0.045	
	Length of the holes	m	0.3	0.3	0.3	0.3	0.3	0.3	
	Thickness of lining	m	0.4	0.4	0.4	0.4	0.4	0.4	
	No. of holes per section		12	12	12	12	12	12	
	Longitudinal spacing c/c	m	2	2	2	2	2	2	
	Total drill length	m		825.6	4918.8	1236		1236	8216.4
	Supply & installation of GI pipes filled with filter material	m		1915.2	11466	2872.8		2872.8	19126.8
b	**For consolidation grouting**								
	Dia of holes	m				0.045	0.045		
	Drill length	m				6	6		
	Longitudinal spacing c/c	m				2.0	2.0		
	Holes per section					12.0	12.0		
	Total drill length	m				24642	72		24714.0
c	**For Pressure relief (In selected reaches only)**								
	Dia of holes	m				0.075	0.075		
	Drill length	m				9.0	9.0		
	Thickness of lining	m				0.4	0.4		
	Longitudinal spacing c/c	m				2.0	2.0		
	Holes per section					8.0	8.0		
	Total drill length	m				24642.0	72.0		24714.0
	Supply & installation of PVC pipes filled with filter material	m				25662.0	0.0		25662.0

TUNNEL PORTALS ,BRIDGES AND ROAD DIVERSION WORKS

1	Silkayara Tunnel Portal Approach		Beams (Cum)	Cross Girder (Cum)	Slab (Cum)
	Bridge at Silkayara	Comcrete M40 (Cum)	162	30	160
		Wearing Coat (Cum)	45		
		Abutments M25 (Cum)	300		
		Reinforcement (MT)	69.7		
2	Road Diversion at Barkot End				
		Backfilling (Cum)	40000		
		Retaining Wall M25	5250		
		Reinforcement MT	367.5		

Rock Excavation

S.No	Description	No.	Avg. Length (m)	Sectional Area (m^2)	Quantity (m^3)	Remarks
1	At Start		70	600	42000.000	
2	At End		55.00	500	30250.0	
					72250.0	

Concreting

S.No	Description	No.	Length (m)	Breadth (m)	Height/Depth (m)	Area (m^2)	Quantity (m^3)
1	Column	2	1	1	10.3	1	20.6
2	Beam	1	13.7	1	1	1	13.7
3	Base Slab	1	13.7	1	1	1	13.7
4	10m Stretch	1	10			54.8	548.0
5	Above tunnel & inside portal	1	1			7.6	7.6
6	Lagging	19	19.5	0.15	0.075		4.2
	Total						**607.7**
7	Reinforcement in MT	Assume	150.0Kg/Cum				91.2

STEEL RIBS

Spacing of steel ribs (c/c)	=	0.5	m
Perimeter of ribs	=	19.50	m
Steel weight (ISMB 250)	=	37.3	kg/m
Nos along Length (10m)	=	21.0	Nos
Total length of steel ribs	=	390.0	m
Total quantity of steel ribs	=	**14.547**	**MT**

GROUTED ROCK ANCHORS

Dia. of rock anchor		=		0.025	m
Length of rock anchor		=		6	m
Spacing of rock anchors		=		2	m
No. of rock anchors		=		1450	No.
Total length of rock anchors		=		**8700**	**m**

DRAINAGE HOLES

Dia. Of drainage hole		=		0.075	m
Length of drainage hole		=		8	m
Spacing of drainage hole		=		2	m
No. of drainage holes		=		370	No.
Total Length of Drainage Holes		=		**2960**	**m**

SHOTCRETE WITH WIREMESH

Thickness of Shotcrete	=	0.1	m
Perimeter for Shotcrete	=	5800	Sq.m
Shotcrete Quantity	=	**580**	**Cum**

Concrete Lagging

Thickness of Lagging		=		0.075	m
width of Lagging		=		0.15	m
Nos of Lagging per section		=		130	Nos
Vol. of One Lagging		=		0.005625	Cum
Total Volume		=		**14.625**	**Cum**

Tie Rod

Weight		=		3.84	Kg/m
Dia of rod		=		20	mm
Longitudinal Spacing		=		1	m
Length of Rod		=		0.7	m
Nos per section		=		21	Nos
Total Length of Rod		=		308.7	m
Total Weight of Rod		=		**1.19**	**MT**

Total Cost of E&M (in lakhs)		
Sl. No.	**Description**	**INR.**
1	**General**	
1.1	Design works	1000.0
A.	**Tunnel Operation Safety and Traffic Control Section**	
A.2.0	Integrated Tunnel Control System	1500.0
A.3.0	Local Control Centres	400.0
A.4.0	Traffic Control System	1200.0
A.5.0	Acces Control	200.0
A.6.0	Electrical Fire Signalling System	800.0
A.7.0	Emergency Call System	1200.0
A.8.0	Video Surveillance System (Close Circuit TV)	500.0
A.9.0	Fire Fighting System (Automatic High Pressure Water Mist)	6000.0
B.	**Electro-Mechanical Equipment Section**	
B.14.0	Power Supply System	1800.0
B.15.0	Ventilation System	1850.0
B.15.2	Physical Values Measurement	350.0
B.16.0	Tunnel Lighting	600.0
B.17.0	Communication Systems	450.0
C.	**Management and coordination**	
C.1.0	Contractor works	1250.0
C.2.0	Accessory Documentation	250.0
	Total contract (in lakhs)	**19350.0**

BILL OF QUANTITIES			
Design Doc. Ref.	**Description**	**Units**	**Quantit y**
A	**TUNNEL OPERATION SAFETY AND TRAFFIC CONTROL**		
A.2.0	**Integrated Tunnel Control System**		
	GENERAL NOTES: - To all Cost Estimate Items shall be applicable GENERAL WORK SPECIFICATIONS, which are a constitutional part of Work Execution Contract, the same as COST ESTIMATE WITH SPECIAL PROVISIONS - Assembling material and kits (connection terminals with terminal marks and terminal strip marks, inter-plates, terminal plates, scheme wire with all terminals labeled, jackets, perforated channels, cable bushings with appropriate diameter (in conformity with cable list), DIN rails for mounting electric elements, copper rails with insulating holders and corresponding terminal elements for cables, labels for all elements in conformity with schemes, engraved self-adhesive PVG label plates, etc). Equipment within cabinet is similar to below listed types. - Cabinets of Central Control And Monitoring System may be equipped by similar equipment as presented with Bill of Quant¡ties and Cost Estimate, under condition that such equipment by technical specifications corresponds to the above mentioned one		
1	Cabinet of Main PLC Station Cas¡ng of pedestal cab¡net, protection IP55, prefabricated, plelisized, d¡m. 2000(h)x800(w)x400(d) mm; Elhemet Switch for placing on DIN rail; the Main PLG - Potential Power Source 24 VDC, 150 W CPU Module, Ethernet Module, Bus Module PLC interface relay 24VDC¡ F¡ber Opt¡c Modem, Power Ventilation	pcs.	**4**
2	Cabinet of the Portal and Field PLC Station Casing of pedestal cabinet, protection IP55, prefabricated, plastisized, dim. 2000(h)x800(w)x400(d) mm; the PLC - Potential Power Source 24 VDC, 150 W Intercommunication Module, Input/Output Modules, PLC interface relay 24 VDC; Fiber Optic;/Metal Converter, Power Ventilation	pcs.	**18**
3	Equipment that shall be placed in Control centre South - Serviceable Server, two powerful Personal Computers, with Accessory complete	pcs.	**1**
4	Equipment that shall be placed in Control centre North - Serviceable Server, one powerful Personal Computers, with Accessory complete	pcs.	**1**
5	Program software for supporting the Integrated Tunnel Control System that corresponds to listed hereinafter or similar - Logic developer, SAFE for logic developer, HMI Development server, HMI Run time server, Server redundancy, Modbus, PC OS, System Ware, Software programming; Complete	pcs.	**1**
6	Data cables- completely conforming to Special Provisions	set	**1**
6.1	Cable PP00-Y 10x1.5mm^2, 1kV,	m	**1200**
6.2	Cable IY(St)Y 15x2x0.8mm^2	m	**4800**
6.3	Duplex fiber optic cable, 50/125 micron, placed into previously prepared cable chambers and cable ducts, average length 5200 m	pcs.	**2**
7	On-line (Continuous) uninteiruptible power supply device (UPS) for input and output voltage 220 V AC, power 425VA/ 255 W, autonomy operation 60 minutes	pcs.	**4**
8	On-line (Cont¡nuous) un¡nterruptible power supply device (UPS) for ¡nput and output voltage 220 V AC, power 625 VA/ 375 W autonomy operation 60 minutes	pcs.	**2**

9	Probation and system testing, duration 30 days	set	**1**
10	Implementation design documentation	set	**1**
11	As-built documentation	set	**1**
A.3.0	**Local Control Centres**		
	To all Cost Estimate ltems shall be applicable GENERAL WORK SPECIFICATIONS, which are a constitutional part of Work Execution contract, the same as COST ESTIMATE WTH SPECIAL PROVISIONS		
1	Local centre South - Operator's Workplace Desk	pcs.	**1**
2	Local centre North - Operator's Workplace Desk	pcs.	**1**
3	Implementation design documentation	set	**1**
4	As-built documentat¡on	set	**1**
A.4.0	**Traffic Control System**		
	To all Cost Estimate ltems shall be applicable GENARAL WORK SPECIFICATIONS, wh¡ch are a constitutional part of Work Execution Contract, the same as COST ESTIMATE WTH SPECIAL PROVISIONS, Presented quantity explication do not include spare pieces of an item.		
1	Distribution Cabinet of the Traffic Control System for outdoor location by crossroads - Casing of pedestal cabinet, protection IP65, prefabricated, stainless steel execution, dim- 1600(h)x1600(w)x400(d) mm; equipped by appropriate bus-bars, terminals, breakers, fuses and Circuit brakers, relays, contactors etc.; manual control of relevant traffic control equipment	pcs.	**2**
2	D¡stribution Cabinet of the Traffic Control System for inner installation - Casing of pedestal cabinet, protection IP55, prefabricated, plastisized, dim. 2000(h)x800(w)x400(d) mm; equ¡pped by appripriate bus-bars, terminals, breakers, fuses and circuit brakers, relays, contactors etc.	pcs.	**6**
3	Traffic Lights Three Coloured (TLTC) - power supply 230 V AC, ligh sources LED, plastic casing, vertical installation setting, lense diameter 300 mm, with direction symbols	pcs.	**2**
4	Traffic Lights Three coloured (TLTC) - power supply 230 v AC, l¡ght sources LED, plastic casing, vertical installation setting, lense d¡ameter 300 mm	pcs.	**38**
5	Fixation structure for TLTC gantry mount¡ng outs¡de the tunnel, stainless steel execution, possibility of three level adjustment	pcs.	**6**
6	Fixation structure for TLTC tunnel wall mounting inside the tunnel, stainless steel execut¡on, possibility of three level adjustment	pcs.	**35**

7	Dynamic Road lnformation Panel (DRIP) for installation beside a road, s¡ze 4 m x 2.5 m, textual information in three rows heating system, galavanized Al alloy casing, incl. fixation structure	pcs.	**4**
8	Speed Limit Variable S¡gn (SLVS), power supply 230 V AC, LED light sources, symbols 30, 50, 70 (km.hod^{-1}), galvanized Al alloy casing, transparent symbol cover, size of the front elevation of 56 cm x 56 cm	pcs.	**35**
9	Amber Flashing Warning Light (AFWL) - power supply 230 V AC, light sources LED, plast¡c casing, lense diameter 210 mm	pcs.	**214**
10	Fixation structure for SLVS with two AFWL - tunnel wall mounting ins¡de the tunnel, stainless steel execution, possibility of three level adjustment	pcs.	**35**
11	Speed Limit Variable Sign (SLVS), power supply 230 V AC, LED light sources, symbols 30, 50, 70 (km.hod^{-1}), galvanized Al alloy casing, transparent symbol cover, size of the front elevation of 96 cm x 96 cm	pcs.	**2**
12	Speed L¡m¡t Variable Sign (SLVS), power supply 230 V AC, LED light sources, symbols 30, 50, 70 (km.hod^{-1}) and Entryway prohibited, galvanized Al alloy casing, transparent symbol cover, size of the front elevation of 96 cm x 96 cm	pcs.	**4**
13	Fixation structure for SLVS - for installation outside the tunnel, stainless steel execution, possibility of three level adjustment; incl. hot deep galvanised pole	pcs.	**6**
14	Entrance variable s¡gn (EVS), power supply 230 V AC, LED l¡ght sources, symbols "Green Arrow", "Red Cross", "Crossover Yellow Arrow" and "Traffic Prohibition", galvanized Al alloy casing, transparent symbol cover, size of the front elevation of 96 cm x 96 cm, incl. fixation structure for installalion on a gantry	pcs.	**8**
15	Tunnel Variable Lane Signal (TLS) with red cross symbol and green arrow symbol - power supply 230 V AC, light sources LED, Al alloy casing, size of the front elevation 56 cm x 56 cm	pcs.	**72**
16	TLS tunnel roof underslung fixation structure, stainless steel adjustable execution	pcs.	**72**
17	Information sign with VMS "Entryway Prohibited"	pcs.	**2**
18	Fixation structure for lnformation Sign w¡th VMS - for installation outside the tunnel, stainless steel execut¡on, possibility of three level adjustment, incl. hot deep galvan¡zed carrying structure	pcs.	**2**
19	Traffic Sign llluminated (TSl_1) for marking of SOS boxes, double-sided execution, power supply 230 V AC, LED lighting sources	pcs.	**62**
20	Fixation structure for TSI_1 with two AFWL - tunnel wall mounting inside the tunnel, stainless steel execution	pcs.	**72**
21	Fixation structure for TSI_1 w¡th two AFWL - installation on outdoor SOS boxes in front of the tunnel portals, sta¡nless steel execution	pcs.	**2**

22	Traffic Sign Illum¡nated (TSl_2) for mark¡ng of escape exits, double-sided execution, power supply 230 V AC, LED l¡ght¡ng sources	pcs.	**29**
23	Fixation structure for TSI_2 - tunnel wall mounting inside the tunnel, stainless steel execution	pcs.	**29**
24	Traffic Sign Illuminated (TSl_3) for marking of escape direction between escape exits, one-sided flat execution, power supply 230 V AC, LED lighting sources, symbols of escape direction to the right and to the left with marked distance of 50 m, 100 m and 150 m	pcs.	**108**
25	Curbstone light (CL) - power supply 230 V AC, LED l¡ghting source	pcs.	**360**
26	Traffic Counting System (TCS) based on a videodetection principle	pcs.	**4**
27	Outside entrance road gantry (for TCS, TLTC, VMS and Rigid Height Barrier) of an bridge type, hot deep zinc galvanized steel execution	pcs.	**4**
28	Entrance Overheating Vehicle Control System (EOD) based on a thermovision detection principle	pcs.	**2**
29	Entrance Smoking Vehicle Control System (ESD) based on a videodetection principle	pcs.	**2**
30	Entrance Height Excessive Vehicle Control System (EHD) based on a light barrier detection principle	pcs.	**2**
31	Frame of Entrance Detection Control System (EDCS) for EOD, ESD and EHD, of an bridge type, hot deep zinc galvanized steel execution	pcs.	**2**
32	Mechanical Barrier	pcs.	**2**
33	Rigid Height Barrier	pcs.	**2**
34	Traffic Sign "Overtaking prohibition" in standard reflective execution, incl. fixation structure	pcs.	**2**
35	Traffic s¡gn "switch vehicle Lights On !" in standard reflective execution, incl. fixation structure	pcs.	**2**
36	Traff¡c s¡gn "switch vehicle Lights Off !" in standard reflective execution, incl. fixation structure	pcs.	**2**
37	Traffic Sign "Limits Cancelled !" in standard reflective execution, incl fixation structure	pcs.	**2**
38	Information Plate with tunnel length and name, size 2 m x 1.5 m, double fringe Al alloy sheet, highly adhesive reflecting foil, incl. fixation structure	pcs.	**2**
39	Information traffic sign with transmitted broadcasting station frequency and name, in standard reflective execution, incl. fixation structure	pcs.	**2**
40	Traffic Sign "Lay-bay Ahead" in standard reflective execution, incl. fixation structure on the tunnel wall	pcs.	**7**

41	Probation and system testing, duration 10 days	set	**1**
42	Implementation design documentation	set	**1**
43	As-built documentation	set	**1**
A.6.0	**Electrical Fire Signalling System**		
1	EFS Central	pcs.	**2**
2	EFS line detector evalution unit	pcs.	**4**
3	EFS discrete automatic detectors	pcs.	**132**
4	EFS manual push-button detector, wall mounted	pcs.	**14**
5	EFS manual push-button detector as part of the SOS box	pcs.	**31**
6	Fibre laser sensor cable	m	**5000**
7	Connection cable for EFS detectors	m	**1800**
8	Probation and system testing, duration 10 days	set	**1**
9	Implementation design documentation	set	**1**
10	As-built documentation	set	**1**
A.7.0	**Emergency call system**		
1	SOS box for installation in emergency call niche	pcs.	**31**
2	SOS box for installation for outside the tunnel tube	pcs.	**2**
3	Emergency switch board	pcs.	**2**
4	Recording accessories	set	**1**

5	Emergency call interconnection cable	m	**6000**
6	Probation and system testing, duration 10 days	set	**1**
7	Implementation design documentation	set	**1**
8	As-built documentation	set	**1**
A.8.0	**Video surveillance system**		
1	Revolving surveillance camera, incl. control/signal/feed cables and support stru	pcs.	**2**
2	Traffic surveillance camera, incl. signal/feed cables and support structure	pcs.	**32**
3	Tunnel safety camera, incl. s¡gnal/feed cables and support structure	pcs.	**32**
4	Video transmission system	set	**1**
5	Video central system	set	**1**
6	Video surveillance switchboard	pcs.	**2**
7	Video monitor 21"	pcs.	**7**
8	Video large-screen monitor 40"	pcs.	**2**
9	Recording accessories	set	**1**
10	Probation and system testing, duration 1 0 days	set	**1**
11	Implementation design documentation	set	**1**
12	As-built documentation	set	**1**
A.9.0	**Fire Fighting System (Automatic High Pressure Water Mist)**		
B	**ELECTRO-MECHANICAL EQUIPMENT SECTION**		
B.14.0	**Power Supply System**		
	To all Cost Estimate ltems shall be applicable GENERAL WORK SPECIFICATIONS, which are a constitutional part of Work Execution contract, the same as COST ESTIMATE WITH SPECIAL PROVISIONS		
1	HV/LV transformer (in technology buildings by the tunnel portals), 1 000 kvA	pcs.	**8**
2	HV/LV transformer (in tunnel), 250 kVA	pcs.	**4**

3	HV/LV transformer room fittings (¡n technology buildings by the tunnel portals)	set	**2**
4	HV/LV transformer room fittings (in tunnel)	set	**3**
5	HV control room fittings (in technology buildings by the tunnel portals)	set	**2**
6	HV control room fittings (in tunnel)	set	**3**
7	LV control room f¡ttings (in technology bu¡ldings by the tunnel portals)	set	**2**
8	LV control room fittings (in tunnel)	set	**18**
9	Uninterruptible power source (in technology buildings by the tunnel portals), 60	pcs.	**2**
10	Uninterruptible power source (in tunnel), 60 minutes	pcs.	**18**
11	High voltage cables	m	**5700**
12	LV backbone cable net (from transformers to main panel boards)	set	**1**
13	Cabling appertaining to LV control room in technology buildings by the tunnel p	set	**1**
14	Cabling appertaining to LV control room in tunnel cross adits	set	**1**
15	Documentation : - As-built documentation, - Safety, operat¡on and maintenance directions, - Directions for first aid by electric shock, Complete	set	**1**
16	Implementation design documentation	set	**1**
17	Probation and system testing, duration 30 days	set	**1**
B.15.0	**Ventilation System**		
	GENERAL NOTES: - To all Cost Estimate ltems shall be applicable GENERAL WORK SPECIFICATIONS, which are a constitutional part of Work Execution contract, the same as COST ESTIMATE WITH SPECIAL PROVISIONS Spare part items shall not be included in the list below.		
1	Main fresh air ventilator (650 kW 200 c.m.s $^{-1}$, 2 000 Pa), incl. accessories and structure	pcs.	**4**
2	Main exhaust air ventilator (650 kW 200 c.m.s $^{-1}$, 2 000 Pa), incl. accessories and structure	pcs.	**4**
3	Escape Passage ventilator (30 kW 35 c.m.s^{-1}), incl. accessories and structure	pcs.	**4**
4	Ax¡al tunnel tube ventilator, incl. accessories and structures, 22 kW	pcs.	**8**
5	Fresh air silencer	pcs.	**2**

6	Exhaust air silencer	pcs.	**2**
7	Ventilation exhaust tunnel tube flap sized 2.5 m x 2.5 m	pcs.	**54**
9	carbon-monooxide and opacity detection system	pcs.	**9**
10	Air circulation detection system	pcs.	**4**
11	Meterorogical detection system	pcs.	**2**
12	Probation and system testing, durat¡on 1 0 days	set	**1**
13	Implementation design documentation	set	**1**
14	As-built documentation	set	**1**
B.16.0	**Tunnel Lighting**		
	GENERAL NOTES: - To all Cost Est¡mate Items shall be applicable GENERAL WORK SPECIFICATIONS, wh¡ch are a constitut¡onal part of Work Execution contract, the same as COST ESTIMATE WITH SPECIAL PROVISIONS Spare part ¡tems shall not be included in the list below.		
1	Main tunnel lighting fixture, CBL system, 400 W HPNL light incl. support structure and ¡nd¡vidual cable bushing	pcs.	**90**
2	Main tunnel lighting fixture, CBL system, 250 W HPNL light incl. support structure and ¡nd¡vidual cable bushing	pcs.	**24**
3	Main tunnel lighting fixture, CBL system, 150 W HPNL light incl. support structure and ¡nd¡vidual cable bushing	pcs.	**6**
4	Main tunnel lighting fixture, symmetric system, 150 W HPNL light incl. support structure and ¡nd¡vidual cable bushing	pcs.	**369**
5	Lay-bay lighting fixture, symmetric system, 70 W HPNL light incl. support structure and ¡nd¡vidual cable bushing	pcs.	**17**
6	Public lighting fixture, 150 W, HPNL light source	pcs.	**14**
7	High pressure natrium discharge lamp 400 W/ 230 V AC	pcs.	**90**
8	High pressure natrium discharge lamp 250 W/ 230 V AC	pcs.	**24**
9	High pressure natrium discharge lamp 150 W/ 230 V AC	pcs.	**390**
10	High pressure natrium discharge lamp 70 W/ 230 V AC	pcs.	**17**
11	Escape way light¡ng f¡xture, LED light sources, ¡ncl. support structure	pcs.	**360**
12	Sidewalk lighting fixture, LED light sources	pcs.	**738**

13	Accentuating lighting fixture LED light sources, incl. support structure	pcs.	**216**
14	Luminance meter	pcs.	**2**
15	Probation and system testing, durat¡on 1 0 days	set	**1**
16	Implementation design documentation	set	**1**
17	As-built documentation	set	**1**
B.17.0	**Communication System**		
	GENERAL NOTES: - To all Cost Est¡mate ltems shall be applicable GENERAL WORK SPECIFICATIONS, wh¡ch are a constitut¡onal part of Work Execution contract, the same as COST ESTIMATE WITH SPECIAL PROVISIONS Spare part ¡tems shall not be included in the list below.		
1	Aerial tower antennas, incl. support structures and feeders	pcs.	**2**
2	main communication central units	pcs.	**1**
3	section communication unit	pcs.	**4**
4	Slot broadband radiation cable antenna	m	**5280**
5	Slot broadband radiation cable antenna feeder	m	**180**
6	Wireless communication switchboard	pcs.	**2**
7	evacuation broadcasting end amplifier block	pcs.	**16**
8	Tunnel hom loudspeaker, incl. fixation structure	pcs.	**107**
9	Loudspeaker feeder	m	**6120**
10	Evacuation Broadcasting switchboard	pcs.	**2**
11	Probation and system testing, durat¡on 1 0 days	set	**1**
12	Implementation design documentation	set	**1**
13	As-built documentation	set	**1**
C	**Technical Accessories Coordination**		
1	Implementation design coordination documentation	set	**1**
2	As-built coordination documentation	set	**1**

3	Hardware manual	set	**1**
4	Software manual	set	**1**
5	Maintenance and service manual	set	**1**
6	Tunnel operation and traffic control manual	set	**1**
7	Tunnel safety documentation and manual	set	**1**

WORKING RATE - OPEN EXCAVATION (NO ROCK)

A Machinery Charges				
a) Hydraulic Excavator (1.0 cum)				
- Final output of hydraulic excavator per hour		=	cum	**61**
- Use rate of excavator per hour		=		**2,305.00**
	Rate per cum.	=		37.79
b) Tipper (10 T)				
- Average Lead		=	km	5.00
- Capacity		=	cum.	6.37
Cycle Time				
- Loading Time		=	min	6.27
- Spotting Time		=	min	0.50
- Turning & Dumping Time		=	min	2.00
- Empty haul @ 25kmph		=	min	12.00
- Loaded haul @ 20kmph		=	min	15.00
	Total Cycle Time	**=**	**min**	**35.77**
- No. of trips per 45min working hours		=	Nos.	1.26
- Output of Tipper per working hour		=	cum.	8.02
- Use rate of Tipper per hour		=		**1,045.00**
		=		130.33
c) Crawler/ Dozer (90 HP)				
- Assuming one Crawler/ dozer will be enough for one excavator				
- Output of Excavator = Output of Crawler/ Dozer per hour		=	cum.	61
- Use rate of Crawler/ dozer per hour		=	Rs.	**3,895.00**
	Rate per cum.	=		63.85
TOTAL MACHINERY CHARGES (a + b + c)	Rate per cum.	=	Rs.	231.97
B Others				
- Construction and maintenance of haul road @ 5% of (A)		=	Rs.	11.60
- Electrical Energy charges @ 2% of (A)		=	Rs.	4.64
- Leveling & trimming of waste piles etc. @ 3% of (A)		=	Rs.	6.96
PRIME COST (A + B)		=	Rs.	255.16
c) Overhead + Contractors profit @ **20%**		=	Rs.	51.03
	Total Cost / cum.	=	Rs.	306.20
Therefore,				
	Cost per cum.	**=**	**Rs.**	**306.00**

Silkayara Barkot Tunnel

WORKING RATE - OPEN EXCAVATION (IN ROCK BY 100 % BLASTING)

A	Drilling & blasting charges per cum.(100% Blasting Rate)		=	Rs.	500.00
B	**Machinery Charges**				
	a) Front End Loader (1.7 cum)				
	- Final output of Loader per hour		=	cum	60.00
	- Use rate of front end loader per hour		=		2,115.00
		Rate per cum.	=		35.25
	b) Dumper (15 T)				
	- Average Lead		=	km	5.00
	- Capacity		=	cum.	9.56
	Cycle Time				
	- Loading Time		=	min	9.56
	- Spotting Time		=	min	0.50
	- Turning & Dumping Time		=	min	2.00
	- Empty haul @ 25kmph		=	min	12.00
	- Loaded haul @ 20kmph		=	min	15.00
			=	**min**	**39.06**
	- No. of trips per 45min working hours		=	Nos.	1.15
	- Output of Dumper per working hour		=	cum.	11.01
	- Use rate of dumper per hour		=		1,985.00
		Rate per cum.	=		180.22
	c) Crawler/ Dozer (90 HP)				
	- Assuming one Crawler/ dozer will be enough for one excavator				
	- Output of Excavator = Output of Crawler/ Dozer per hour		=	cum.	60.00
	- Use rate of Crawler/ dozer per hour		=	Rs.	3,895.00
		Rate per cum.	=		64.92
	TOTAL MACHINERY CHARGES (a + b + c)	Rate per cum.	=	Rs.	280.39
C	**Others**				
	- Construction and maintenance of haul road @ 5% of (B)		=	Rs.	14.02
	- Electrical Energy charges @ 2% of (B)		=	Rs.	5.61
	- Leveling & trimming of waste piles etc. @ 3% of (B)		=	Rs.	8.41
	PRIME COST (A + B + C)		=	Rs.	808.43
	c) Overhead + Contractors profit @ 20%		=	Rs.	161.69
		Total Cost / cum.	=	Rs.	970.12
	Therefore,				
		Cost per cum.	**=**	**Rs.**	**975.00**

WORKING RATE - ROCK EXCAVATION OF TUNNEL - GOOD & FAIR ROCK

A Hard Rock Tunnelling

I Quantity of excavation per m. length

Finished Size of Tunnel (14 *m (W) x 9.9m(H) - Modified Horse Shoe Shaped*)

Average thickness of lining	=	**0.40**	m
Thickness for pay line, Shotcrete	=	**0.175**	m
Cross Sectional Area of Tunnel	=	**132.73**	m^2
Quantity of excavation per m length of tunnel	=	**132.73**	m^3
Average Progress per face per cycle	=	**2.00**	m
Total qty. of excavation per cycle	=	**265.46**	m^3
Maximum working hours assumed in 24hrs in 3 shift allowing 2hrs for shift change	=	20.00	hrs
Progress per day	=	**0.50**	cycle/day
Quantity of Excavation Per Day per face	=	**132.73**	m^3

II Cycle of Operation

Profile Marking & Setting of Operation	=	**2.00**	Hours
Drilling Time	=	**4.28**	Hours
Charging & Blasting	=	**4.00**	Hours
Defuming & clearing	=	**4.00**	Hours
Scaling and Bottom Clearing	=	**4.00**	Hours
Mucking and Cleaning	=	**6.91**	Hours
Rock bolting	=	**6.00**	Hours
Shotcreting	=	**6.00**	Hours
Cycle time	=	**37.18**	Hours
		Say	**37.20 Hrs.**

III Direct labour charges

	Category	Shift/day	Nos.	Rate	Amt. (Rs.)
(i)	Foreman	3	2	29,104	1,74,622
(ii)	Blastman	3	2	22,752	1,36,512
(iii)	Electrician	3	2	22,752	1,36,512
(iv)	Beldar	3	6	5,063	91,125
(v)	Helper to Electrician	3	2	5,063	30,375
(iv)	Hole Cleaner	3	2	5,063	30,375
				Total	5,99,521

Total Direct Labour Charges per month

Indirect Cost @	**80%**	for skilled labour	Rs.	3,58,116
Indirect Cost @	**55%**	for un-skilled labour	Rs.	83,531

-	Total Labour Cost per Month	Rs.	10,41,168
-	Total Labour Cost per day	Rs.	41,647
	Rate of Labour Per cum of excavation	Rs.	313.76

IV Machinery Charges

	Equipment	Nos.	Working Hrs	Total Working Hrs.	Use Rate	Amt.
			Hrs/cycle	Hrs/day	Rs./Hr.	In Rs.
(i)	2 boom Hydraulic Drill	1	12.0	6.00	7,560	45,360
(ii)	Excavator - 1Cum	3	22.0	33.00	2,305	76,065
(iii)	Tipper - 10T	8	22.0	88.00	1,045	91,960
(iv)	Crawler / Dozer - 90 HP	0.5	22.0	5.50	3,895	21,423
			Total Machinery Charges		=	2,34,808
			Rate of Machinery Per cum.		=	1,769.03

V Materials Charges

1 Drilling and Blasting

(a) It is proposed that to attain 2. meter progress per cycle per face

Depth of holes to be drilled.	=	**2.25**	m
Cross sectional area of tunnel (heading)	=	132.73	m^2
Assume area of rock cross-section per hole	=	**0.72**	sqm
No. of holes required per face	=	184	nos.
Additional hole for line drilling/ burn hole	=	**6**	nos.
Total no. of holes	=	190	nos.
Total depth of drilling	=	427.50	m
Output of 2-Boom Drill Jumbo	=	**100.00**	m
Drilling time required	=	4.28	hrs
Rate of drill steel	=	124.00	m
Cost of drill steel	=	53,010	Rs
Quantity of rock excavated / cycle	=	265.46	cum.
Rate of drill steel per cum	=	199.69	Rs. per cum.

Mucking

Total Muck (bank) per cycle	=	265.46	m^3
Swell factor		0.63	
Total Loose muck per pull	=	421.37	m^3
Output of Hydraulic Excavator (1 Cum) (Loose)	=	**61**	m^3
Total Mucking hrs required	=	6.91	hrs
Loose density of muck	=	1.569	T/m^3
Tipper capacity	=	10.00	T
Tipper output (loose)	=	6.37	m^3
Average lead distance	=	**5.00**	km
Loading Time	=	6.27	min
Spotting Time	=	0.50	min
Turning and dumping time	=	2.00	min
Empty haul @ 25 Km/hr	=	12.00	min
Loading haul @ 20 Km/hr	=	15.00	min
Total cycle time	=	**35.77**	min
No. of Trips per working hour of 45 minutes	=	1.26	nos.
Output of Tipper per 45 minutes	=	8.02	cum
Number of Tipper required	=	8	nos.

2	Explosives						
	(i)	GELATIN					
		Gelatin required/cum		=	1.00	Kg	
		Cost of gelatin		=	150.00	Rs. / Kg	
		Rate/cum		=	150.00	Rs. / Cum.	
	(ii)	DETONATORS					
		No. of Detonators required		=	190	Nos.	
		Rate of Detonator + Fuse		=	62.00	per piece	
		Total Cost of Detonators		=	11,780.00	Rs	
		Quantity of rock excavated/cycle		=	265.46	cum.	
		Rate/cum		=	44.38	Rs. / Cum.	
	(iii)	OTHERS					
		Other consumable @ 50% of (I)		=	75.00	Rs. / Cum.	
		Rate of Explosives + Detonator		=	269.38	per cum.	
3	Timber for Support & Packing			=	10.00	LS	
4	Miscellaneous Supplies LS			=	10.00	LS	
	Total Material Charges per cum (1+2+3+4)			=	489.06	per cum.	
VI	Ventilation						
		Use rate of Blower per working hour		=	400.00		
		No of working hours per day @	80%	=	19.20		
		Total ventilation Charges per day for 2 blowers		=	15,360.00		
		Rate for Ventilation Per Cum..		=	115.72	per cum.	
VII	Shop Charges						
	(i)	Machine Shop	L.S.	=	Rs.		15.00
	(ii)	Structural shop	L.S.	=	Rs.		15.00
	(iii)	Steel Metal shop	L.S.	=	Rs.		10.00
	(iv)	Air & Water pipe shop	L.S.	=	Rs.		10.00
	(v)	Carpentry	L.S.	=	Rs.		10.00
			Total	=	Rs.		60.00
VIII	Electrical Material Charges Per Cum..		L.S.	=	Rs.		20.00
IX	Compressed Air		L.S.	=	Rs.		20.00
X	Water Charges Per Cum..		L.S.	=	Rs.		15.00
	Abstract of Charges Per Cum..						
	Direct Labour Charges			=	Rs.		313.76
	Machinery Charges			=	Rs.		1,769.03
	Material Charges			=	Rs.		489.06
	Ventilation Charges			=	Rs.		115.72
	Shop Charges			=	Rs.		60.00
	Electrical Material Charges			=	Rs.		20.00
	Compressed Air			=	Rs.		20.00
	Water Charges			=	Rs.		15.00

Rock Excavation in tunnel (per cum)		
Total Charges Per Cum	Rs.	2,802.58
Add for electrical energy charges at 2% of total charges	Rs.	56.05
Add for cons. & maintenance of haul road 5% of total charges	Rs.	140.13
Prime Cost	Rs. per cum.	2,998.76
Overhead charges and contractor's profit @ 20%		599.75
Grand Total	Rs.	3,598.51
HENCE RATE PER CUM. (in Hard Rock)	**Rs. per cum.**	**3,600.00**

WORKING RATE - ROCK EXCAVATION IN TUNNEL- POOR ROCK

A Hard Rock Tunnelling

I Quantity of excavation per m. length

Finished Size of Tunnel (*14m (W) x 9.9m(H) - Modified Horshoe Shaped*)

Average thickness of lining	=	0.40	m
Thickness for pay line, Shotcrete, Lagging	=	0.200	m
Cross Sectional Area of Tunnel	=	143.14	m^2
Quantity of excavation per m length of tunnel	=	143.14	m^3
Progress per face per cycle	=	1.00	m
Total qty. of excavation per cycle	=	143.14	m^3
Maximum working hours assumed in 24hrs in 3 shift allowing 2hrs for shift change	=	22.00	hrs
Progress per day	=	0.4	cycle/day
Quantity of Excavation Per Day per face	=	64.27	**m^3**

II Cycle of Operation

Profile Marking & Setting of Operation	=	2.00	Hours
Forepoling time	=	3.00	Hours
Drilling Time	=	6.00	Hours
Charging & Blasting	=	6.00	Hours
Defuming & clearing	=	4.00	Hours
Scaling and Bottom Clearing	=	4.00	Hours
Mucking and Cleaning	=	12.00	Hours
Erection of steel Ribs	=	12.00	Hours
Cycle time	=	49.00	**Hours**
		Say	49.00 Hrs.

III Direct labour charges

	Category	Shift/day	Nos.	Rate	Amt. (Rs.)
(i)	Foreman	3	2	29,104	1,74,622
(ii)	Blastman	3	2	22,752	1,36,512
(iii)	Electrician	3	2	22,752	1,36,512
(iv)	Beldar	3	6	5,063	91,125
(v)	Helper to Electrician	3	2	5,063	30,375
(iv)	Hole Cleaner	3	2	5,063	30,375
				Total	**5,99,521**

Total Direct Labour Charges per month

Indirect Cost @	80%	for skilled labour	Rs.	3,58,116
Indirect Cost @	55%	for un-skilled labour	Rs.	83,531

-	Total Labour Cost per Month	Rs.	10,41,168
-	Total Labour Cost per day	Rs.	41,647
	Rate of Labour Per cum of excavation	**Rs.**	**648.03**

IV Machinery Charges

	Equipment	Nos.	Working Hrs Hrs/cycle	Total Working Hrs. Hrs/day	Use Rate Rs./Hr.	Amt. In Rs.
(i)	2 boom Hydraulic Drill	1	12.0	5.39	7,560	40,731
(ii)	Excavator -1Cum	3	12.0	16.16	2,305	37,256
(iii)	Tipper - 10T	9	12.0	48.49	1,045	50,672
(iv)	Crawler / Dozer - 90 HP	0.5	12.0	2.69	3,895	10,493
			Total Machinery Charges		=	1,39,152
			Rate of Machinery Per cum.		**=**	**2,165.24**

V Materials Charges

1 Drilling and Blasting

(a) It is proposed that to attain 1. meter progress per cycle per face

Depth of holes to be drilled.	=	**1.25**	m
Cross sectional area of tunnel (heading)	=	143.14	m^2
Assume area of rock cross-section per hole	=	**0.72**	sqm
No. of holes required per face	=	199	nos.
Additional hole for line drilling/ burn hole	=	6	nos.
Total no. of holes	=	205	nos.
Total depth of drilling	=	256.25	m
Output of 2-Boom Drill Jumbo	=	**100.00**	m
Drilling time required	=	2.56	hrs
Rate of drill steel	=	124.00	m
Cost of drill steel	=	31,775	Rs
Quantity of rock excavated / cycle	=	143.14	cum.
Rate of drill steel per cum	**=**	**221.99**	**Rs. per cum.**

Mucking

Total Muck (bank) per cycle	=	143.14	m^3
Swell factor		0.63	
Total Loose muck per pull	=	227.20	m^3
Output of Hydraulic Excavator (1 Cum) (Loose)	=	**61**	m^3
Total Mucking hrs required	=	3.72	hrs
Loose density of muck	=	1.569	T/m^3
Tipper capacity	=	10.00	T
Tipper output (loose)	=	6.37	m^3
Average lead distance	=	**6.00**	km
Loading Time	=	6.27	min
Spotting Time	=	0.50	min
Turning and dumping time	=	2.00	min
Empty haul @ 25 Km/hr	=	14.40	min
Loading haul @ 20 Km/hr	=	18.00	min
Total cycle time	=	**41.17**	min
No. of Trips per working hour of 45 minutes	=	1.09	nos.
Output of Tipper per 45 minutes	=	6.97	cum
Number of Tipper required	=	9	nos.

2	Explosives					
	(i)	GELATIN				
		Gelatin required/cum		=	**1.00**	Kg
		Cost of gelatin		=	**106.00**	Rs. / Kg
		Rate/cum		=	106.00	Rs. / Cum.
	(ii)	DETONATORS				
		No. of Detonators required		=	205	Nos.
		Rate of Detonator + Fuse		=	**62.00**	per piece
		Total Cost of Detonators		=	12,710.00	Rs
		Quantity of rock excavated/cycle		=	143.14	cum.
		Rate/cum		=	88.79	Rs. / Cum.
	(iii)	OTHERS				
		Other consumable @ 50% of (I)		=	53.00	Rs. / Cum.
		Rate of Explosives + Detonator		**=**	**247.79**	**per cum.**
3	Timber for Support & Packing			=	10.00	LS
4	Miscellaneous Supplies LS			=	10.00	LS
	Total Material Charges per cum (1+2+3+4)			**=**	**489.78**	**per cum.**
VI	**Ventilation**					
		Use rate of Blower per working hour		=	**400.00**	
		No of working hours per day @	80%	=	19.20	
		Total ventilation Charges per day for 2 blowers		=	15,360.00	
		Rate for Ventilation Per Cum..		=	**239.01**	**per cum.**

VII	**Shop Charges**					
	(i)	Machine Shop	L.S.	=	Rs.	15.00
	(ii)	Structural shop	L.S.	=	Rs.	15.00
	(iii)	Steel Metal shop	L.S.	=	Rs.	10.00
	(iv)	Air & Water pipe shop	L.S.	=	Rs.	10.00
	(v)	Carpentry	L.S.	=	Rs.	10.00
			Total	**=**	**Rs.**	**60.00**
VIII	**Electrical Material Charges Per Cum..**		**L.S.**	**=**	**Rs.**	**20.00**
IX	**Compressed Air**		**L.S.**	**=**	**Rs.**	**20.00**
X	**Water Charges Per Cum..**		**L.S.**	**=**	**Rs.**	**15.00**

Abstract of Charges Per Cum..

Direct Labour Charges	=	Rs.	648.03
Machinery Charges	=	Rs.	2,165.24
Material Charges	=	Rs.	489.78
Ventilation Charges	=	Rs.	239.01
Shop Charges	=	Rs.	60.00
Electrical Material Charges	=	Rs.	20.00
Compressed Air	=	Rs.	20.00
Water Charges	=	Rs.	15.00

Rock Excavation in tunnel (per cum)		
Total Charges Per Cum	Rs.	3,657.06
Add for electrical energy charges at 2% of total charges	Rs.	73.14
Add for cons. & maintenance of haul road 5% of total charges	Rs.	182.85
Prime Cost	**Rs. per cum.**	**3,913.06**
Overhead charges and contractor's profit @ 20%		782.61
Grand Total	**Rs.**	**4,695.67**
HENCE RATE PER CUM. (in Hard Rock)	**Rs.** per cum.	**4,700.00**

WORKING RATE - ROCK EXCAVATION IN TUNNEL- VERY POOR ROCK

A Hard Rock Tunnelling

I Quantity of excavation per m. length

Finished Size of Tunnel (*14 m (W) x 9.9m(H) - ModifiedHorse Shoe Shaped*)

Average thickness of lining	=	0.40	m
Thickness for pay line, Shotcrete, Lagging	=	0.200	m
Cross Sectional Area of Tunnel	=	153.94	m^2
Quantity of excavation per m length of tunnel	=	153.94	m^3
Progress per face per cycle	=	1.50	m
Total qty. of excavation per cycle	=	230.91	m^3
Maximum working hours assumed in 24hrs in 3 shift allowing 2hrs for shift change	=	22.00	hrs
Progress per day	=	0.4	cycle/day
Quantity of Excavation Per Day per face	=	89.75	**m^3**

II Cycle of Operation

Profile Marking & Setting of Operation	=	0.50	hrs
Forepoling time	=	2.00	hrs
Drilling Time	=	6.00	hrs
Charging & Blasting	=	6.00	hrs
Defuming & clearing	=	6.00	hrs
Scaling and Bottom Clearing	=	6.00	hrs
Mucking and Cleaning	=	6.01	hrs
Erection of Steel Rib	=	24.00	hrs
Cycle time	=	56.51	**Hours**
		Say	56.60 Hrs.

III Direct labour charges

	Category	Shift/day	Nos.	Rate	Amt. (Rs.)
(i)	Foreman	3	4	29,104	3,49,243
(ii)	Blastman	3	4	22,752	2,73,024
(iii)	Electrician	3	4	22,752	2,73,024
(iv)	Beldar	3	6	5,063	91,125
(v)	Helper to Electrician	3	4	5,063	60,750
(iv)	Hole Cleaner	3	4	5,063	60,750
				Total	**11,07,916**

Total Direct Labour Charges per month

Indirect Cost @	80%	for skilled labour	Rs.	7,16,233
Indirect Cost @	55%	for un-skilled labour	Rs.	1,16,944

-	Total Labour Cost per Month	Rs.	19,41,093
-	Total Labour Cost per day	Rs.	77,644
	Rate of Labour Per cum of excavation	**Rs.**	**865.09**

IV Machinery Charges

	Equipment	Nos.	Working Hrs	Total Working Hrs.	Use Rate	Amt.
			Hrs/cycle	Hrs/day	Rs./Hr.	In Rs.
(i)	2 boom Hydraulic Drill	1	12.0	10.00	**7,560**	75,600
(ii)	Excavator -1Cum	3	12.0	13.99	**2,305**	32,254
(iii)	Tipper - 10T	9	12.0	41.98	**1,045**	43,868
(iv)	Crawler / Dozer - 90 HP	2	12.0	9.33	**3,895**	36,335
			Total Machinery Charges		=	1,88,057
			Rate of Machinery Per cum.		**=**	**2,095.29**

V Materials Charges

1 Drilling and Blasting

(a) It is proposed that to attain 1.5 meter progress per cycle per face

Depth of holes to be drilled.	=	**1.75**	m
Cross sectional area of tunnel (heading)	=	153.94	m^2
Assume area of rock cross-section per hole	=	**0.72**	sqm
No. of holes required per face	=	214	nos.
Additional hole for line drilling/ burn hole	=	**8**	nos.
Total no. of holes	=	222	nos.
Total depth of drilling	=	388.50	m
Output of 2-Boom Drill Jumbo	=	**50.00**	m
Drilling time required	=	7.77	hrs
Rate of drill steel	=	124.00	m
Cost of drill steel	=	48,174	Rs
Quantity of rock excavated / cycle	=	230.91	cum.
Rate of drill steel per cum	**=**	**208.63**	**Rs. per cum.**

Mucking

Total Muck (bank) per cycle	=	230.91	m^3
Swell factor		0.63	
Total Loose muck per pull	=	366.52	m^3
Output of Hydraulic Excavator (1 Cum) (Loose)	=	**61**	m^3
Total Mucking hrs required	=	6.01	hrs
Loose density of muck	=	1.569	T/m^3
Tipper capacity	=	10.00	T
Tipper output (loose)	=	6.37	m^3
Average lead distance	=	**6.00**	km
Loading Time	=	6.27	min
Spotting Time	=	0.50	min
Turning and dumping time	=	2.00	min
Empty haul @ 25 Km/hr	=	14.40	min
Loading haul @ 20 Km/hr	=	18.00	min
Total cycle time	=	**41.17**	min
No. of Trips per working hour of 45 minutes	=	1.09	nos.
Output of Tipper per 45 minutes	=	6.97	cum
Number of Tipper required	=	9	nos.

2	Explosives					
	(i) GELATIN					
	Gelatin required/cum		=	**1.00**	Kg	
	Cost of gelatin		=	**106.00**	Rs. / Kg	
	Rate/cum		=	106.00	Rs. / Cum.	
	(ii) DETONATORS					
	No. of Detonators required		=	222	Nos.	
	Rate of Detonator + Fuse		=	**62.00**	per piece	
	Total Cost of Detonators		=	13,764.00	Rs	
	Quantity of rock excavated/cycle		=	230.91	cum.	
	Rate/cum		=	59.61	Rs. / Cum.	
	(iii) OTHERS					
	Other consumable @ 50% of (I)		=	53.00	Rs. / Cum.	
	Rate of Explosives + Detonator		**=**	**218.61**	**per cum.**	
3	Timber for Support & Packing		=	10.00	LS	
4	Miscellaneous Supplies LS		=	10.00	LS	
	Total Material Charges per cum (1+2+3+4)		**=**	**447.24**	**per cum.**	
VI	**Ventilation**					
	Use rate of Blower per working hour		=	**400.00**		
	No of working hours per day @	80%	=	19.20		
	Total ventilation Charges per day for 2 blowers		=	15,360.00		
	Rate for Ventilation Per Cum..		=	**171.14**	**per cum.**	
VII	**Shop Charges**					
	(i) Machine Shop	L.S.	=	Rs.		50.00
	(ii) Structural shop	L.S.	=	Rs.		50.00
	(iii) Steel Metal shop	L.S.	=	Rs.		50.00
	(iv) Air & Water pipe shop	L.S.	=	Rs.		50.00
	(v) Carpentry	L.S.	=	Rs.		50.00
		Total	**=**	**Rs.**		**250.00**
VIII	**Electrical Material Charges Per Cum..**	**L.S.**	**=**	**Rs.**		**50.00**
IX	**Compressed Air**	**L.S.**	**=**	**Rs.**		**50.00**
X	**Water Charges Per Cum..**	**L.S.**	**=**	**Rs.**		**50.00**

Abstract of Charges Per Cum..

Direct Labour Charges	=	Rs.	865.09
Machinery Charges	=	Rs.	2,095.29
Material Charges	=	Rs.	447.24
Ventilation Charges	=	Rs.	171.14
Shop Charges	=	Rs.	250.00
Electrical Material Charges	=	Rs.	50.00
Compressed Air	=	Rs.	50.00
Water Charges	=	Rs.	50.00

Rock Excavation in tunnel (per cum)		
Total Charges Per Cum	Rs.	3,978.76
Add for electrical energy charges at 2% of total charges	Rs.	79.58
Add for cons. & maintenance of haul road 5% of total charges	Rs.	198.94
Prime Cost	**Rs. per cum.**	**4,257.28**
Overhead charges and contractor's profit @ 20%		851.46
Grand Total	**Rs.**	**5,108.73**
HENCE RATE PER CUM.	**Rs.** per cum.	**5,110.00**

Working Rate - M15 Concreting in Tunnel

A Material

Sr. No.	Item	Quantity	Unit	Rate			Amount
1	Cement (incl. waste	6.00	bags	450	=	Rs.	2,700.00
2	Sand	0.45	cum	700	=	Rs.	315.00
3	Coarse aggregate	0.90	cum	700	=	Rs.	630.00
4	Water	LS			=	Rs.	5.00
5	Admixture	LS			=	Rs.	50.00
	Total material cost per cum.				**=**	**Rs.**	**3,700.00**

B Batching, mixing and laying of concrete

I) Use 45 cum batching and mixing plant

-	Use rate of mixing plant per hour	=	Rs.	4,350.00
-	Consider, actual output of mixer per hour (at 62% efficiency	=	cum	27.90
-	Rate of mixing plant per cum	=	Rs.	**155.91**

ii) Transportation by transit mixer from batching and mixing plant to work site

-	Average Lead	=	2.50	km
-	Transit mixer (Capacity - 4.0 cum)	=	4.00	cum.
-	Actual carrying capacity (considering 75% efficenecy)	=	3.00	cum.

CYCLE TIME

-	Loading time	=	6.5	min
-	Spotting time & waiting time	=	2.5	min
-	Turning and dumping time	=	7.0	min
-	Loading haul @ 15 Km/hr	=	10.0	min
-	Empty haul @ 20 Km/hr	=	7.5	min
	Total cycle time	**=**	**33.45**	**min**

-	Consider, Actual working time in 1 hour duration	=	min	45.00
-	No. of trips in 45 min working hour	=		1.35
-	Output of transit mixer	=	cum	5.38
-	Use rate of transit mixer (4 cum. Capacity)	=	Rs.	1,785.00
	Transportation rate per cum	**=**	**Rs.**	**331.73**

iii) Placement charges

(a) Placement by concrete pump (80% efficiency)

-	Theoretical Output of concrete pump per hour	=	cum	25
-	Actual output	=	cum	20.00
-	Use rate of pump	=	Rs.	2,110.00
	Use rate of pump per cum	**=**	**Rs.**	**105.50**

(b) Labour for placement

	Categ	Nos.	Rate	Amt.
1	Mason	1	22,752	22,752
2	Beldar	4	5,063	20,250
			Sub-Total	**43,002**

Indirect Cost @	80%	for skilled labour	=	Rs.	18,202
Indirect Cost @	55%	for un-skilled labour	=	Rs.	11,138

Therefore,

-	Total Crew Charges per Month		Rs.	72,341
	Total Crew Charges per cum.	**=**	**Rs.**	**24.11**

iv) Vibrating charges **= Rs. 15.00**

v)	Cleaning, curing and finishing					
	-	Sand blasting	(LS)	=	Rs.	5.00
	-	Cement for slurry mort	(LS)	=	Rs.	5.00
	-	Cleaning and wastage	(LS)	=	Rs.	5.00
	-	Curing and finishing	(LS)	=	Rs.	10.00
			Total cost	**=**	**Rs.**	**25.00**
vi)	Catwalks and other aids for concreting		(LS)	=	Rs.	**15.00**
vii)	Other charges					
	-	Electric charges	(LS)	=	Rs.	5.00
	-	Compressed air	(LS)	=	Rs.	2.50
	-	Work shop	(LS)	=	Rs.	5.00
	-	Haul road	(LS)	=	Rs.	2.50
			Total cost	**=**	**Rs.**	**15.00**
viii)	Misc charges such as hose pipe gum bolts and small tools		(LS)	**=**	**Rs.**	**10.00**
	Total cost for batching, mixing etc.			**=**	**Rs.**	**697.26**
C	**Shuttering charges**		(LS)	=	Rs.	**200.00**

Abstract of charges

A	Material		=	Rs.	3,700.00
B	Batching and mixing		=	Rs.	697.26
C	Shuttering		=	Rs.	200.00
		Total cost	**=**	**Rs.**	**4,597.26**

Add 20% for Overhead & Profit on prime cost	=	Rs.	919.45
Cost for concrete per cum	**=**	**Rs.**	**5,520**

Working Rate - M40 Concreting in Tunnel

A Material

Sr. No.	Item	Quantity	Unit	Rate			Amount
1	Cement (incl. waste	10.00	bags	500	=	Rs.	5,000.00
2	Sand	0.42	cum	700	=	Rs.	294.00
3	Coarse aggregate	0.84	cum	700	=	Rs.	588.00
4	Water	LS			=	Rs.	5.00
5	Admixture	LS			=	Rs.	75.00
	Total material cost per cum.				**=**	**Rs.**	**5,962.00**

B Batching, mixing and laying of concrete

I) Use 45 cum batching and mixing plant

-	Use rate of mixing plant per hour	=	Rs.	4,350.00
-	Consider, actual output of mixer per hour (at 62% efficienc	=	cum	27.90
-	Rate of mixing plant per cum	=	Rs.	**155.91**

ii) Transportation by transit mixer from batching and mixing plant to work site

-	Average Lead	=	5.00	km
-	Transit mixer (Capacity - 4.0 cum)	=	4.00	cum.
-	Actual carrying capacity (considering 75% efficenecy)	=	3.00	cum.

CYCLE TIME

-	Loading time	=	6.5	min
-	Spotting time & waiting time	=	2.5	min
-	Turning and dumping time	=	7.0	min
-	Loading haul @ 15 Km/hr	=	20.0	min
-	Empty haul @ 20 Km/hr	=	15.0	min
	Total cycle time	**=**	**50.95**	**min**

-	Consider, Actual working time in 1 hour duration	=	min	45.00
-	No. of trips in 45 min working hour	=		0.88
-	Output of transit mixer	=	cum	3.53
-	Use rate of transit mixer (4 cum. Capacity)	=	Rs.	1,785.00
	Transportation rate per cum	**=**	**Rs.**	**505.27**

iii) Placement charges

(a) Placement by concrete pump (80% efficiency)

-	Theoretical Output of concrete pump per hour	=	cum	25
-	Actual output	=	cum	20.00
-	Use rate of pump	=	Rs.	2,110.00
	Use rate of pump per cum	**=**	**Rs.**	**105.50**

(b) Labour for placement

Cat	Nos.	Rate	Amt.
1 Mason	4	22,752	91,008
2 Beldar	8	15,000	1,20,000
		Sub-Total	**2,11,008**

Indirect Cost @ 80%	for skilled labour	=	Rs.	72,806
Indirect Cost @ 55%	for un-skilled labour	=	Rs.	66,000

Therefore,

-	Total Crew Charges per Month		Rs.	3,49,814
	Total Crew Charges per cum.	**=**	**Rs.**	**116.60**

iv) Vibrating charges = **Rs.** 15.00

	v)	Cleaning, curing and finishing				
		- Sand blasting	(LS)	=	Rs.	50.00
		- Cement for slurry mort	(LS)	=	Rs.	50.00
		- Cleaning and wastage	(LS)	=	Rs.	50.00
		- Curing and finishing	(LS)	=	Rs.	50.00
			Total cost	**=**	**Rs.**	**200.00**
	vi)	Catwalks and other aids for concreting	(LS)	=	Rs.	**15.00**
	vii)	Other charges				
		- Electric charges	(LS)	=	Rs.	50.00
		- Compressed air	(LS)	=	Rs.	50.00
		- Work shop	(LS)	=	Rs.	50.00
		- Haul road	(LS)	=	Rs.	50.00
			Total cost	**=**	**Rs.**	**200.00**
	viii)	Misc charges such as hose pipe gum bolts and small tools	(LS)	**=**	**Rs.**	**10.00**
			Total cost for batching, mixing etc.	**=**	**Rs.**	**1,323.29**
C	**Shuttering charges**		(LS)	=	Rs.	**200.00**

Abstract of charges

A	Material		=	Rs.	5,962.00
B	Batching and mixing		=	Rs.	1,323.29
C	Shuttering		=	Rs.	200.00
		Total cost	**=**	**Rs.**	**7,485.29**
	Add 20% for Overhead & Profit on prime cost		=	Rs.	1,497.06
	Cost for concrete per cum		**=**	**Rs.**	**8,990**

WORKING RATE - PRE CAST CONCRETE LAGGINGS

A Material

Sr. No.	Item	Quantity	Unit	Rate			Amount
1	Cement (incl. waste)	8.00	bags	500	=	Rs.	4,000.00
2	Sand	0.43	cum	700	=	Rs.	301.00
3	Coarse aggregate	0.86	cum	700	=	Rs.	602.00
4	Reinforcement steel	60.00	Kg	60	=	Rs.	3.60
4	Water	LS			=	Rs.	10.00
5	Admixture	LS			=	Rs.	125.00
	Total material cost per cum.				**=**	**Rs.**	**5,041.60**

B Batching, mixing and laying of concrete

Use 30 cum batching and mixing plant

-	Use rate of mixing plant per hour	=	Rs.	3,575.00
-	Consider, actual output of mixer per hour (at 62% efficiency	=	cum	18.60
-	**Rate of mixing plant per cum**	**=**	**Rs.**	**192.20**

C Form work charges @ 10% of (A + B) = Rs. **523.38**

D Cost of Loading & Carriage

-	Lead	=	7.50	km
-	Rate per km	=	67	Rs./km
-	RCC Lagging carried in a trip	=	200	
-	Wt. Of laggings Carried per trip	=	5.63	MT
-	Volume of Laggings carried per trip	=	2.25	cum.

Transportation rate per cum = Rs. 446.67

E Labour charges

Casting & Fixing of Lagging per day	=	No.	300
Volume of a Lagging (1000mm x 150mm x 75mm)	=	cum	0.011
Volume of concrete place per day	=	cum	3.38

	Category	Nos.	Rate	Amt.
1	Beldar	4	22,752	91,008
2	Mason	1	5,063	5,063
			Sub-Total	**96,071** per month

Indirect Cost @ 55%	for un-skilled labour	=	Rs.	50,054
Indirect Cost @ 80%	for skilled labour	=	Rs.	4,050

Therefore,

- Total Crew Charges per Month		Rs.	1,50,175
Total Crew Charges per cum.	**=**	**Rs.**	**1,780**
Total cost	=	Rs.	**7,983.70**
Add 20% for Overhead & Profit on prime cost	=	Rs.	1,596.74
Rate of lagging per cum.	**=**	**Rs.**	**9,590.00**
Rate of lagging per piece	**=**	**Rs.**	**108.00**

WORKING RATE - C/C BLOCKS

A Material

Sr. No.	Item	Quantity	Unit	Rate			Amount
1	Cement (incl. waste)	8.00	bags	500	=	Rs.	4,000.00
2	Sand	0.43	cum	700	=	Rs.	301.00
3	Coarse aggregate	0.86	cum	700	=	Rs.	602.00
4	Reinforcement steel	40.00	Kg	60	=	Rs.	2,400.00
4	Water	LS			=	Rs.	10.00
5	Admixture	LS			=	Rs.	50.00
	Total material cost per cum.				**=**	**Rs.**	**7,363.00**

B Batching, mixing and laying of concrete

Use 30 cum batching and mixing plant

- Use rate of mixing plant per hour	=	Rs.	3,575.00
- Consider, actual output of mixer per hour (at 62% efficiency	=	cum	18.60
- **Rate of mixing plant per cum**	**=**	**Rs.**	**192.20**

C Form work charges @ 5% of (A + B) = Rs. **377.76**

D Transportation of concrete blocks to site by (15 MT) Dumper

- Average Lead	=	2.00	km
- Dumper Capacity	=	12.50	cum.
- Actual carrying capacity (considering 80% efficenecy)		10.00	cum.

CYCLE TIME

- Loading time	=	5.0	min
- Spotting time & waiting time	=	2.0	min
- Turning and unloading time		5.0	min
- Loading haul @ 10 Km/hr	=	75.0	min
- Empty haul @ 15 Km/hr	=	50.0	min
Total cycle time	**=**	**137.00**	**min**

- Consider, Actual working time in 1 hour duration	=	min	50.00
- No. of trips in 50 min working hour	=		0.36
- Output of 15T Dumper	=	cum	4.56
- Use Rate of 15T Dumper	=	Rs.	1,985.00
Transportation rate per cum	**=**	**Rs.**	**435.11**

E Cost of Loading, Unloading & Placement charges

@ 10% of (A + B) = Rs. **755.52**

Total cost	=	Rs.	**8,931.39**
Add 20% for Overhead & Profit on prime cost	=	Rs.	1,786.28
Rate of C/C Block per cum. (say)	**=**	**Rs.**	**10,720.00**

WORKING RATE - DRILLING OF 38MM HOLE (UPTO 5 METER DEPTH)

a)	Use Rate of Jack Hammer	=	Rs./hrs	**2,000.00**
	Average rate of drilling 38mm dia. Hole per hour is 4m.	=	m/hr	**6.00**
	Hence, rate of drilling per meter	=	Rs.	333.33
b)	Cost of Drill Rod per meter	=	Rs.	**34.00**
c)	Labour and Scaffolding @60% of (b)	=	Rs.	20.40
d)	Ventilation, lighting and workshop charges @40% of (b)	=	Rs.	13.60
	Sub - Total	=	Rs.	401.33
e)	Overhead + Contractors profit @ **20%**	=	Rs.	80.27
	Total Cost	=	Rs.	481.60
	Therefore,			
	Cost per meter drilling by Jack Hammer	**=**	**Rs.**	**482.00**

WORKING RATE - ROCK BOLTING (25.0 mm Dia.)

A	**Drilling cost**					
	Rate of jack hammer (Per hour)			=	Rs.	2,000.00
	I)	Average rate of drilling 38mm dia. hole per hour		=	m	4.8
		Hence rate of drilling per meter		=	Rs.	416.67
	ii)	Cost of drill rod per meter of drill rod		=	Rs.	34.00
	iii)	Labour lighting and scaffolding etc. @ 60% of (ii)		=	Rs.	20.4
	iv)	Ventilation and shop charges @ 40% of (ii)		=	Rs.	13.6
			Total	**=**	**Rs.**	**484.67**
B	**Supply and making of Rock Bolts**					
	I)	Rock bolt 25 mm dia , 3.85Kg/m @ Rs. 53,340	Rs./MT	=	Rs.	205.36
	ii)	Wastage in cutting @ 2.5% of B(i)		=	Rs.	5.13
	iii)	Cutting and making tips LS		=	Rs.	10.00
	iv)	Threading L.S.		=	Rs.	10.00
	v)	Cost of nut and bolts, plates LS		=	Rs.	20.00
			Total	**=**	**Rs.**	**250.49**
C	**Installation**					
	i)	Placing of rock bolt in position using rock bolting machine, LS		=	Rs.	10.00
	ii)	Grouting of rock bolt, LS		=	Rs.	15.00
	iii)	Miscellaneous work, LS		=	Rs.	10.00
			Total	**=**	**Rs.**	**35.00**
			Total	=	Rs.	770.16
		Add 20% for Overhead and Contractor's Profit		=	Rs.	154.03
		Cost of Rock Bolting per m		**=**	**Rs.**	**930.00**
D	**Rock Bolting In Pressure Shaft**					
		Take 50% higher of other locations		=	Rs.	465.00
		Cost of Rock Bolting in Tunnel per m		=	**Rs.**	**1,395.00**

WORKING RATE - PLAIN SHOTCRETING

A Material

Sr. No.	Item	Quantity	Unit	Rate			Amount
1	Cement (5% wastage)	10.0	bags	500	=	Rs.	5,000.00
2	Sand	1.020	cum	700	=	Rs.	714.00
3	Coarse aggregate	0.340	cum	700	=	Rs.	238.00
4	Water	LS			=	Rs.	50.00
5	Admixture	LS			=	Rs.	225.00
	Total cost of material per cum				**=**	**Rs.**	**6,227.00**

B Mixing charges of material (per cum.)in 45 cumBM plant

-	Hourly use rate of 45 cum BM plant		=	Rs.	4,350.00
-	Capacity of BM plant		=	cum/hr	45.00
-	Efficiency	50%			
-	Actual production of BM plant		=	cum/hr	22.50
-	Cost of mixing of material per cum		**=**	**Rs.**	**193.33**

C Transportation of Mix to site by transit Mixer

-	Average Lead	=	5.00	km
-	Transit Mixer (Capacity- 4 cum)	=	4.00	cum.
-	Actual carrying capacity (considering 75% efficenecy)		3.00	cum.

CYCLE TIME

-	Loading Time (4*60/22.5)	=	8.0	min
-	Spotting time & waiting time	=	1.5	min
-	Turning and unloading time	=	10.0	min
-	Loading haul @ 20 Km/hr		15.0	min
-	Empty haul @ 25 Km/hr	=	12.0	min
	Total cycle time	**=**	**46.50**	**min**

-	Consider, Actual working time in 1 hour duration	=	min	45.00
-	No. of trips in 45 min working hour	=		0.97
-	Output of transit mixer	=	cum	3.87
-	Use rate of Transit Mixer (Capacity- 4 cum)	=	Rs.	1,785.00
	Transportation rate per cum	**=**	**Rs.**	**461.13**

D Placement charges

-	Use rate of Shotcrete machine		=	Rs.	4,105.00
-	Capacity of Shotcrete machine		=	Cum	10.00
-	Efficiency	60%			
-	Actual production of shotcrete machine		=	cum/hr	6.00
	Use rate of Shotcrete machine per cum		**=**	**Rs.**	**684.17**

E	Lighting, work shop charges and other misc. Items @ 100 % of **D**	=	Rs.	**684.17**
	Sub Total (A+B+C+D+E)	**=**	**Rs.**	**8,249.79**
F	Add 20% for loss in rebound	=	Rs.	1,649.96
	Total (Sub Total + F)	=	**Rs.**	**9,899.75**
G	Add 20% for Overhead & Profit on prime cost			1,979.95
	Rate per cum of shotcrete	**=**	**Rs.**	**11,880.00**
	Rate per sq. m / 100mm thick shotcrete	**=**	**Rs.**	**1,188.00**

Therefore,

Rate per sqm of Shotcrete (50 mm thick)	=	**Rs.**	**595.00**
Rate per sqm of Shotcrete (75 mm thick)	=	**Rs.**	**891.00**
Rate per sqm of Shotcrete (100 mm thick)	=	**Rs.**	**1,188.00**
Rate per sqm of Shotcrete (150 mm thick)	=	**Rs.**	**1,782.00**

With wiremesh

Rate per sqm of Shotcrete (75 mm thick)	=	**Rs.**	**1,651.00**
Rate per sqm of Shotcrete (100 mm thick)	=	**Rs.**	**1,948.00**
Rate per sqm of Shotcrete (150 mm thick)	=	**Rs.**	**2,542.00**

WORKING RATE - PROVIDING AND FIXING WIREMESH

A	**Material Charges**						
	1	Cost of scaffolding	LS	=	Rs.	50.00
	2	Cost of wire mesh materials				
		Rate per kg.		=	Rs.	100.00
		Wiremesh required per sqm area =	4 kg			
		Cost of wire mesh material		=	Rs.	400.00
		Cost of spikes @ 15% of above		=	Rs.	60.00
			TOTAL	=	Rs.	460.00
		Add towards lapping etc. @ 5%		=	Rs.	23.00
		Total Material Charges (A)		**=**	**Rs.**	**533.00**
B	**Machinery Charges for fixing wiremesh**					
		Drilling for fixing spikes	LS	=	Rs.	50.00
C	**Labour Charges**					
		Labour Charges	LS	=	Rs.	50.00
		Total Charges (A+B+C)		**=**	**Rs.**	**633.00**
		Prime Cost		=	Rs.	633.00
	Add 20% for Overhead & Profit on prime cost					126.60
			Rate per sqm	**=**	**Rs.**	**760.00**

CONTACT GROUTING IN TUNNELS.

A	-	Cost of one bag of cement on site		=	Rs.	500.00
	-	Cost of sand in 1:2 mix for one bag at site		=	Rs.	100.00
		Total cost		=	Rs.	**600.00**
B		Drilling				
	-	Cost of drilling per meter by jack hammer		=	Rs.	**482.00**
	-	Average requirement of cement per meter in bags		=		4.00
	-	Cost of drilling per bag		=	Rs.	**120.50**
C		Washing of holes				
	-	Cost of Equipment	L.S	=	Rs.	50.00
	-	Cost of labour	L.S.	=	Rs.	50.00
		Total cost		=	Rs.	**100.00**
D		Grouting				
	-	Grouting machine charges		=	Rs.	2500.00
	-	Use Rate of Grouting machine		=	Rs.	416.67
		Taking 6 bags progress of machine per hour				
	-	Cost of Labour	L.S.	=	Rs.	50.00
		Total cost				**466.67**
E		Other Misc. charges such as G.I pipes fitting etc.		=	Rs.	100.00
		Total prime cost		=	Rs.	**1387.17**
		Add 20% Overhead and contractors profit		=	Rs.	277.43
		Total cost per bag		**=**	**Rs.**	**1665**

WORKING RATE - STONE FILLING

A Material

I) 1.17 cum stone at site @ 800 Rs/Cum = Rs. 936

B Labour charges

Stone pitching done per day in cum	=	cum	3
Number of working days per month	=	days	25
work done in a month (Cum)	=	cum.	75

	Category	Nos.	Rate	Amt.
1	Mason	1	22,752	22,752
2	Beldar	3	5,063	15,188
			Sub-Total	**37,940**

Indirect Cost @	80%	for skilled labour	=	Rs.	18,202
Indirect Cost @	55%	for un-skilled labour	=	Rs.	8,353

Therefore,

- Total Crew Charges per Month		Rs.	64,494
Total Crew Charges per cum.	**=**	**Rs.**	**859.92**
- Prime cost (A+B)	=	Rs.	1,796
Add for royalty of material		Rs.	20.00
Add 20% for Overhead and contractors profit	=	Rs.	359.18
Rate of Stone pitching	=	Rs.	2,175.11

Rate of Stone pitching per cum	**=**	**Rs.**	**2,180**

WORKING RATE - STEEL FIBRE REINFORCED CONCRETE (SFRS)

A Material

Sr. No.	Item	Quantity	Unit	Rate			Amount
1	Cement (incl. waste	1.050	bags	500	=	Rs.	525.00
2	Sand	0.102	cum	700	=	Rs.	71.40
3	Coarse aggregate	0.034	cum	700	=	Rs.	23.80
4	Steel Fibers	4.00	Kg	150	=	Rs.	600.00
5	Water	LS			=	Rs.	10.00
6	Admixture	LS			=	Rs.	50.00
	Total cost of material per bag				**=**	**Rs.**	**1,280.20**

B Mixing charges of material (per cum.)in 30 cum BM plant

-	Hourly use rate of 30 cum BM plant		=	Rs.	3,575.00
-	Capacity of BM plant		=	cum/hr	30.00
-	Efficiency	62%			
-	Actual production of BM plant		=	cum/hr	18.60
-	Cost of mixing of material per Bag		**=**	**Rs.**	**17.47**

C Transportation of Mix to site by transit Mixer

-	Average Lead	=	5.00	km
-	Transit Mixer (Capacity- 4 cum)	=	4.00	cum.
-	Actual carrying capacity (considering 75% efficenecy)		3.00	cum.

CYCLE TIME

-	Loading Time (4*60/18.6)	=	9.7	min
-	Spotting time & waiting time	=	1.5	min
-	Turning and unloading time	=	11.7	min
-	Loading haul @ 20 Km/hr		15.0	min
-	Empty haul @ 25 Km/hr	=	12.0	min
	Total cycle time	**=**	**49.85**	**min**

-	Consider, Actual working time in 1 hour duration	=	min	45.00
-	No. of trips in 45 min working hour	=		0.90
-	Output of transit mixer	=	cum	3.61
-	Use rate of Transit Mixer (Capacity- 4 cum)	=	Rs.	2,120.00
	Transportation rate per Bag	**=**	**Rs.**	**53.38**

D Placement charges

-	Use rate of Shotcrete machine		=	Rs.	4,105.00
	Capacity of Shotcrete machine		=	Cum	10.00
-	Efficiency	80%			
-	Actual production of shotcrete machine		=	cum/hr	8.00
	Use rate of Shotcrete machine per Bag		**=**	**Rs.**	**46.65**

E Lighting, work shop charges and other misc. Items @ 100 % of **D** = Rs. **46.65**

	Sub Total (A+B+C+D+E)	**=**	**Rs.**	**1,444.35**
F	Add 20% for loss in rebound	=	Rs.	288.87
	Total (Sub Total + F)	=	**Rs.**	**1,733.22**
G	Add 20% for Overhead & Profit on prime cost			346.64
	Rate per Bag of shotcrete	**=**	**Rs.**	**2,080.00**
	Rate per sq. m (100mm)	**=**	**Rs.**	**2,288.00**

Therefore,

Rate per sqm of Shotcrete (100 mm thick)	=	**Rs.**	**2,290.00**
Rate per sqm of Shotcrete (150 mm thick)	=	**Rs.**	**3,435.00**

WORKING RATE - STONE CRATERS IN WIRE NETS

A Material

I)	1.17 cum stone at site	@	**800**	Rs/Cum	=	**Rs.**	**936.00**
II)	Wire net for crate size (1m x 1m x 1m)						
	wire mesh size 15cm x 15cm,		**5**	mm thick			
	Length of wire per meter per face				=	m	18
	Length of wire per meter for 6 faces				=	m	108
	Add **10%** extra				=	m	118.80
	weight of wire per meter				=	kg	0.15
	Total weight per crate				=	kg	17.84
	cost of wire per crate, steel	@	**50**	Rs/kg	=	**Rs.**	**892.23**
				Total material charges	**=**	**Rs.**	**1,828.23**

B Labour charges

Number of Crates constructed per day	=	No.	**3**
Number of working days per month	=	days	**25**
work done in a month (Cum)	=	cum	75

	Category	Nos.	Rate	Amt.
1	Mason	**1**	22,752	22,752
2	Black smith	**1**	22,752	22,752
3	Beldar	**3**	5,063	15,188
			Sub-Total	**60,692**

Indirect Cost @	**80%**	for skilled labour	=	Rs.	36,403
Indirect Cost @	**55%**	for un-skilled labour	=	Rs.	8,353

Therefore,

- Total Crew Charges per Month			Rs.	1,05,448
	Total Crew Charges per crater.	**=**	**Rs.**	**1,405.97**
- Prime cost (A+B)		=	Rs.	**3,234**
Add for royalty of material			Rs.	20
Add 20% for Overhead and contractors profit		=	Rs.	646.84
	Rate of Stone wire crates	=	Rs.	3,901.04
Rate of Stone wire crates per cum		**=**	**Rs.**	**3,901**

Silkyara Bend – Barkot Road Tunnel
Design of Tunnel Support
(A part of Detailed Project Report)

Of

2 Lane/ 2 Lane upgradation proposal of Highway between Km 144.00 (Dharasu) and Km 220.00 (Yamunotri) falling along NH - 94 and 123 in the State of Uttarakhand

Submitted to

Ministry of Road Transport & Highways
(Government of India)

By

TASPL
(Committed to resource and energy conservation)

M/s TECHNOCRATES ADVISORY SERVICES PVT.LTD.
(Earlier M/s MC Consulting Engineers Pvt. Ltd.)

JV with

G.E.S. & Association with S.I.P.L.

Contents

1 INTRODUCTION

1.1 General

The Ministry of Road Transport and Highways (MORT&H) is poised to develop all remote and strategically important roads in hilly terrains to perennial routes. In continuation to these developments National Highways And Infrastructure Development Corporation has been appointed by MORT&H, to implement the projects.

NHIDCL have appointed the M/s MC Consulting Engineers Pvt. Ltd., in Joint Venture with G.E.S. and in association with S.I.P.L, lndia, as consultants to carry out the detailed design, for the Silkyara Bend – Barkot Tunnel of the NH-94, between Dharasu and Barkot section (CH.25.400 to CH.51.00), in the State of Uttarakhand.

1.2 Proposed Silkyara Bend – Barkot Tunnel Alignment

This tunnel is aligned to reduce the distance between Silkyara Bend (CH. 25.400) and Barkot (CH. 51.000) on NH-94, a total of 25.6km to less than 5.0 km. In current scenario this distance through road can be covered by crossing almost 5 hairpin bends with an ascending journey from approx. EL.1720 to EL.2250 and then again a descending journey to EL. 1500. The upper reaches of this ridge receive heavy snowfall during winters and as a result the highway gets blocked for one-two weeks every year.

1.3 Geotechnical Design Parameters

The geotechnical design parameters for the analysis are derived from drill holes information of at the both the portal adopting UCS value of intact rock in range of 80 to 40 MPa, modulus of elasticity of intact rock as 25 to 20 GPa and using mi value of 18 in a conservative manner. All parameter has been based on Geological report of Tunnel. All geotechnical parameter has been extracted from intact rock properties by using RocLab Software.

1.4 Discontinuities & Rock Mass Parameters

Majority of discontinuity encountered along tunnel portal area are taken as reference for discontinuities along tunnel alignment for doing Unwedge analysis. Direction of tunnel alignment is N175^0

Table 1: Discontinuity Sets for Tunnel

Joint Set	Dip Direction (°)	Dip Amount (°)	Friction Angle (Φ_j), (°)	Cohesion (c_j), MPa
J1	N35-60	40-55	26	0.01
J2	N315-355	55-78	26	0.01

J3	N230-260	40-58	26	0.01

1.5 Wedge Stability Analysis

The possibility for wedge formations due to intersection of the joints defined above is also checked with Unwedge software. The stereographic projections for tunnel are shown in Figure- 1 for tunnel directions N186 ^{0}. The formation of wedges due to three joint sets without any support system and with support system (50 mm thk. shotcrete) is shown in Figures 2.

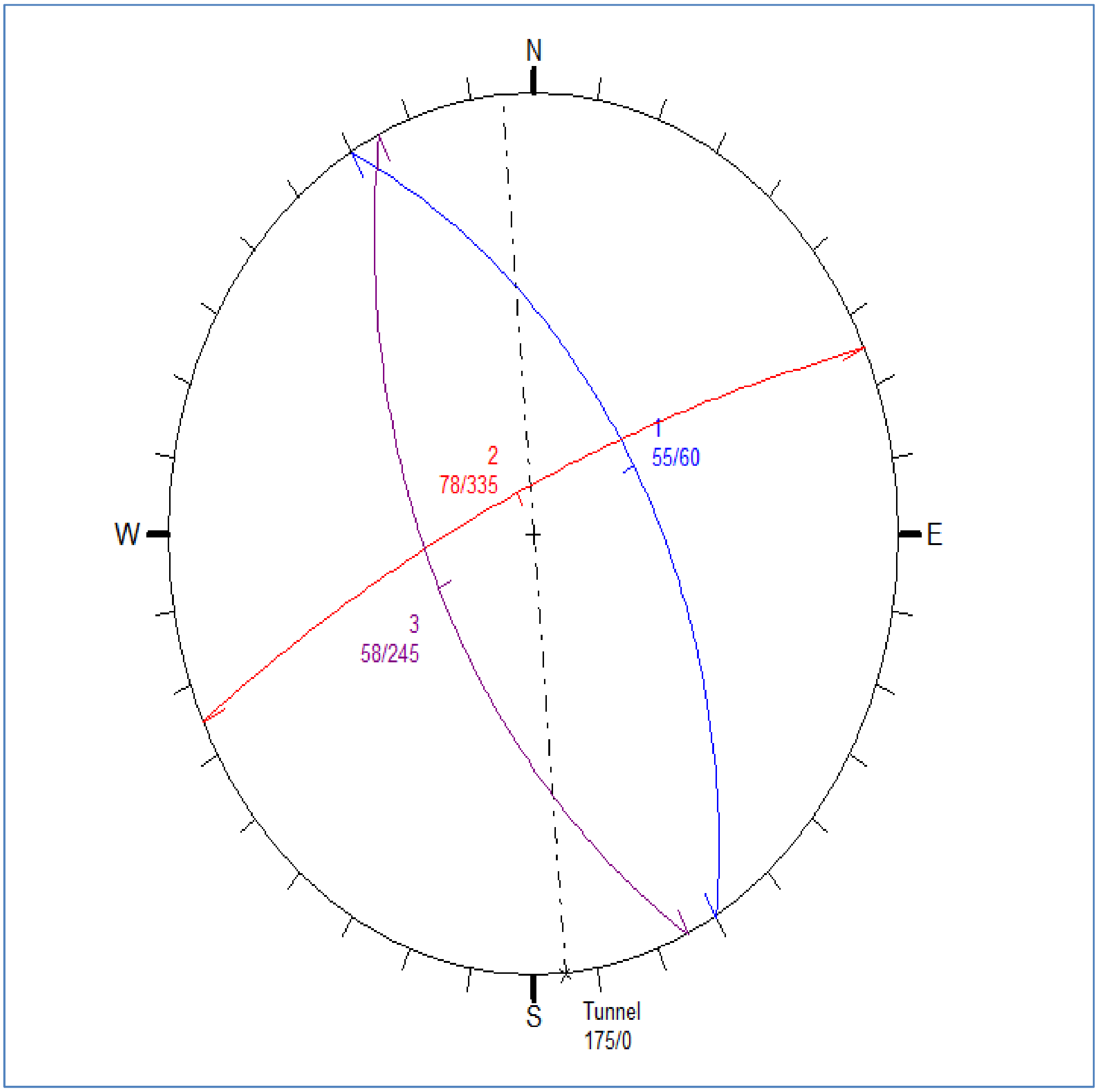


Figure-1: Stereographic Projection of Tunnel

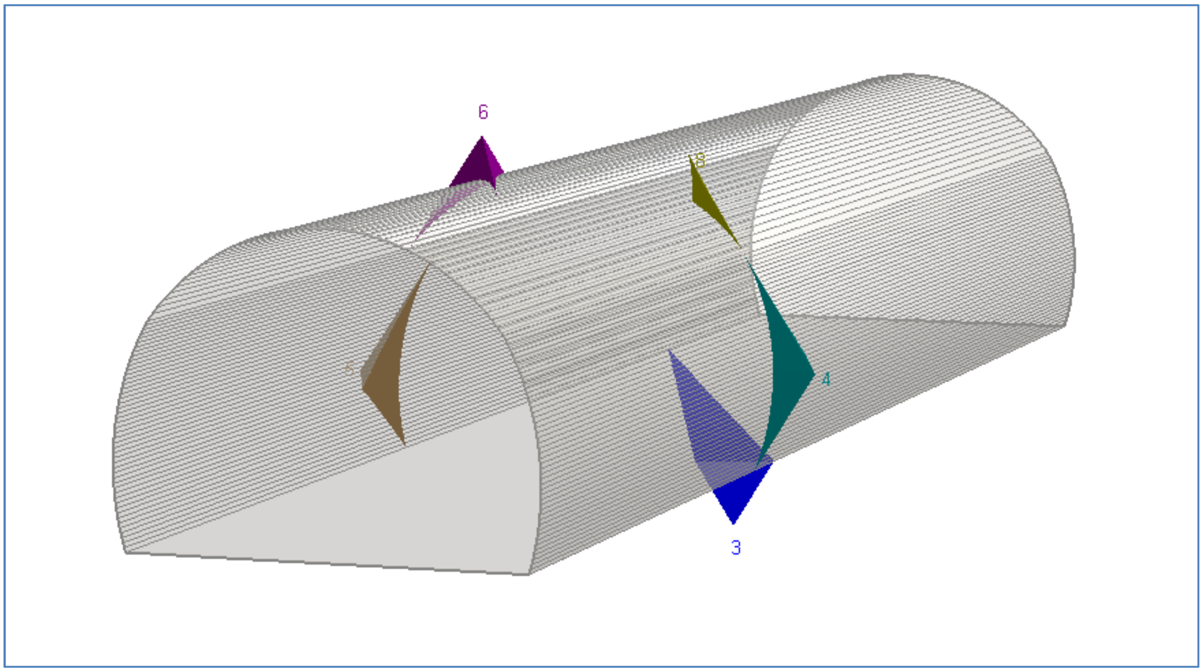


Figure-2: Wedges formed due to Joints Intersections

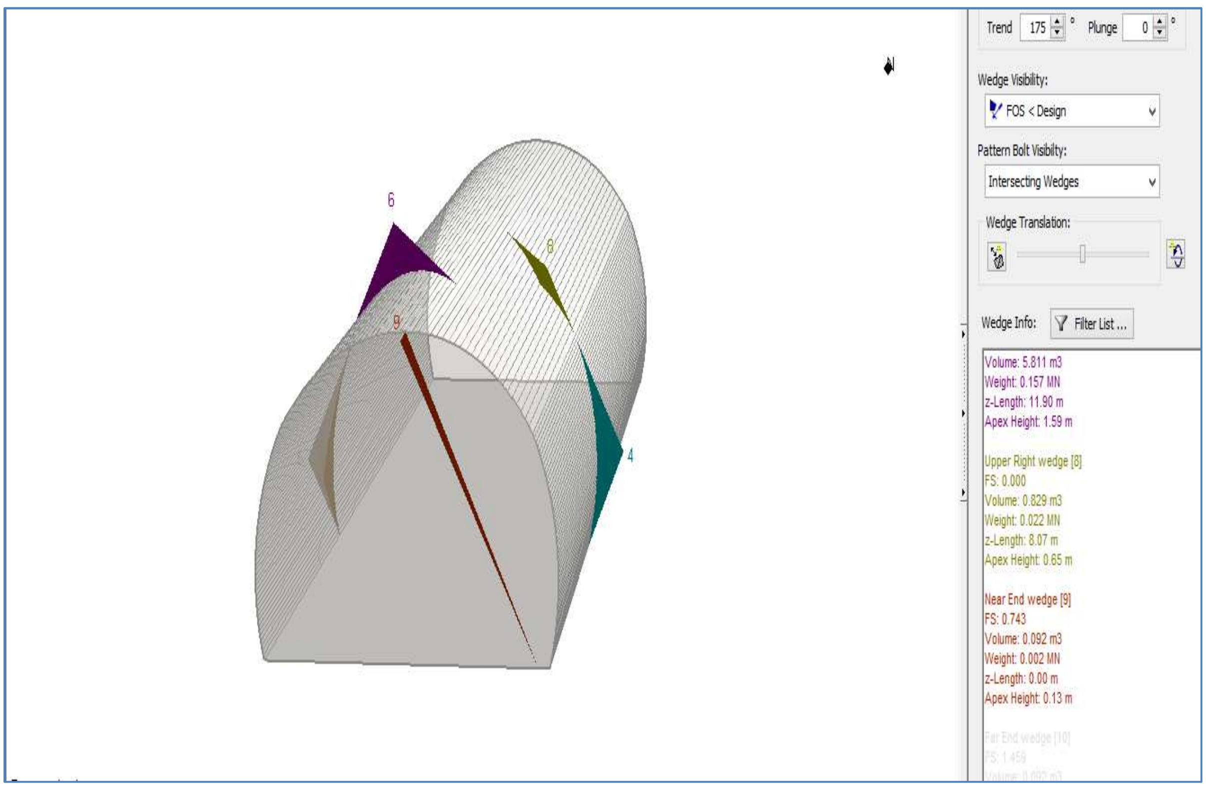


Figure-3: Unstable Wedges formed due to Joints Intersections

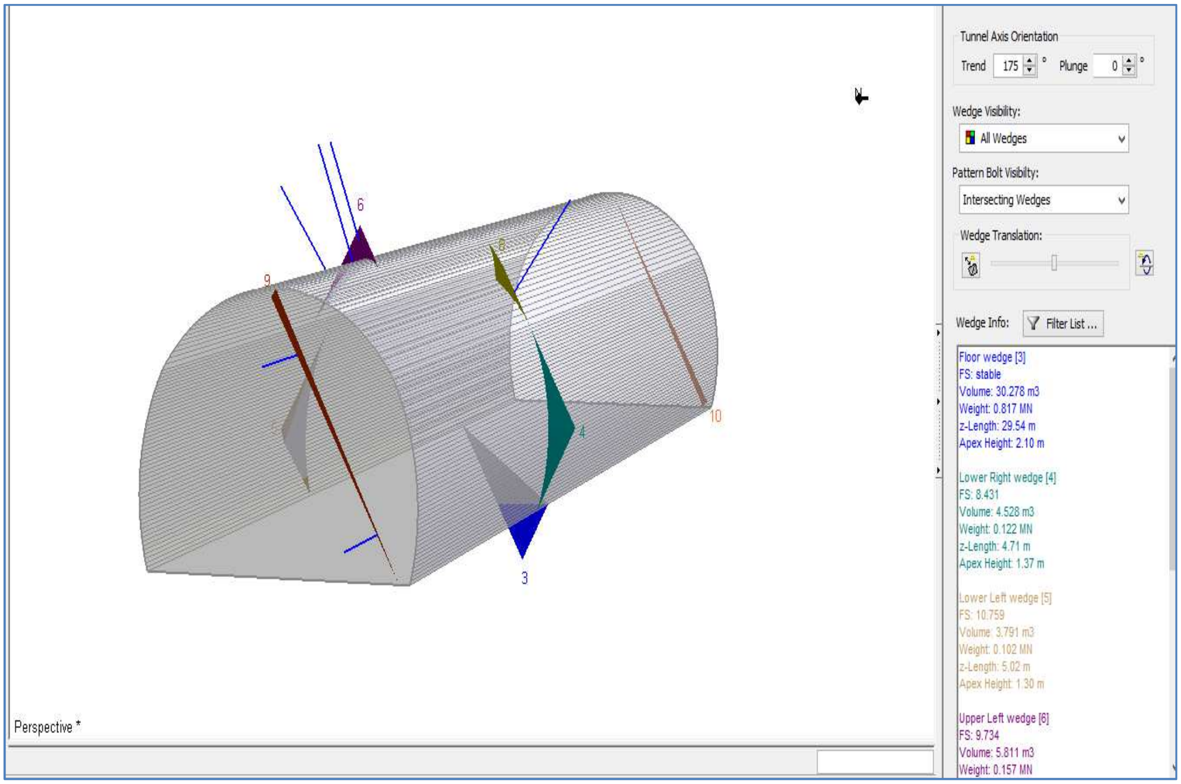


Figure-4: Stable Wedges (After minimum support)

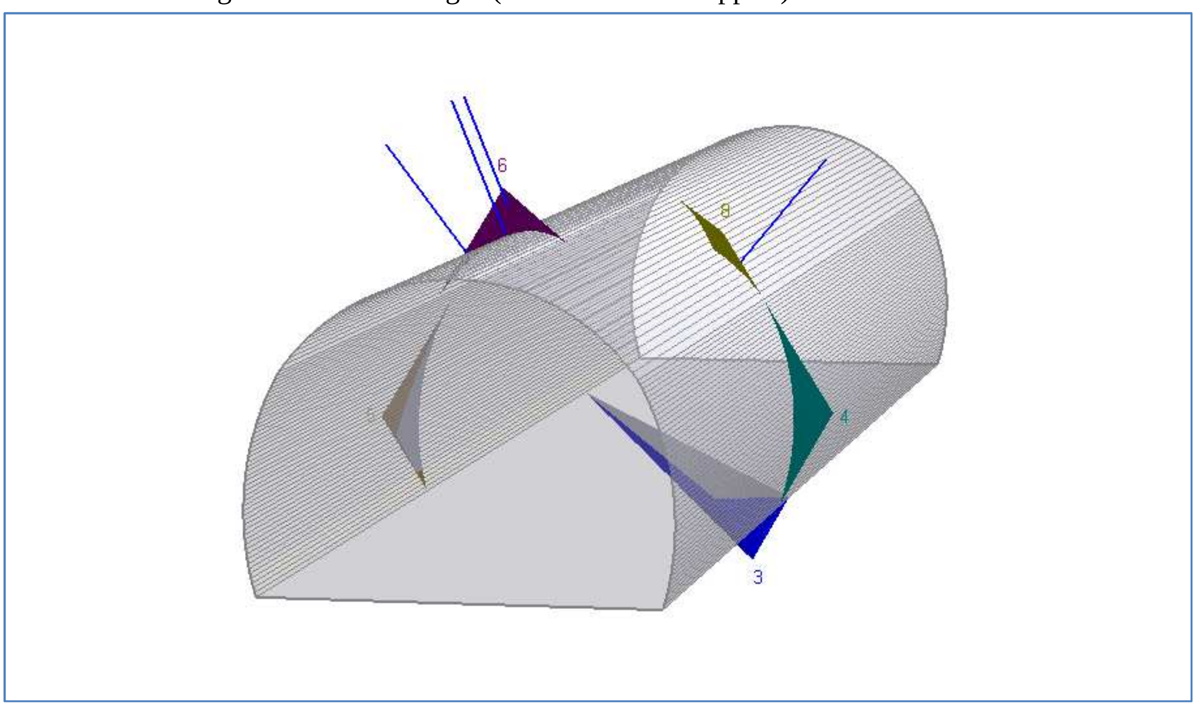


Figure-5: Stable Side Wedges (After minimum support)

Table 2: Rock Mass Parameters Adopted for Tunnel

Description		Unit	Class A	Class B	Class C	Class D	Class E
Intact Rock Properties	UCS	MPa	80	70	60	50	40
	GSI		85	65	50	30	20
	m_i		18	18	18	18	18
	D		0.3	0.3	0.3	0.3	0.3
	E_i	MPa	25000	25000	25000	20000	20000
	ѵ		0.2	0.2	0.2	0.25	0.3
	Rock Cover	m	500	500	500	150	100
Rock Mass Parameters	c (peak)	MPa	5.258	2.569	1.759	0.52	0.278
	Φ (peak)	deg	52.728	46.406	40.187	40.65	37.334
	c (residual)	MPa	4.588	2.043	1.318	0.334	0.162
	Φ (residual	deg	50.93	41.459	32.859	30.079	25.069
	Tensile Strength	MPa	1.31	0.225	0.057	0.009	0.003
	Deformation Modulus	MPa	18896	11366	4986	1107	692
In-Situ Stress	Vertical Stress (σ_3)	MPa	13.5	13.5	13.5	4.05	2.7
	In Plane Horizontal Stress (σ_1)	MPa	13.5	13.5	13.5	4.05	2.7
	Vertical Stress (σ_3)	MPa	13.5	13.5	13.5	4.05	2.7

In-situ stress has been considered as hydrostatic condition due to unavailability of data .Which will be later verified using hydro-fracture test in proposed drill hole during detail design.

1.6 Concrete Lining

- Unit Weight - 24 KN/m^3
- Young's Modulus - 25000 MPa
- Poisson Ratio - 0.2
- Friction Angle (Peak) - 42^0
- Cohesion (Peak) - 0.1 MPa

1.7 Shotcrete

- Unit Weight - 24 KN/m3
- Young's Modulus - 30000 MPa
- Poisson Ratio - 0.2
- Compressive Strength - 40 MPa
- Tensile Strength - 4.10
- Wiremesh - 6mm dia @ 100mm c/c spacing

1.8 Rock Bolts

- Dia. - 25 mm
- Young's Modulus - 200000 MPa
- Tensile Capacity - 190 kN

1.9 Steel Rib

- Type - ISMB250
- Young's Modulus - 200000 MPa
- Area of Cross Section -4750 mm^2
- Moment of Inertia of Rib -5.13 E-5
- Yield Stress - 250 MPa

2 Road Tunnel

A 14.075m (W) x 9.9.00m (H) (excavated size) D shaped tunnel having total length of 4551m is proposed. The following rock mass properties and supports system have been considered in the analysis of different type of rock classes:

3 Empirical Design of Rock Support

As per geological report, general rating of rock mass for the Tunnel has been estimated. The Table-3 shows the values of different geo-mechanical parameters for different classes of rock, which are adopted for the design of rock support:

Table-3: Geo-mechanical Parameters adopted for different Classes of Rock

Rock/ support Class	Type of Rock (Q Range)	Q adopted	Jr
Class A	Very to Extremely Good Rock (40-1000)	40	3
Class B	Good Rock (40-10)	10	3

Class C	Fair Rock (4-10)	4	2
Class D	Poor Rock (1-4)	1	1.0
Class E	Very Poor Rock (0.01-1)	0.1	1.0

3.1 IS Code Method

3.1.1 Estimation of Support Pressures

Section 3.5 of IS 13365 (Part-2):1992 details method to assess the ultimate rock support pressures on roof and wall for squeezing and non-squeezing ground. Ground is termed as squeezing or non-squeezing based on the height of overburden, H, above the crown of tunnel. If H is less than 350×Q1/3 the ground is non-squeezing, otherwise it is termed as squeezing. In the present case the height of overburden above the crown of Tunnel is moderate (varies from 30m to 500m), hence the ground has been considered as non-squeezing for the design of rock support of Tunnel for Class-A to B and Squeezing for Class C to E. For non-squeezing ground IS: 13365 (Part-2) has recommended empirical equations for calculating ultimate and short term support pressures on roof and wall. However, in present case short term support pressures have been neglected and only ultimate support pressures have been considered for the design.

a) Ultimate roof Support Pressure (for Crown)

The ultimate roof support pressure is related to ultimate rock mass quality (Qru) by the following empirical relation:

$$P_{ru} = \frac{2Q_{ru}^{-1/3}}{J_r} f$$

Where:

Pru = ultimate roof support pressure in kg/cm²

Q_{ru} = ultimate rock mass quality for roof = Q

Jr = joint roughness number

f = correction factor for overburden = maximum of {1, 1 + (H-320)/ 800}

H = overburden above crown or tunnel depth below ground level in meters.

b) Ultimate wall support pressure

The ultimate wall support pressure (P_{wu}) in kg/cm² can be obtained from the following equation:

$$P_{wu} = \frac{2Q_{wu}^{-1/3}}{J_r} f$$

Where, Qwu = ultimate wall rock quality index calculated from Table-4.

In view of the more favorable position of walls as compared to roofs, the following hypothetically increased value of wall rock quality (Q_{wu}) are used for different qualities of rock mass

Table-4: Equations for calculation of Qwu for different qualities of rock mass

Type of Rock	**Range of Q**	**Q_{wu}**
exceptionally good to good rock	Q>10	5 Q
fair to very poor rock	0.1 < Q < 10	2.5 Q
extremely poor to exceptionally poor rock	Q < 0.1	Q

Calculation of rock bolt parameters

The minimum spacing of rock bolts (in m) is calculated from the design rock pressure (in kPa, calculated and capacity of rock bolt (in kN) as per following equation.

$$\text{Spacing} = \sqrt{\frac{\text{Capacity of rock bolt}}{\text{Design Pressure}}}$$

The length of rock bolts, L (in m) is calculated by using the following formula

Minimum Length of Rock Bolt = $L = 2 + \frac{0.15B}{ESR}$

Where B is excavated Span in m.

3.1.2 METHODOLOGY

General design methodology for the rock support system comprises the following steps:

Step-1: Evaluation of the rock mass quality (Q) post excavation. In the present case Q value has been adopted on the basis of available geological data.

Step-2: Estimate the parameters like length of rock bolts and their spacing by different empirical relations as per IS Code method for different rock class.

Step-3: Calculate roof and wall support pressures as per **IS: 13365 (Part 2).**

Step-4: Perform detailed calculation and find suitable shotcrete thickness and spacing of rock bolt.

Step-5: Adopt the rock support measures.

3.1.3 ROOF PRESSURE FOR DIFFERENT CLASS OF ROCKS

Roof pressure is calculated as per Para 3.1.1 for different classes of rock and value is shown in Table-5 below:

Table-5: Roof pressure for different classes of rock

Rock Class	**Q**	**J_r**	**P_{roof}** (kN/m^2)
Very to Extremely Good Rock	40	3	30.95
Good Rock	10.2	3	48.80
Fair Rock	4	2	77.17
Poor Rock	1	1.0	289.10
Very Poor Rock to Extremely Poor Rock	0.1 to 1	1.0	527.84

3.1.4 CALCULATIONS AND RESULTS

Rock bolt and shotcrete parameters for different rock types have been computed. Based on these parameters, final rock support measures have been worked out for different rock types as per IS: 13365 (Part-2). The detailed calculations are attached as **Annexure-1 (A to E)**.

4 Stress-Deformation Analysis for Tunnel

4.1 Loads

For the Stress-Deformation analysis, In-Situ Stress corresponding maximum vertical cover above the tunnel is considered in the analysis.

4.2 Method of the Analysis

The stability analysis of the Tunnel have been carried out using Finite Element Programme PHASE2, as a continuum model using Mohr-Coulomb yield criteria and stresses and deformations around the tunnel are estimated to check the stability of the tunnel. The numerical model of excavated cavity has been conceived as plain strain model with external boundaries at about 45m (approx. 3 times of openings) from the excavated tunnel boundaries so that the boundary conditions will have negligible influence on the stress field around it. Six node triangular finite elements with fine meshing is used close to the excavation boundaries of the tunnel, so that the variations in the stress field could be captured with higher precision. Size of the elements is gradually increased toward the external boundaries to reduce the number of elements and calculation time. External boundaries are taken as fixed and insitu stresses are applied as per the loading corresponding to cover for tunnel.

A stress relaxation of 40% has been considered between the excavation of cavity and installation of support. This models the deformations and corresponding field stress release from the time after blasting and up to installation of support.

Excavation sequence, wherever stage excavation is defined, of the tunnel has been simulated in the model using the stage construction approach.   For all Class of rock mass, heading and benching excavation has been simulated as Stage-1 is generation of model and initialization of in-situ stress, stage-2 is material softening of heading portion, stage-3 is heading excavation and support, stage-4 is material softening of benching portion and stage-5 is benching excavation and installation of rock support.

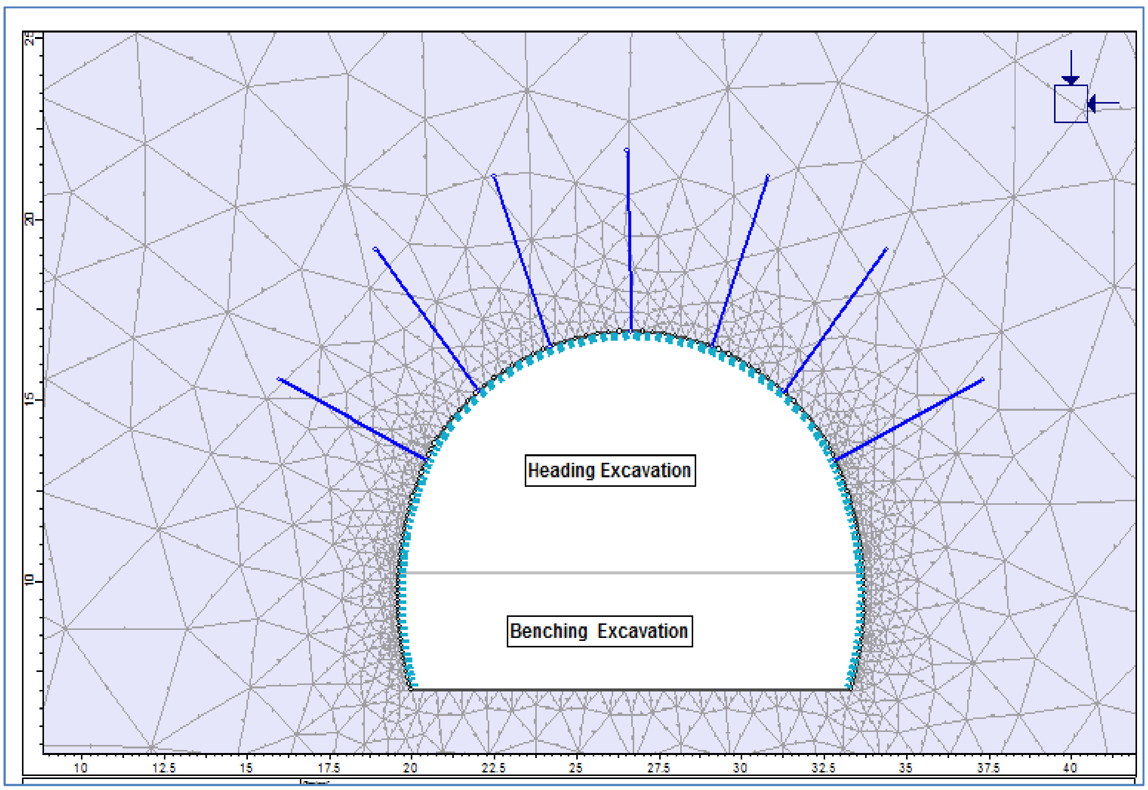


Figure-6: Discretization Model of Excavation

4.3 Assumptions in the Analysis

Following major assumptions were made while designing the support system for tunnel:

1. The geometry of the tunnel is the same along the tunnel length, permitting the three-dimensional problem to be modelled in two dimensions (Plane strain conditions).
2. The rock mass surrounding the tunnel is homogenous, isotropic in all directions.
3. The modulus reduction method is used to simulate the advancement of tunnel excavation and modulus of the tunnel material is reduced by 40% in the analysis before the installation of support system in each stage, however the strength parameters are assumed same as that of the original rock mass material.
4. The excavation is carried out in two stages (in conservative manner) as shown in Figures in subsequent section.
5. An additional precaution as pipe roofing and face support shall be taken in very poor rock class E, although effect of pipe roofing is not considered in the analysis.
6. For Class E 250 mm thick shotcrete is also considered in the analysis at the floor after excavation of heading and benching to control the heave.

4.4 Class-A Rock mass

- Rock Unit Weight - 27 KN/m^3
- Ultimate Compressive Stress - 80 MPa
- Geological Strength Index - 85
- Young's Modulus - 18896 MPa
- Poisson Ratio - 0.20
- Dilation Angle - 40

Support System: Spot bolts of 25 mm dia. 5.0 m long as initial support@ 2.5 m c/c with 50 mm thick plain shotcrete and 400 mm thick concrete lining as final support.

Results & Discussion: The major principal stresses and deformations around the tunnel are shown in Figure 7& 9 respectively. The maximum stress value generated in the rock mass is 63 MPa and maximum deformation at the tunnel boundary is only 7.38 mm. Hence the support system provided is adequate. Axial force in Bolt is around 45 kN. Plastic Zone is within permissible limit.

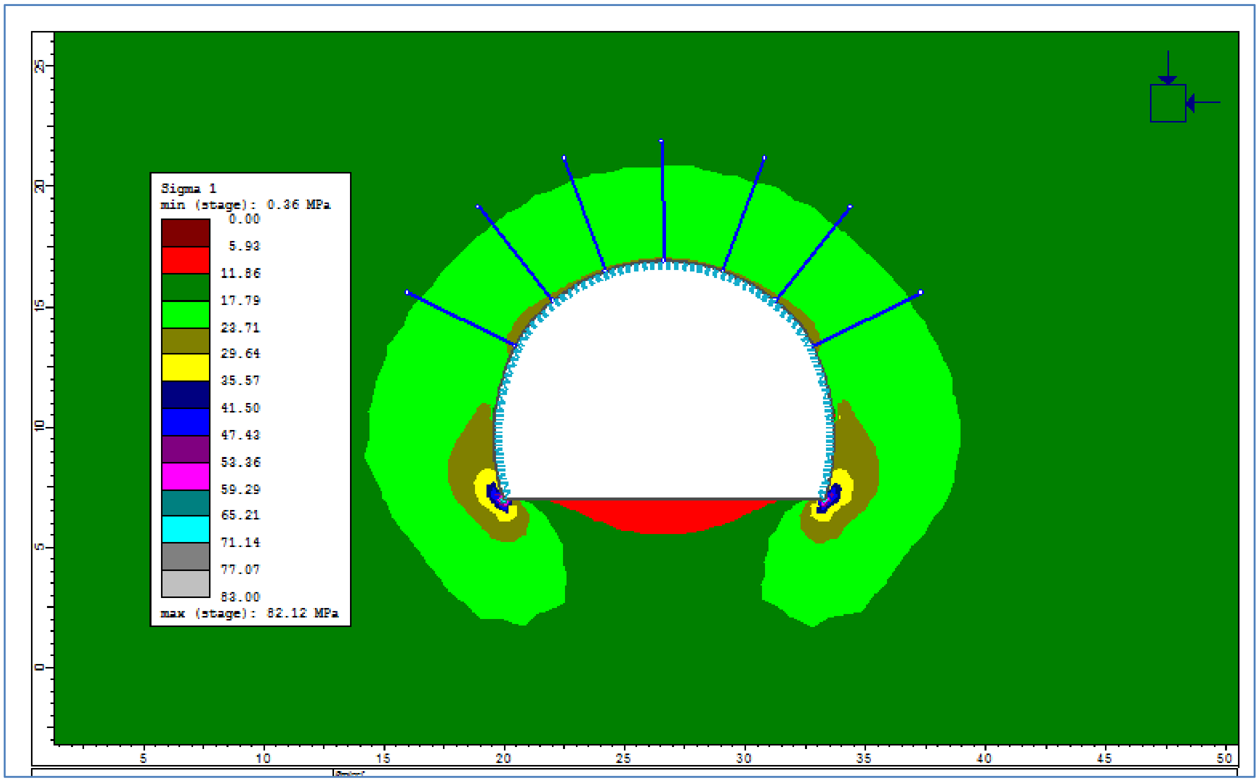


Figure-7: Major Principal Stresses

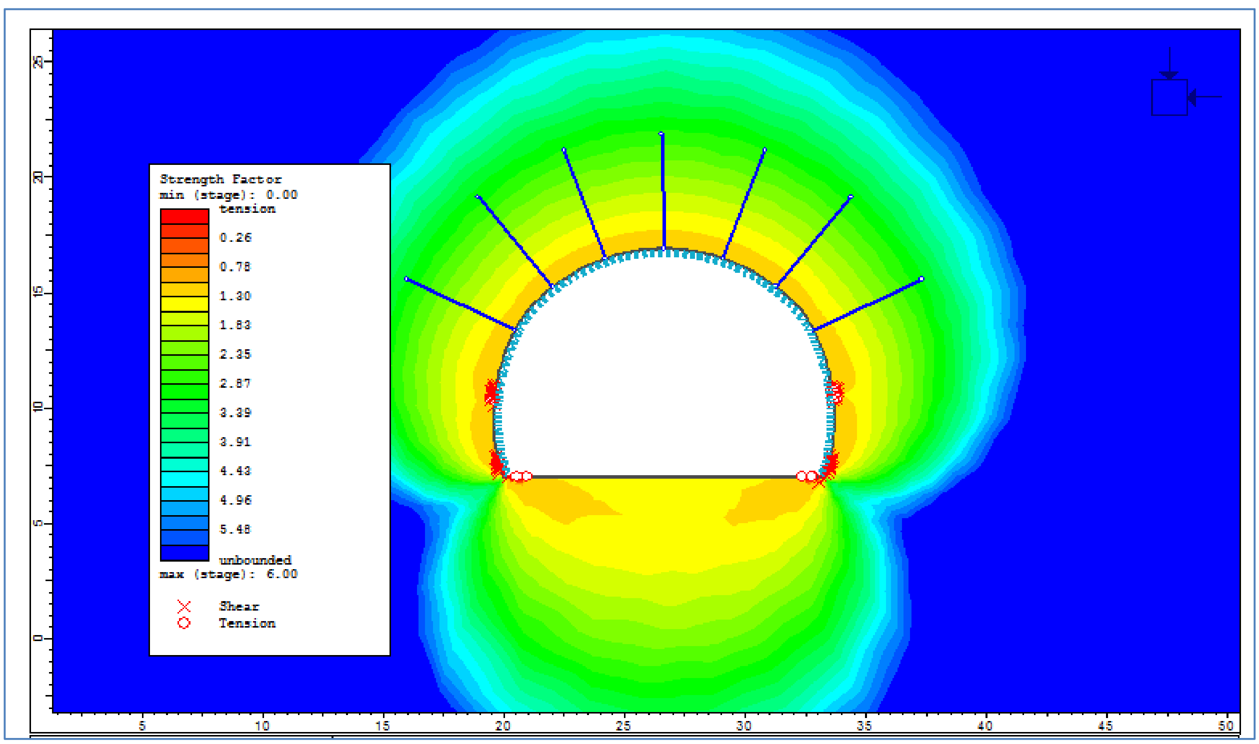


Figure-3: Yielded Element and Strength factor

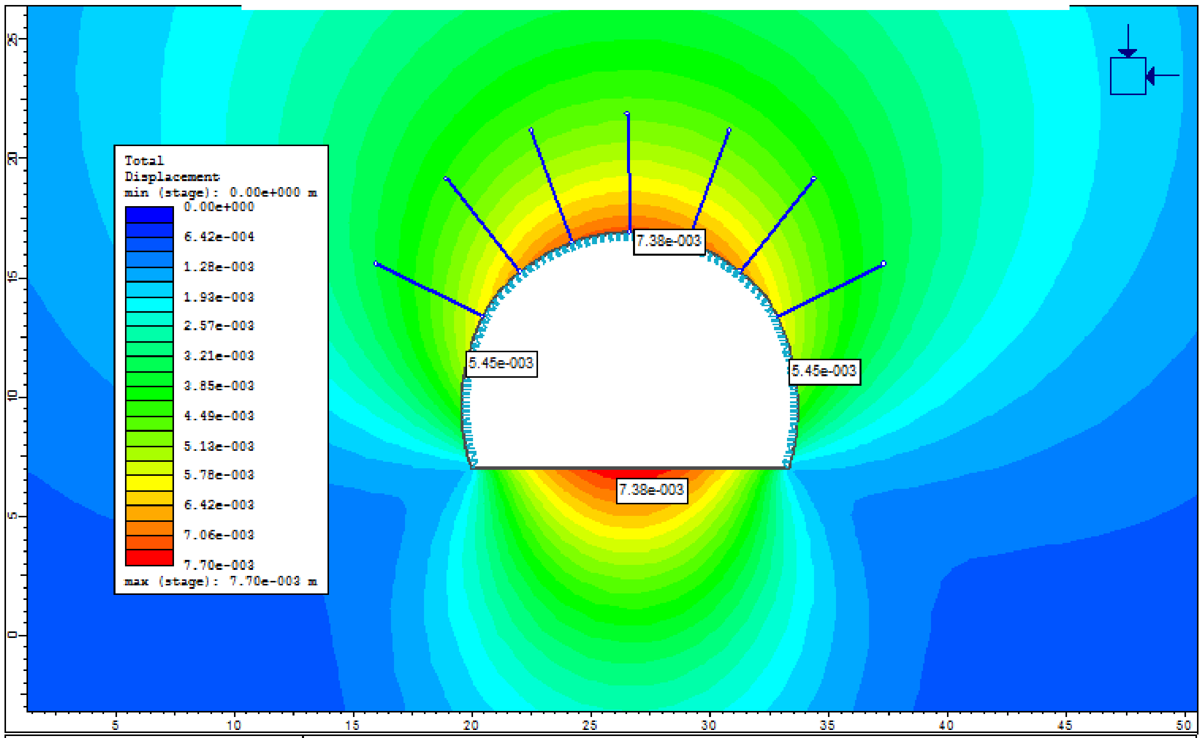


Figure-8: Total Displacement around Opening

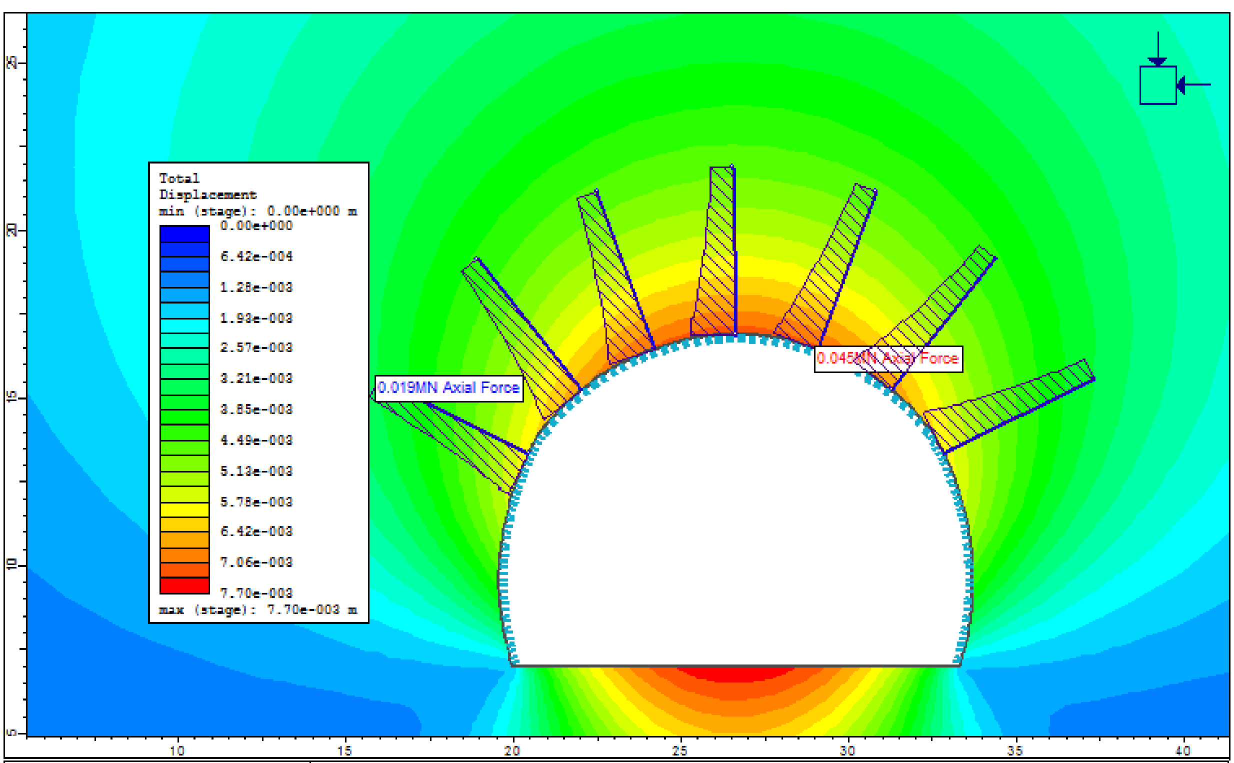


Figure-9: Axial Force in Bolts

4.5 Class-B Rock mass

- Rock Unit Weight - 27 KN/m3
- Ultimate Compressive Stress - 70 MPa
- Geological Strength Index - 65
- Young's Modulus - 11366MPa
- Poisson Ratio - 0.20
- Dilation Angle - 40

Support System: 75 mm thick shotcrete and fully grouted rock bolts of 25 mm dia. 5.0 m long and 2.0 m c/c spacing as initial support and 400 mm thick concrete lining as final support.

Results & Discussion: The major principal stresses and deformations around the tunnel are shown in Figure 10 & 12 respectively. The maximum stress value generated in the rock mass is 38 MPa and maximum deformation at the tunnel boundary is only 14.0 mm. Hence the support system provided is adequate. Axial force in Bolt is around 190kN. Plastic zone is within rock bolt which justify the adequacy of rock bolt.

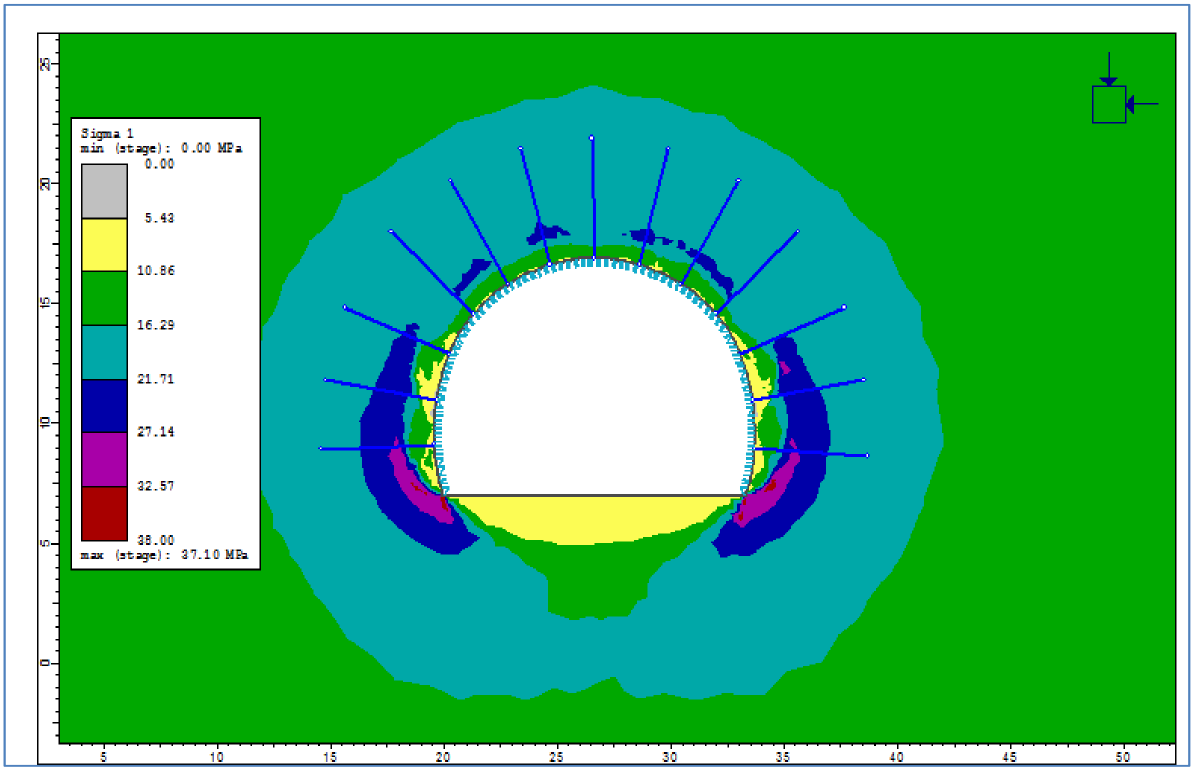


Figure-10: Major Principal

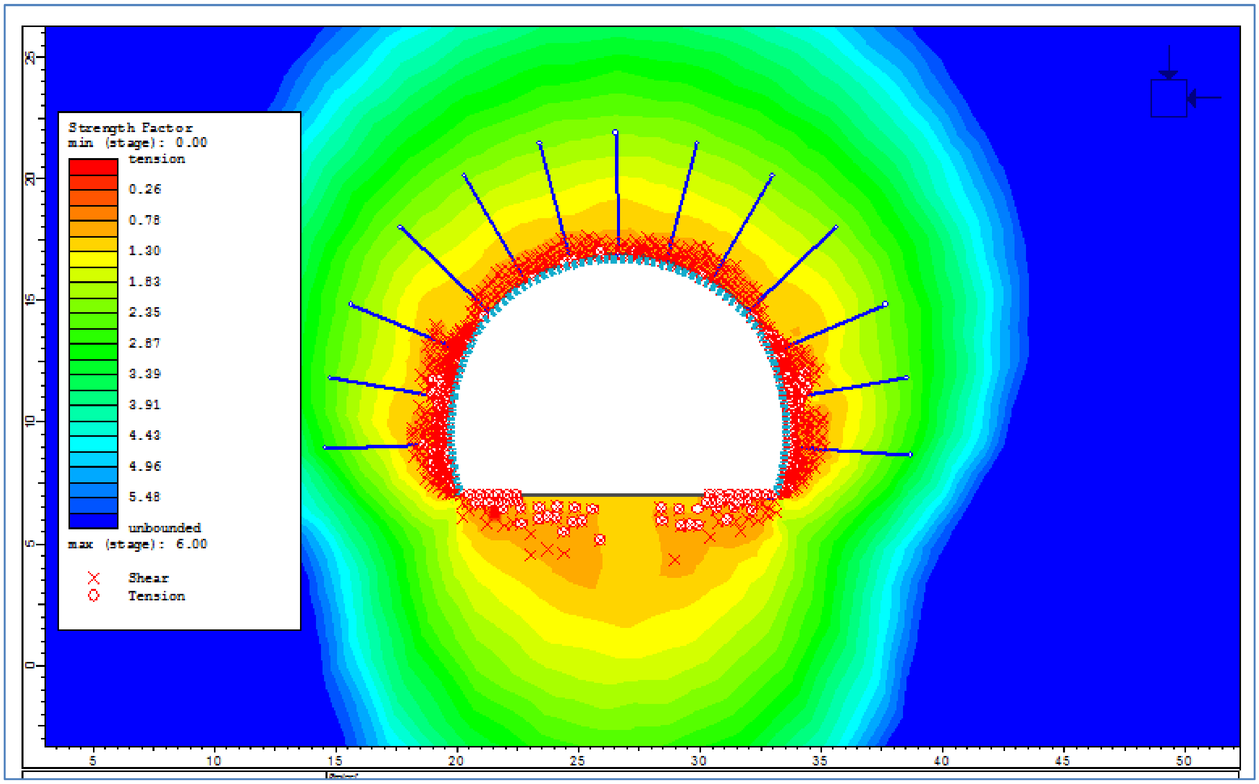


Figure-11: Yielded Element and Strength factor

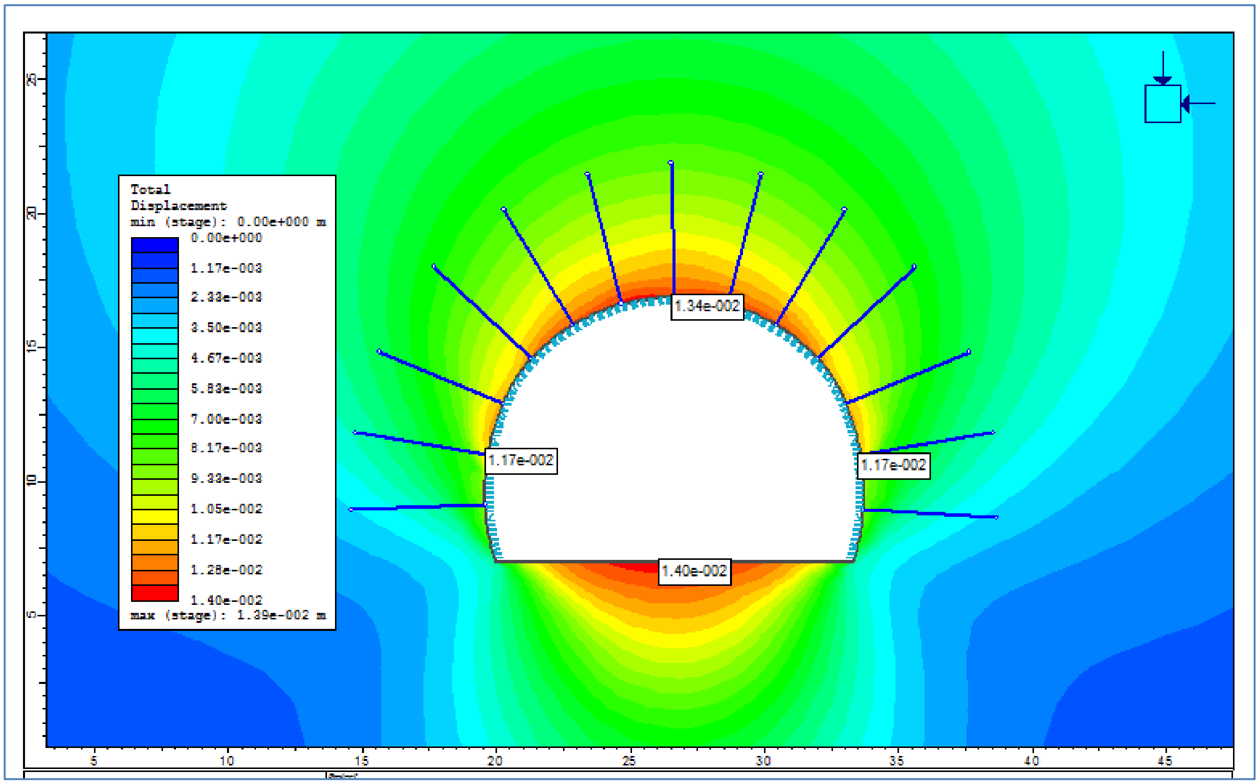


Figure-12: Maximum Deformation

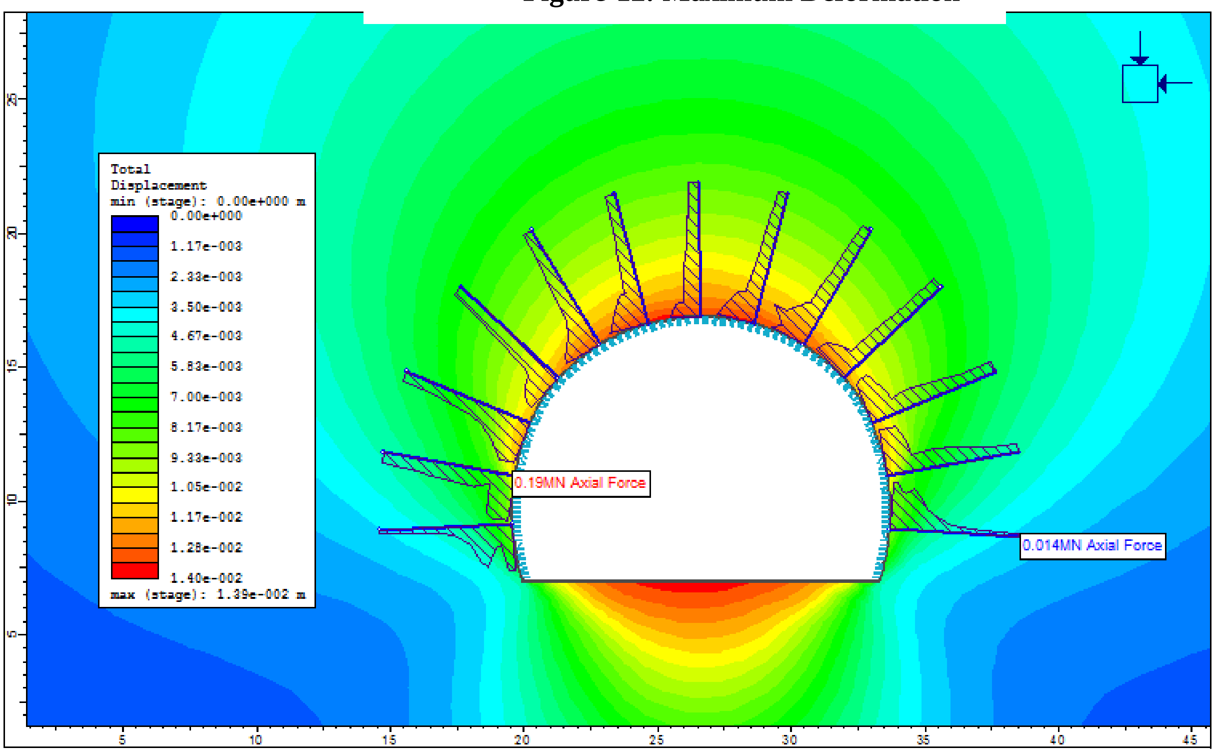


Figure-13: Axial Force in Bolts

4.6 Class-C Rock mass

- Rock Unit Weight - 27 KN/m3
- Ultimate Compressive Stress - 60 MPa
- Geological Strength Index - 50
- Young's Modulus - 4986 MPa
- Poisson Ratio - 0.20
- Dilation Angle - 40

Support System: 100 mm thick shotcrete with wire mesh and rock bolts of 25 mm dia. 5.0 m long and 1.50 m c/c spacing as initial support and 400 mm thick concrete lining as final support.

Results & Discussion: The major principal stresses and deformations around the tunnel are shown in Figure 14 & 16 respectively. The maximum stress value generated in the rock mass is 29.00 MPa and maximum deformation at the tunnel boundary is only 53.0 mm. Hence the support system provided is adequate.

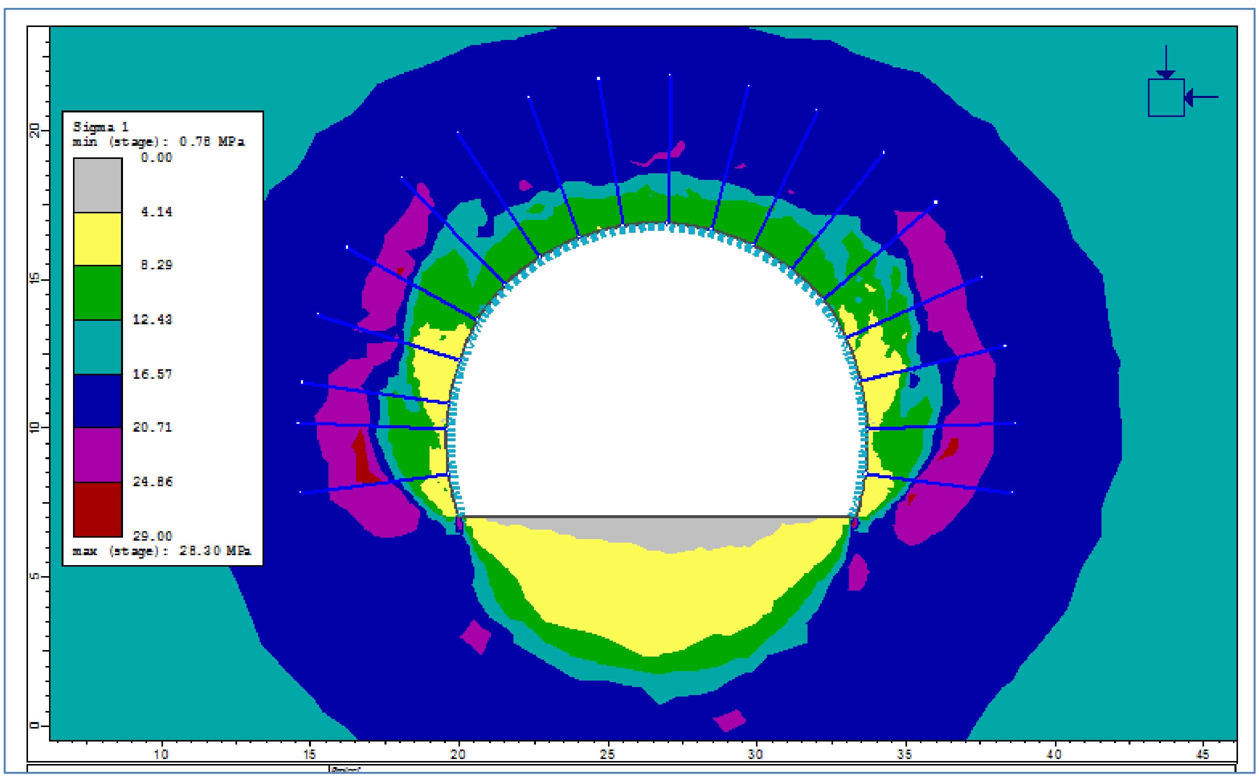


Figure-14: Major Principal Stresses

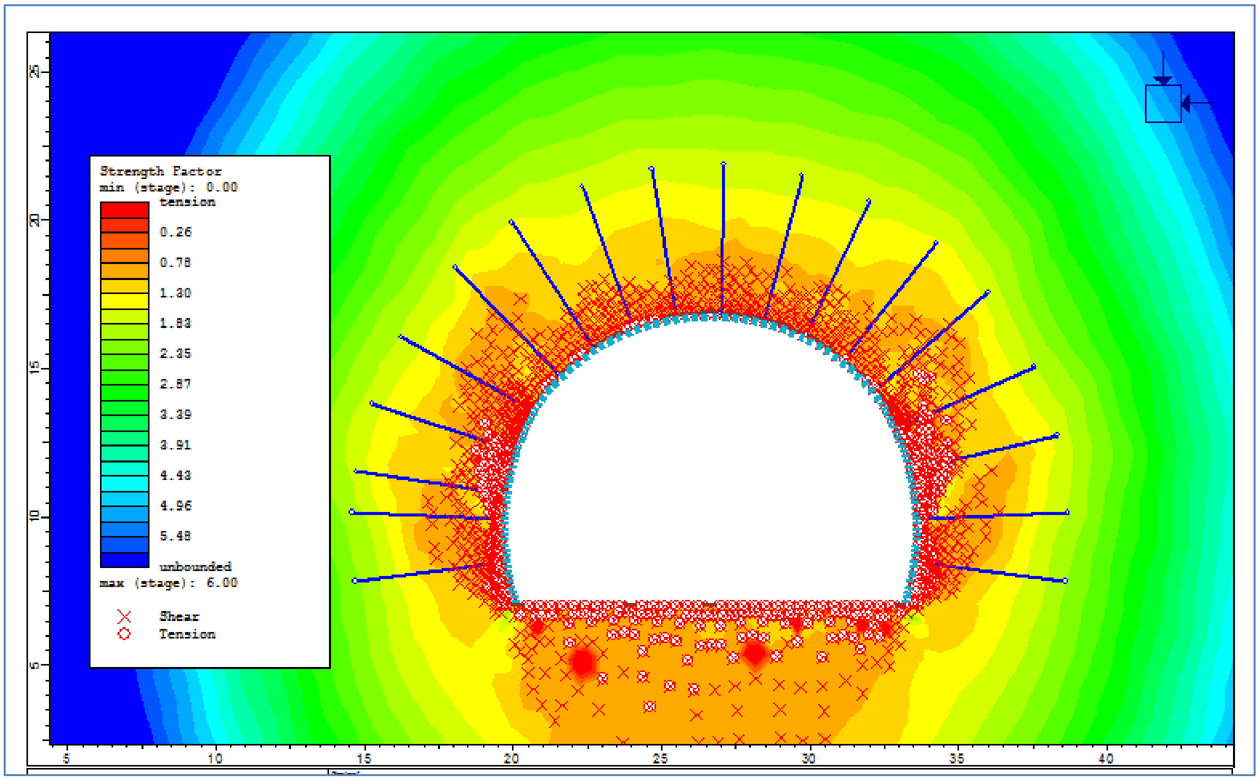


Figure-15: Yield Zone and Strength Factor around Opening

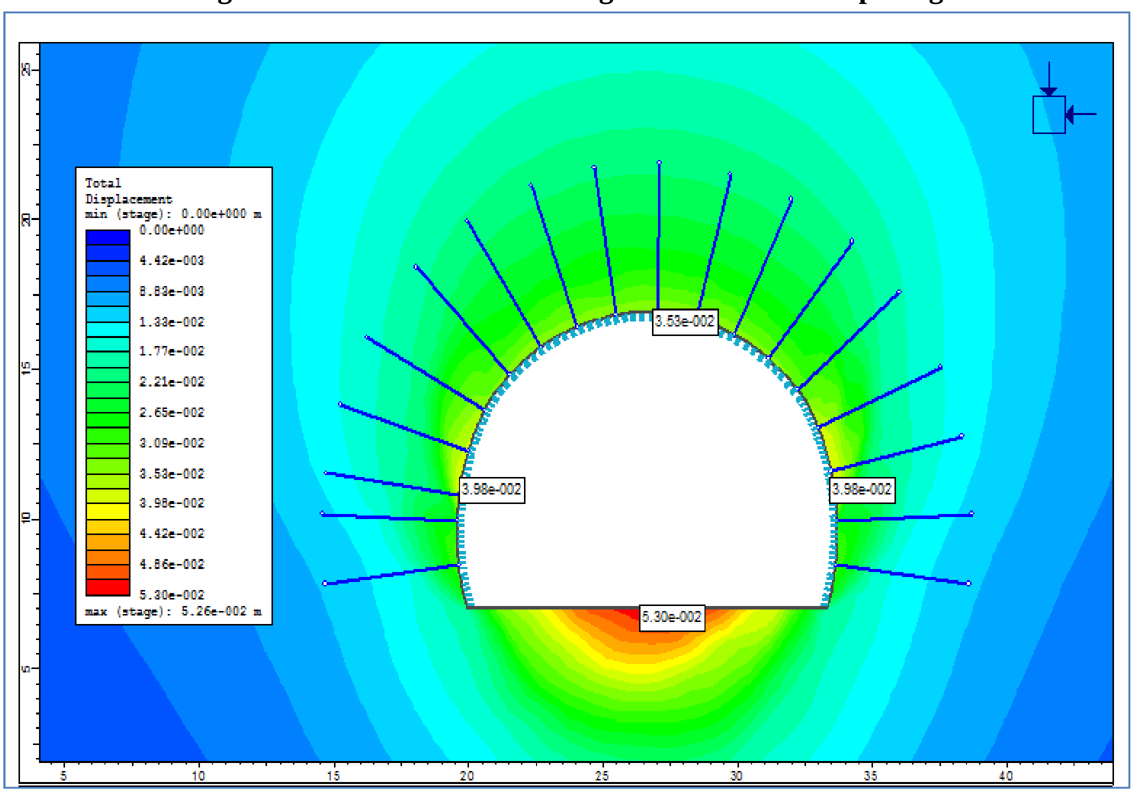


Figure-16: Maximum Deformation

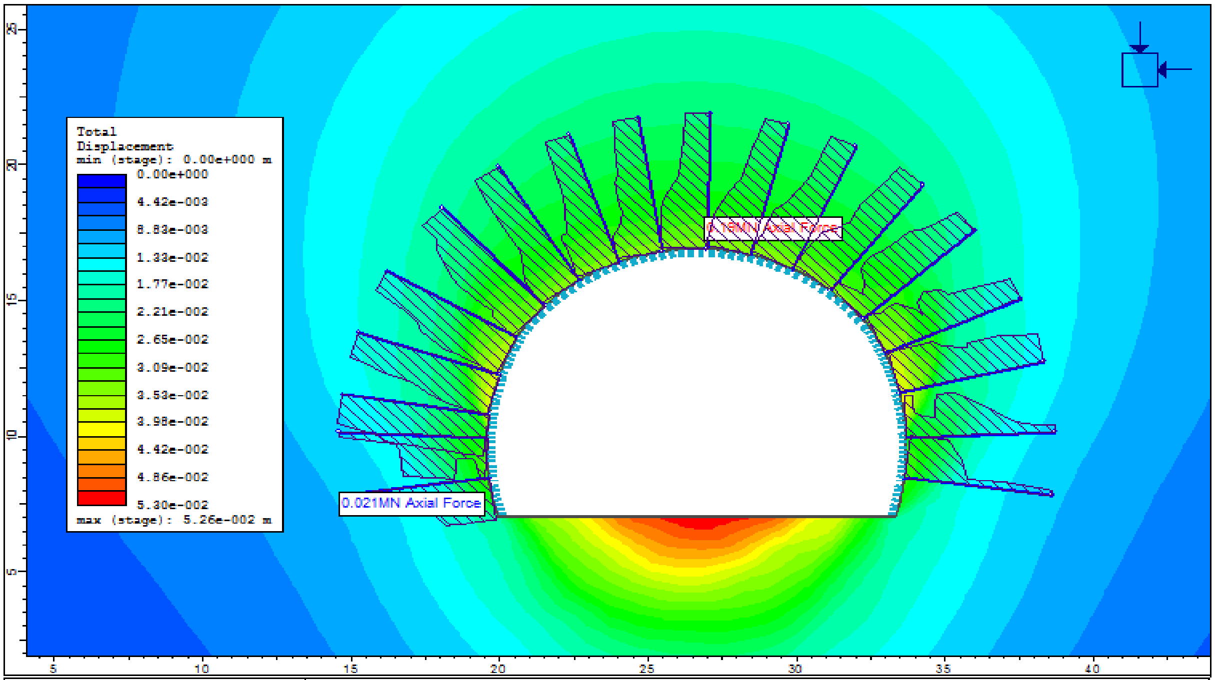


Figure-17: Axial Force in Bolts

4.7 Class-D Rock mass

- ➢ Rock Unit Weight - 27 KN/m3
- ➢ Ultimate Compressive Stress - 40 MPa
- ➢ Geological Strength Index - 30
- ➢ Young's Modulus - 1107 MPa
- ➢ Poisson Ratio - 0.25
- ➢ Dilation Angle - 40

Support System-1: 100 mm thick shotcrete with wire mesh, rock bolts of 25 mm dia. 6.0 m long and 1.5 m c/c spacing and steel ribs of ISMB 250 @ 1000 mm c/c as initial support and 400 mm thick concrete lining as final support.

Support System-2: 100mm thick shotcrete, rock bolts of 25 mm dia. 5.0 m long and 2 m c/c spacing and 3 bar lattice girder @ 1000 mm c/c as initial support and 400 mm thick concrete lining as final support.

Results & Discussion: The major principal stresses and deformations around the tunnel are shown in Figure 18 & 20 respectively. The maximum stress value generated in the rock mass is 7.8 MPa and maximum deformation at the tunnel boundary is only 81.0 mm. Hence the support system provided is adequate.

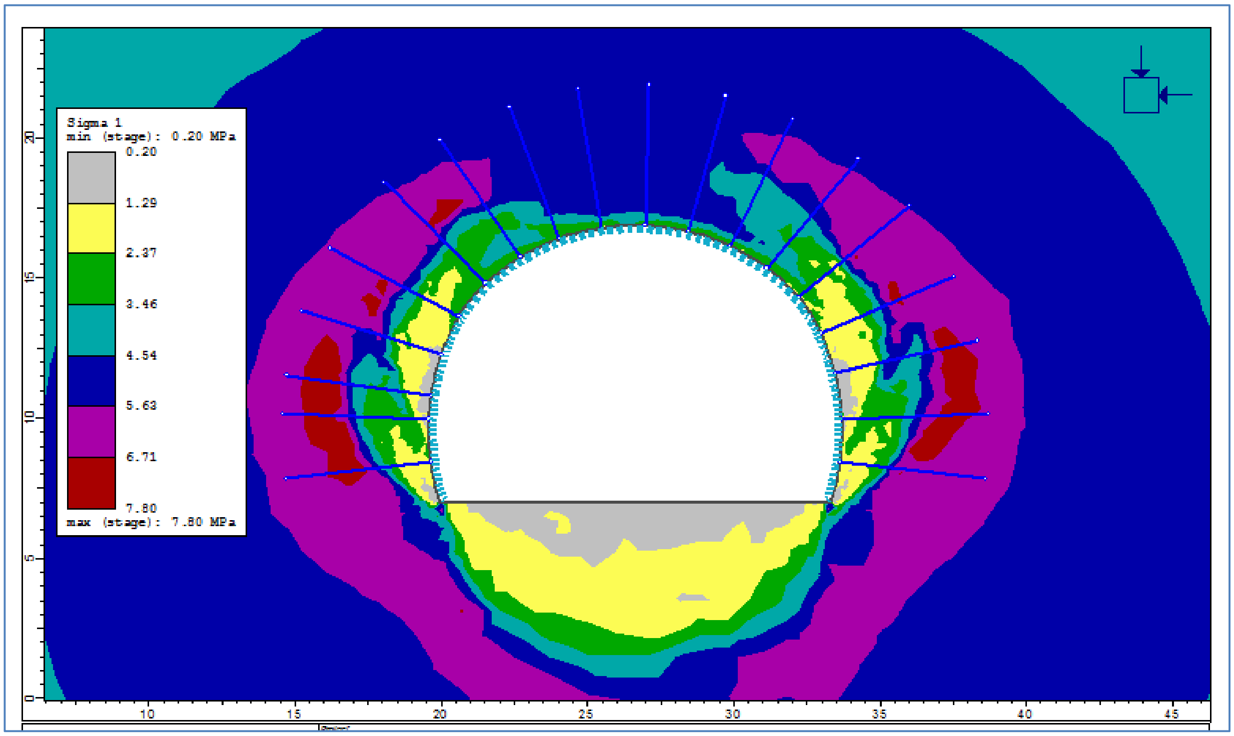


Figure-18: Major Principal Stresses

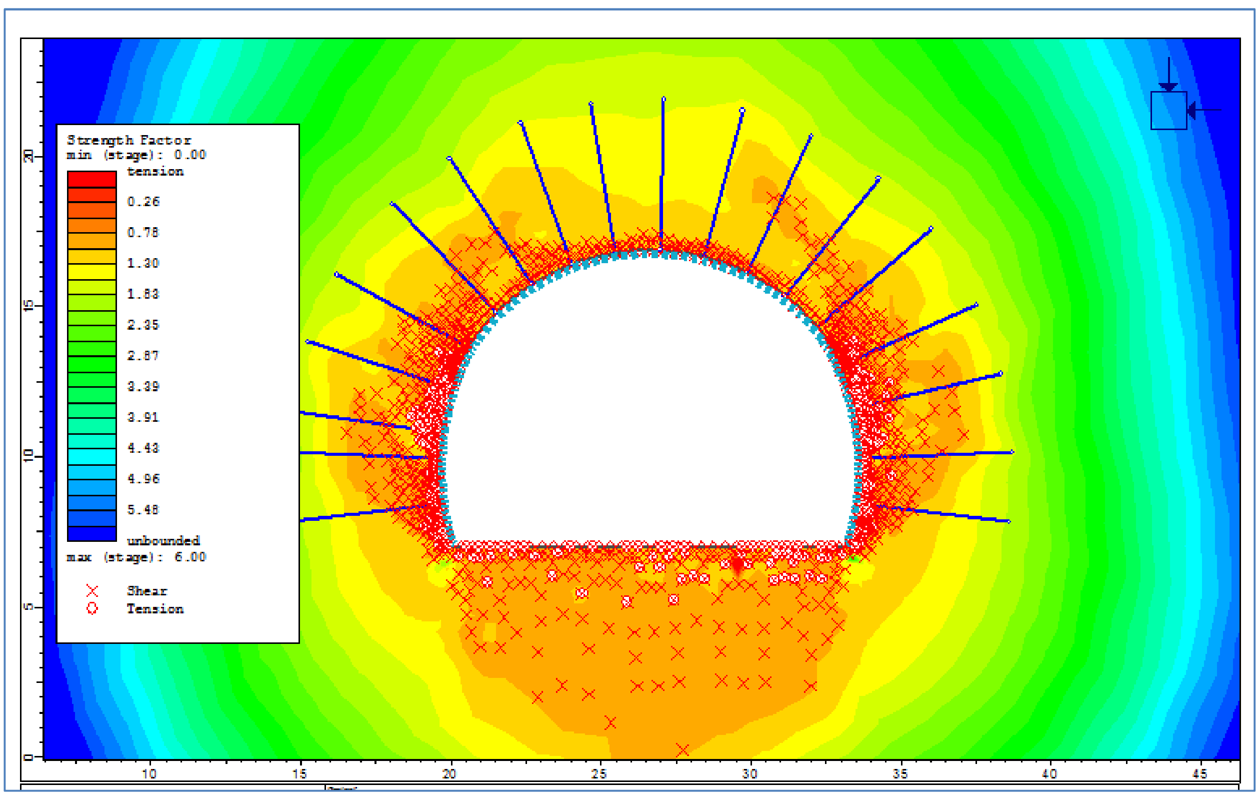


Figure-19: Yield Zone and Strength Factor around Opening

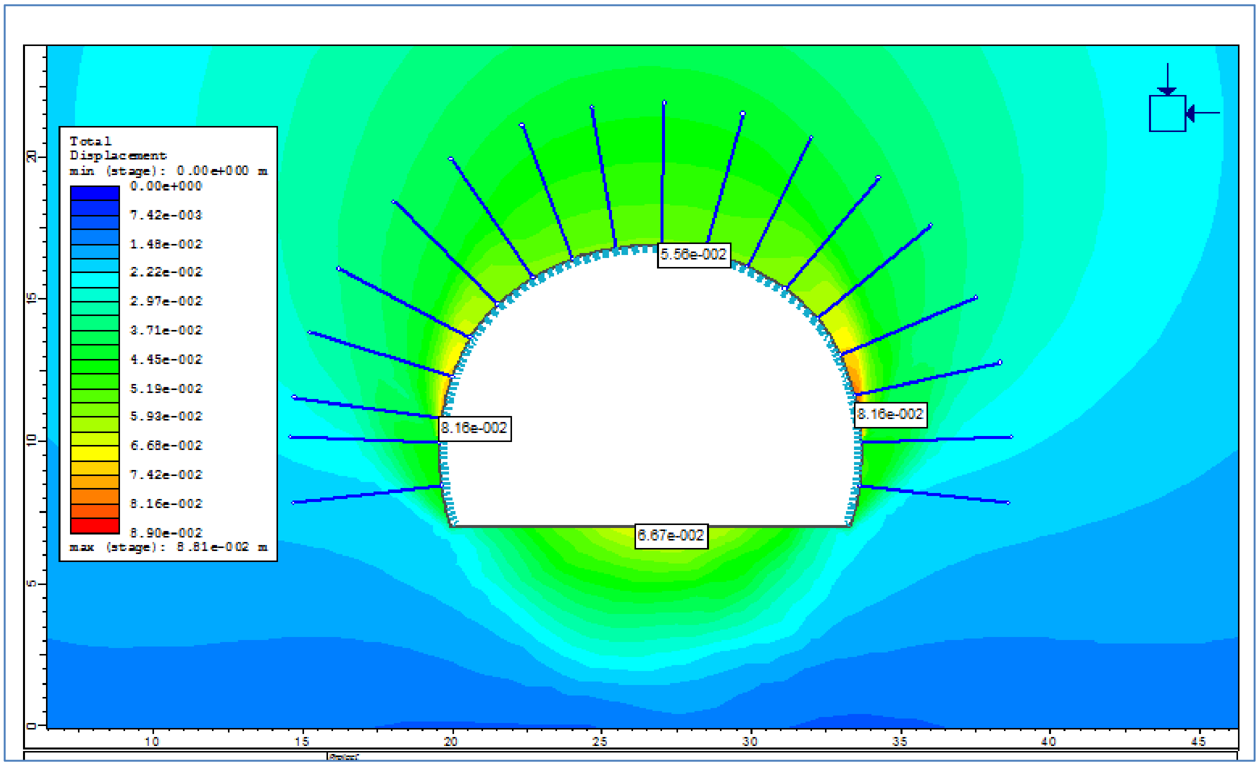


Figure-20: Maximum Deformation

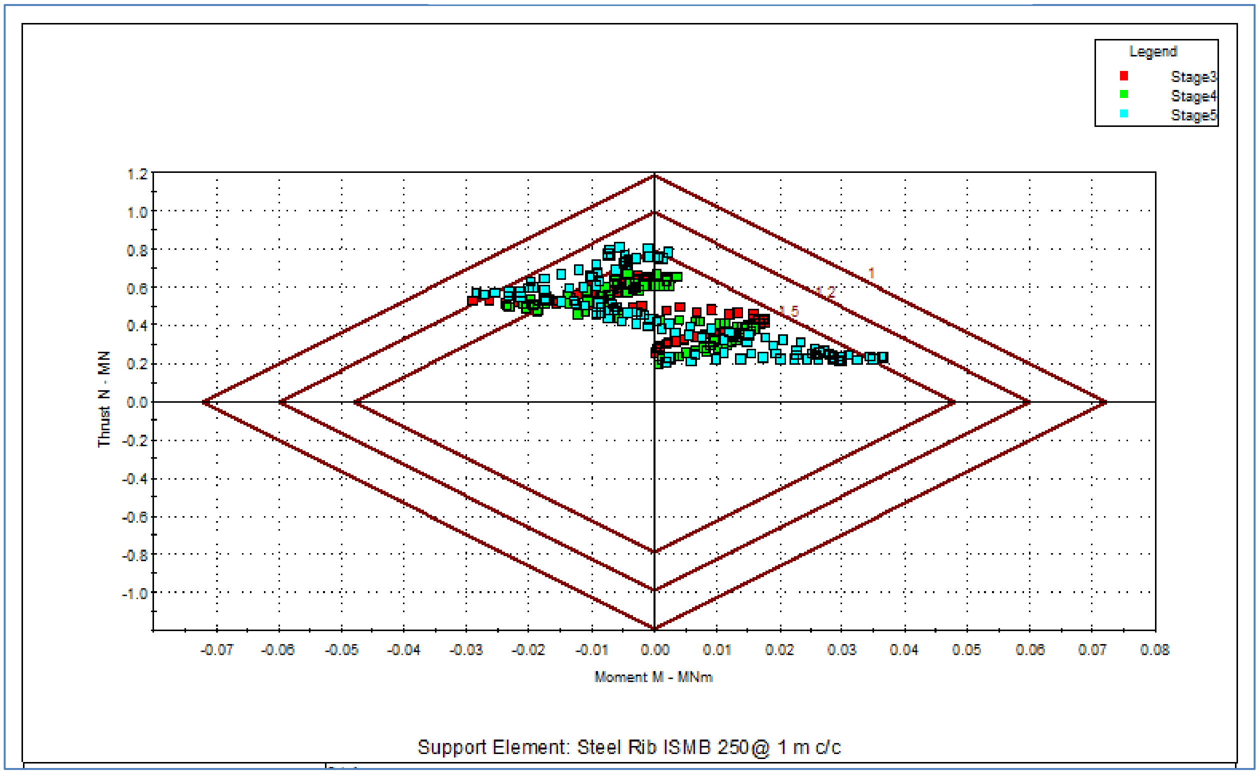


Figure-21: Moment Vs Thrust Capacity ISMB 250@ 1 m c/c

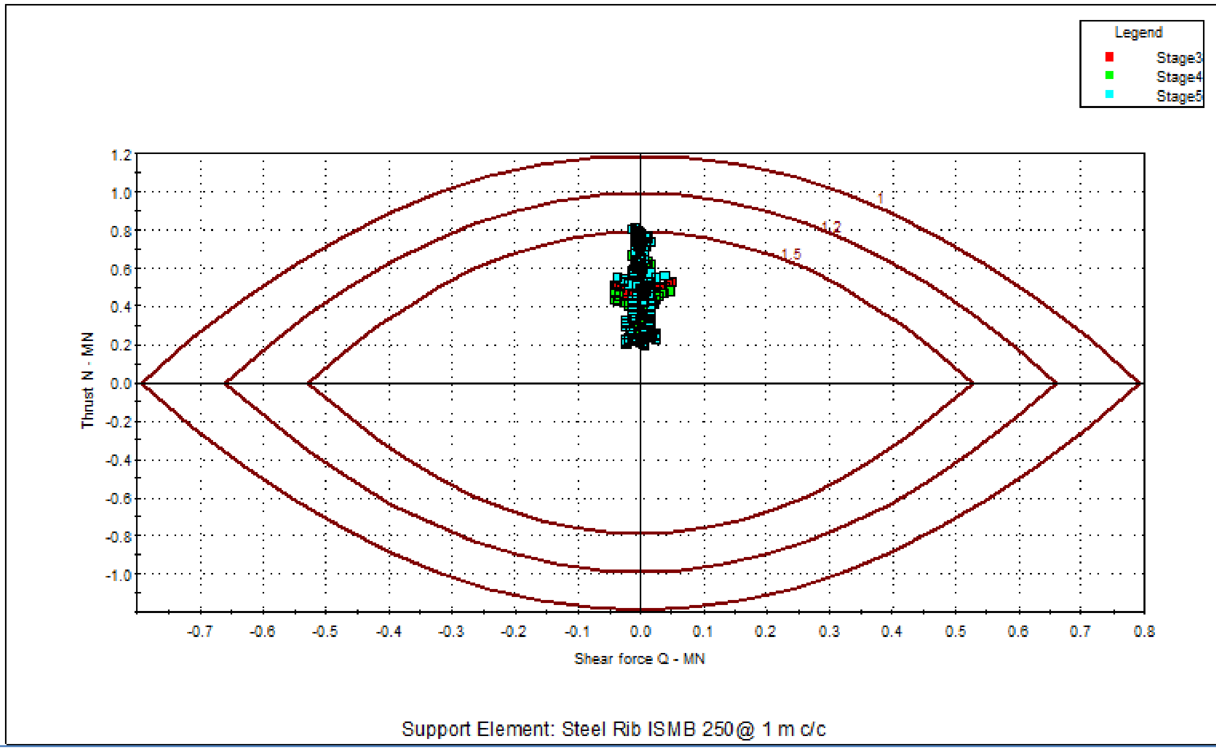


Figure-22: Shear Vs Thrust Capacity ISMB 250@ 1 m c/c

4.8 Class-E Rock mass

- Rock Unit Weight - 27 KN/m3
- Ultimate Compressive Stress - 30 MPa
- Geological Strength Index - 20
- Young's Modulus - 692 MPa
- Poisson Ratio - 0.30
- Dilation Angle - 40

Support System-1: 100 mm thick shotcrete with wire mesh, rock bolts of 25 mm dia. 6.0 m long and 1.5 m c/c spacing and steel ribs of ISMB 250 @ 500 mm c/c as initial support and 400 mm thick concrete lining as final support.

Results & Discussion: The major principal stresses and deformations around the tunnel are shown in Figure 23 & 25 respectively. The maximum stress value generated in the rock mass is 5.00 MPa and maximum deformation at the tunnel boundary is only 128.0 mm. Hence the support system provided is adequate.

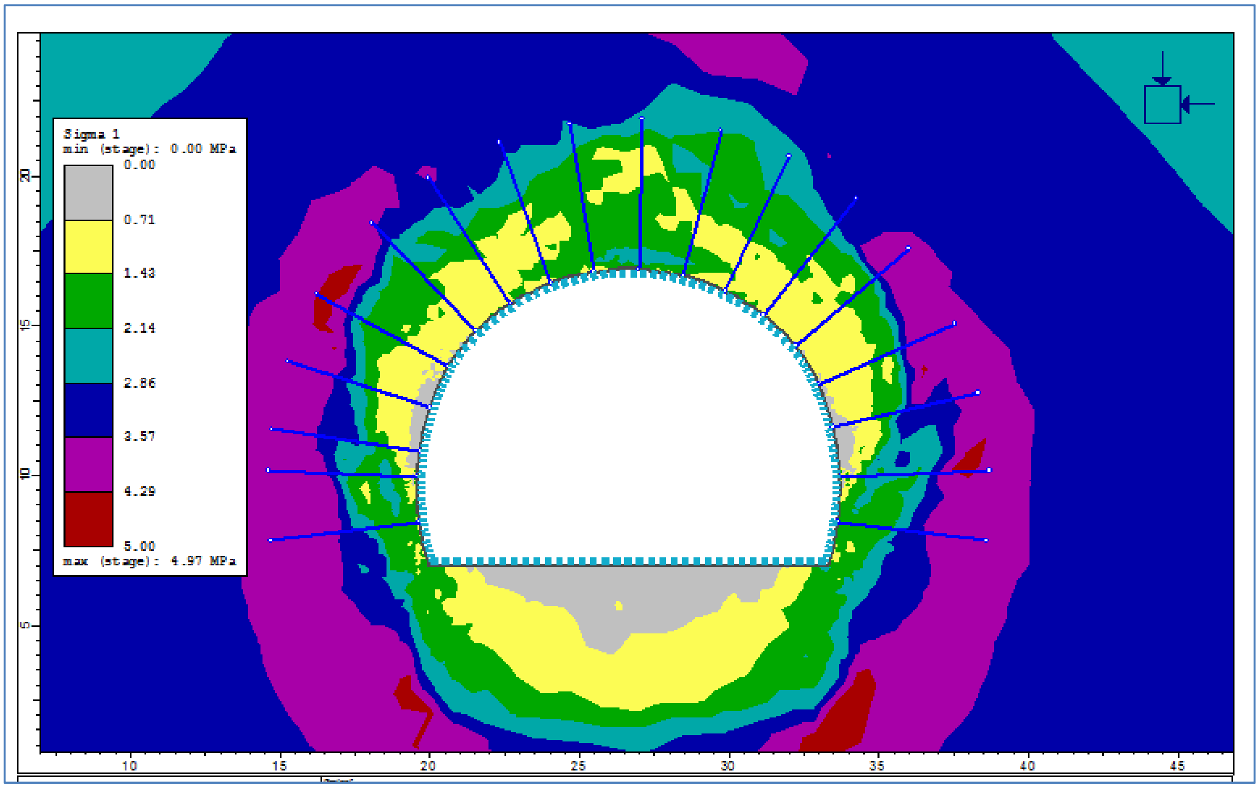


Figure-23: Major Principal Stresses

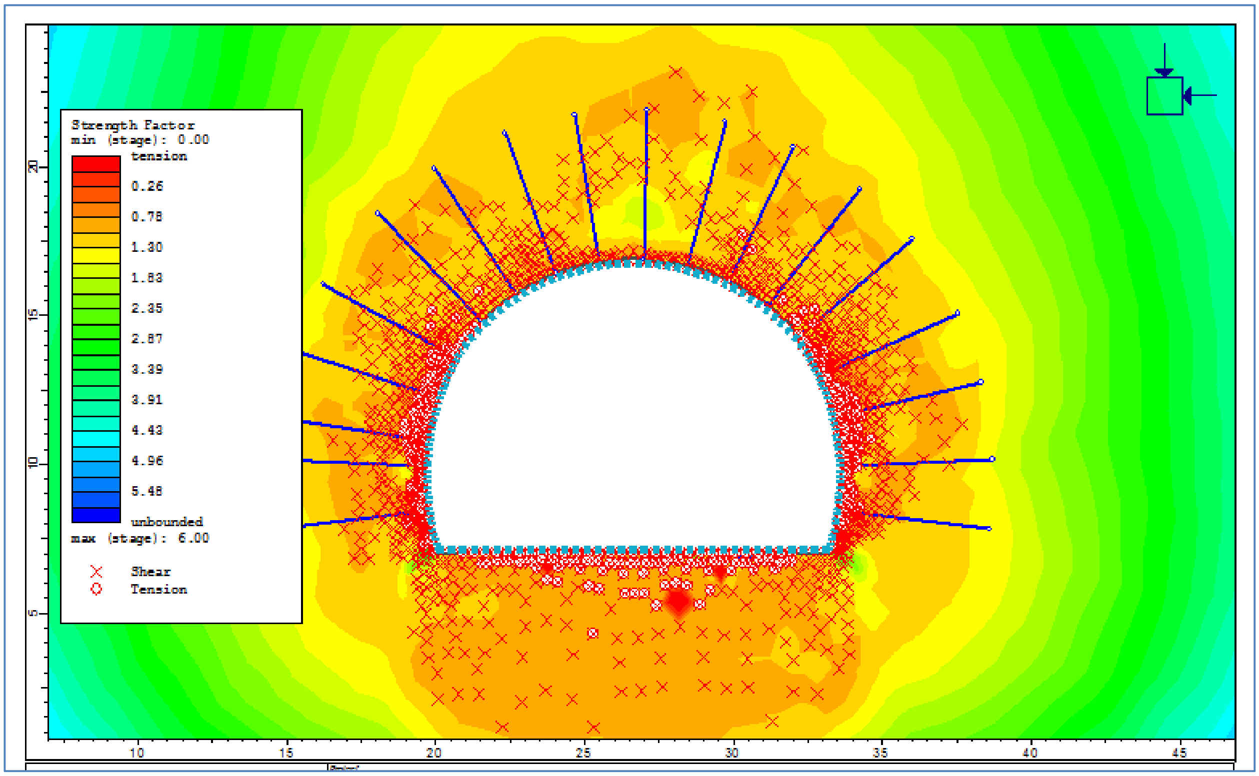


Figure-24: Yield Zone and Strength factor around opening

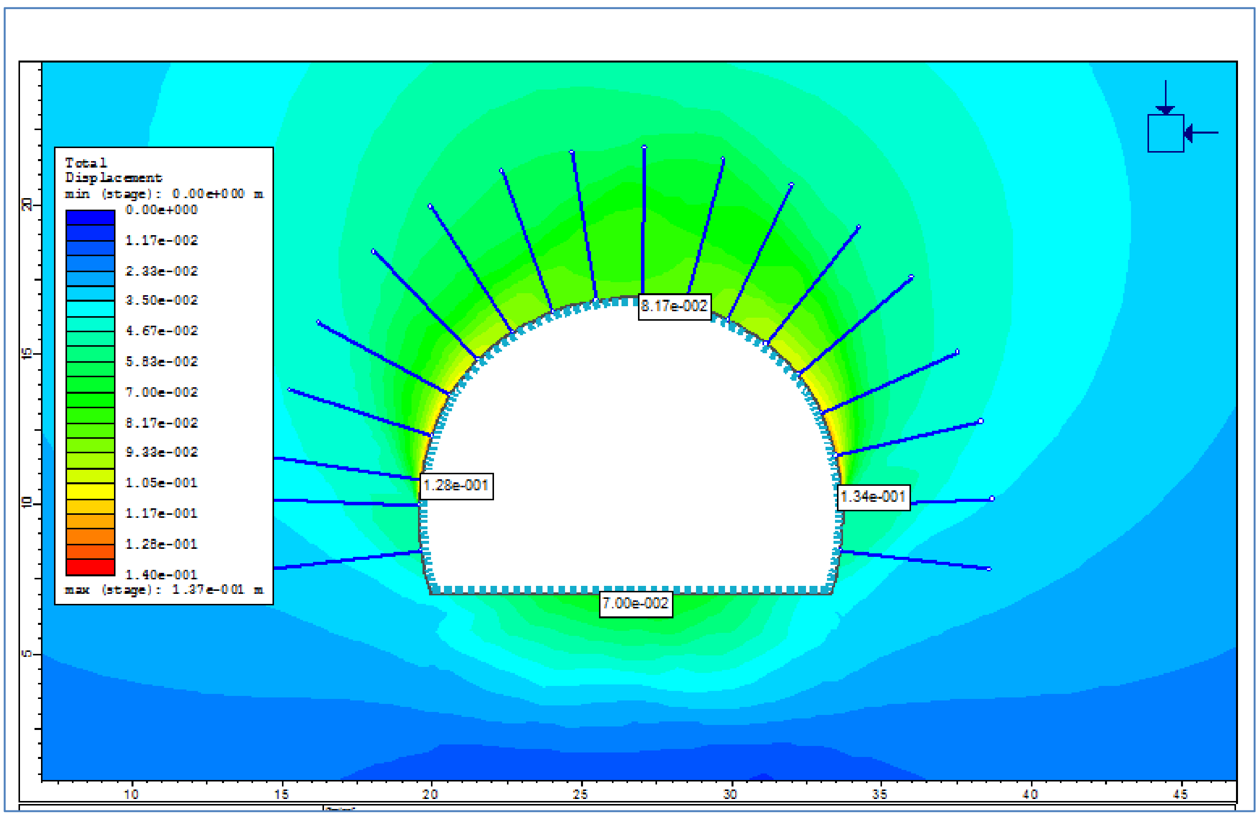


Figure-25: Maximum Deformation

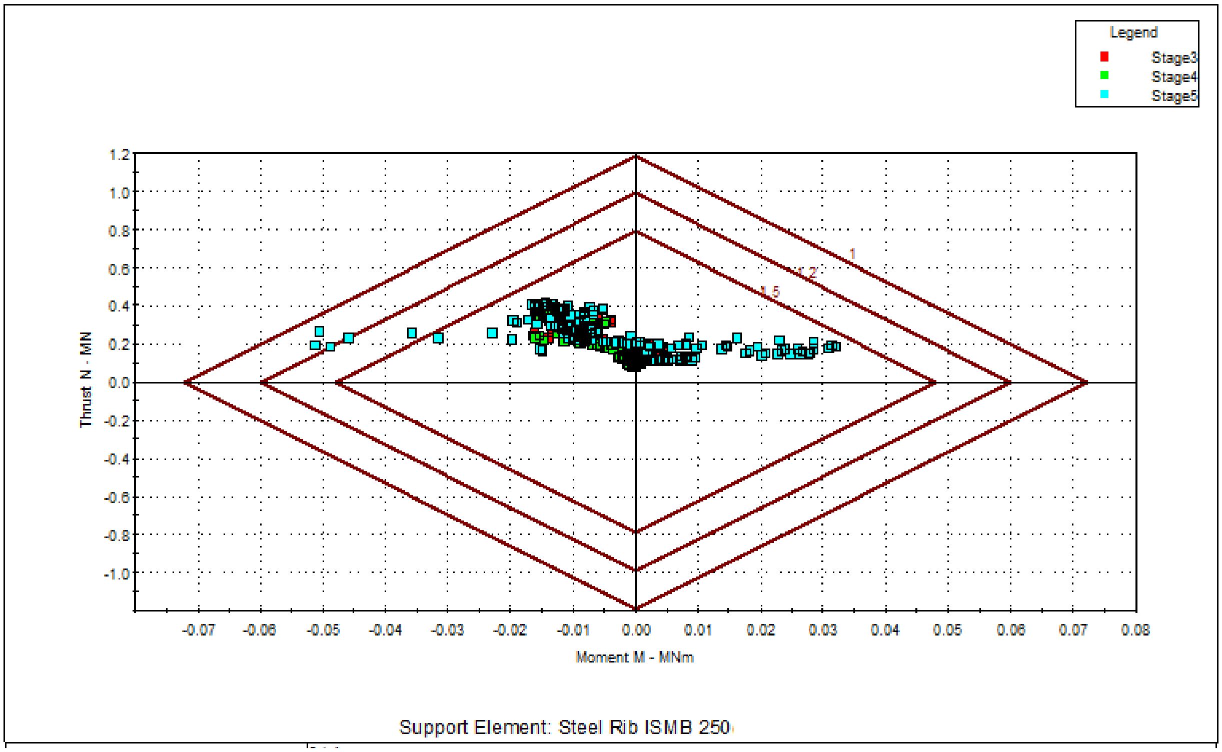


Figure-26: Moment Vs Thrust Capacity ISMB 250@ 0.5 m c/c

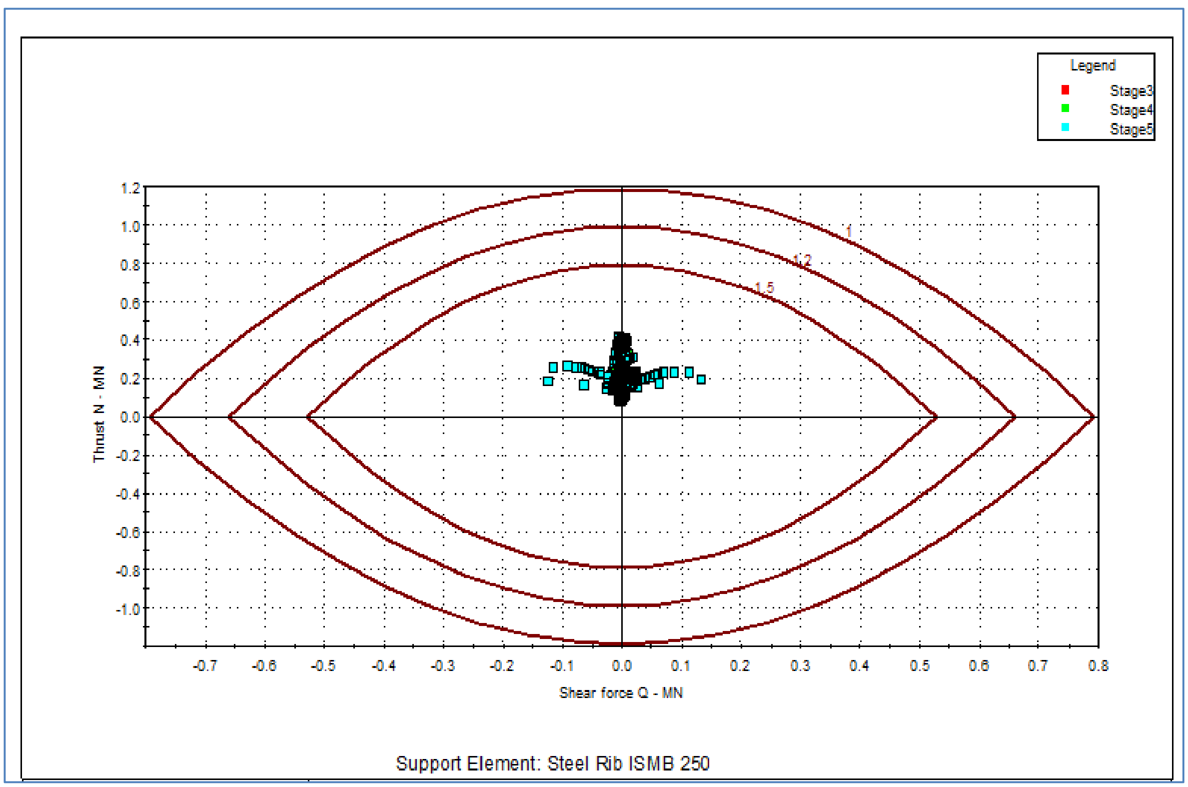


Figure-27: Shear Vs Thrust Capacity ISMB 250@ 0.5 m c/c

5 Analysis, Design & Results

Five numerical models for the rock mass types (Class A to E) defined earlier have been run with stress parameters expected in the field as defined in **Error! Reference source not found.**. The rock mass response to excavation of the tunnel in the different rock mass classes is analyzed. Further to this, the supports have been modeled in the numerical analysis software Phase^2 and checked for its adequacy. Results are presented below for different classes of rock. Results of the analyses are summarized in Table-.

From the comparison of results presented in Table-, it is evident that the stability of the excavation is influenced primarily by the modulus values and strength properties of the rock mass. In particular, zones of possible yielding of the material extend to larger limits with reduced modulus and material properties. Rock mass properties as well as the far-field stresses adopted in the exercise have been assumed on the basis of literature and limited tests result available at this point in time. The steel supports in the analysis are modeled as a liner connected to the excavation nodes.

It is worth noting that the maximum predicted displacement of the Tunnel (in Class Class E type rock) is of the order of **128** mm and tunnel closure is in the range of **256** mm in the present analysis, which is less than 2% of excavated span and it falls under normally accepted limit for rigid support system as per IS: 13365 (Part 2):1992. However in rock class Class A, Class B, Class C and Class D tunnel closures are 16mm, 28mm, 102mm and 160 mm respectively, which is well within the allowable limit. It is also observed that the material behavior improves with the increasing RMR values. The yielded rock mass zone has been observed to remain within the rock bolt lengths

Table-6: Summary of Analysis Results Tunnel

Case	**Rock mass Class**	**Support Condition**	**Description**	**Comments on Analysis Results (After Full Excavation)**
1	Class-A	**With Support**	• Heading and benching excavation. • 50mm thick Shotcrete. • 5m long, Φ25 (20MT capacity) fully grouted rock bolts @ 2.5m c/c.	• Significant yielding zone around (0.9m) but contained within rock bolt length. • Axial force in rock bolt is 4.5MT • Maximum deformation on tunnel boundary equal to 7.8mm. • No yielding of shotcrete above SPL, however at some place

Case	Rock mass Class	Support Condition	Description	Comments on Analysis Results (After Full Excavation)
				yielding of shotcrete at haunch portion is observed. • Though the maximum deformation after installation of support is not substantial, however as the joint sets are closely spaced (1.5m – 2m) the spacing of the bolts are not increased beyond 2.5m c/c
2	Class B	**With Support**	• Heading and benching excavation. • 75mm thick Shotcrete. • 5m long, Φ25 (20MT capacity) fully grouted rock bolts @2m c/c.	• Significant yielding zone around (1.5m) but contained within rock bolt length. • Axial force in rock bolt is 19 MT • No yielding in rock bolts is observed and overall excavation is stable. • Maximum deformation on tunnel boundary equal to 14 mm. • No yielding of Shotcrete above SPL, however at some place yielding of Shotcrete at haunch portion is observed, which not area of concern. • Though the maximum deformation after installation of support is not substantial, however as the joint sets are closely spaced (1.5m – 2m) the spacing of the bolts for Class B are not increased beyond 2m c/c

Case	Rock mass Class	Support Condition	Description	Comments on Analysis Results (After Full Excavation)
3	Class C	**With Support**	• Heading and benching excavation. • 100mm thick SFRS. • 5 m long, Φ25 (20MT capacity) fully grouted rock bolts @1.5m c/c.	• Significant yielding zone around (3m) but contained within rock bolt length. • Axial force in rock bolt is 19 MT • No yielding in rock bolts is observed and overall excavation is stable. • Maximum deformation on tunnel boundary equal to 52 mm. • No yielding of Shotcrete above SPL, however at some place yielding of Shotcrete at haunch portion is observed, which not area of concern. • Though the maximum deformation after installation of support is not substantial, however as the joint sets are closely spaced (1.5m – 2m) the spacing of the bolts for Class C are not increased beyond 1.5m c/c

Case	Rock mass Class	Support Condition	Description	Comments on Analysis Results (After Full Excavation)
4	Class-D	**With Support**	• Heading and benching excavation. • 100mm thick Shotcrete. • 6 m long, Φ25, fully grouted rock bolt @1.5m c/c. • Steel Rib (ISMB250) @ 1m c/c. • 75mm thick Precast Lagging. • 175 mm thick M15 Concrete Backfill.	• Maximum Yielding zone is around (3m) but contained within rock bolt length. • Some local yielding in rock bolts is observed however overall excavation is stable. • Maximum deformation on tunnel boundary equal to 82mm. • Stresses in Steel Rib is within permissible limits. • Shotcrete will yield at some places near haunch but that will be retained intact with support of lattice girder and bolt.
5	Class-E	**With Support**	• 100mm thick Shotcrete. • 6 m long, Φ25, fully grouted rock bolt @1.5m c/c. • Steel Rib (ISMB250 @ 0.5m c/c. • 75mm thick Precast Lagging. • 175 mm thick M15 Concrete Backfill • pipe roofing and Face Support as Additional Precaution	• Maximum deformation on tunnel boundary equal to 42mm. • Stresses in Lattice Girder within permissible limits. • Tunnel closure is 256 mm, which is less than 2%, that is allowable in case of Steel Ribs as support.

Excavation sequences in Phase2 is modelled in total five stage ,Stage-1 model generation and initialization of field stress ,Stage-2 material softening for heading portion , Stage 3 Heading excavation and support , Stage-4 material softening for Benching portion and Stage-5 is benching excavation and support installation . The discretisation scheme with boundary conditions and excavation stages is shown above in Fig. 6. The results of the analysis in terms of major principal stresses and total displacement contours for various stages of excavation, yield zone around the tunnel after final excavation stage and axial forces in bolts after complete excavation are shown for all class of rock in Fig. 7to 27.

6 Recommended Support System for Tunnel

Based on the above analysis, the support system recommended for tunnel is, as shown in Table 3

Table -7: Recommended Rock Support System for Tunnel

Rock Class	RMR	Rock Support			
		Shotcrete	Lattice Girders	Rock Bolts	Pipe Roofing
Class A	81-100	50 mm thick shotcrete mainly above springing line	--	Spot bolting (where ever required) @2.5 m c/c	--
Class B	61-80	75 mm thick shotcrete	--	25mmΦ, 5 m long fully grouted rock bolts @ 2.0 m c/c in crown in staggered pattern	--
Class C	41-60	100 mm thick shotcrete with one layer of wire mesh 100mmx100mmx6 mm	--	Systematic rock bolting, 25mmΦ, 5 m long fully grouted rock bolt @ 1.5 m c/c staggered at crown & wall	--
Class D	21-40	100 mm thick shotcrete with one layer of wire mesh 100mmx100mmx6 mm.	Steel Rib ISMB250@ 1 m c/c as shown in drawings 75mm thick Precast Lagging.	Systematic rock bolting, 25mmΦ, 6 m long fully grouted rock bolts @ 1.5 m c/c staggered at crown & wall	If required

			175 mm thick M15 Concrete Backfill		
Class E	<20	100 mm thick shotcrete with one layer of wire mesh 100mmx100mmx6 mm.	Steel Rib ISMB250 @ 0.5 m c/c as shown in drawings. 75mm thick Precast Lagging. 175 mm thick M15 Concrete Backfill	Systematic rock bolting, 25mm Φ, 6 m long fully grouted rock bolts @ 1 m c/c staggered at crown & wall	114 mm Dia 8 mm thick ,10.0 m long Pipe Roofing @ 300 mm c/c

i) Pipe roof umbrella of 114 mm dia. perforated pipes (Four perforations per metre), 8 mm thick, and 10 m long with overlap of 4 m with next pipe roof umbrella @ 300 mm centre to centre at an angle of 5^0 upward. The grouting at pressure of 5 kg/cm^2 shall be carried out through these pipes, to improve the strength of the material around the crown. Only after completing the one pipe (10 m length) drilling and grouting, the next pipe shall be drilled and grouted and so on for the remaining pipes. After Grouting, the pipes shall be filled with grout paste. The Steel rib ISMB 250 @ 0.5 m c/c shall also be placed after 100 mm thick shotcrete with one layer of wire mesh 100mm x 100mm x 6 mm as shown in drawings.

ii) 25 mm dia., 6 m long fully grouted rock bolts @ 1.5 m c/c in crown and walls shall be provided.

The excavation shall be strictly done as per the excavation sequence/stages/ cycles and only after installation of the support system after each excavation cycle, the next cycle of excavation shall be undertaken in each stage of the excavation. The excavation cycle of 750 mm-1000 mm (For Class D & E) length shall be considered as per site conditions for excavation and support system and only after supporting this stretch, the next cycle of excavation shall be undertaken. Only after completing the above support measures in each stage, the next stage of the excavation shall be carried out. Before installation of pipe roof umbrella, the 100 mm thick shotcrete with one layer of wire mesh shall be applied on the face after each excavation cycle i.e. 750-1000 mm length and excavation sequence i.e. after every 6 m length, the pipe roof system, shall be executed in each stage of heading. The design parameters shall be validated at site by actual testing. The capacity of the rock bolts shall be validated at site and shall be communicated to the designer on priority. If the strata encountered during excavation is different than that of the strata considered in the design, then the above design shall be modified and this information shall be provided to the designer and the design shall be updated based on the actual design parameters. The measurement/monitoring of the deformation of tunnel shall be carried out in a systematic manner and this information shall be provided to the designer on continuous basis.

ANNEXURE -1A

TUNNEL ROCK SUPPORT DESIGN FOR CLASS A ROCK, Q=40-1000

1 ASSUMPTIONS:-

Finished Width of Tunnel	=		13.00 m		
Lining Thickness	=		400.00	mm	
Payline	=		100	mm	
Thickness of shotcrete tc	=		50	mm	
Excavated height of Tunnel	=		9.90 m		
Excavated Width of Tunnel	=		14.10 m		

	Q	J_r	Considering Spacing of rock bolt in Crown	Considering Spacing of rock bolt in Wall
Good Rock	40	3	2.5 m	-

Diameter of rock bolt	=	25 mm	
Length of Rock Bolt Where B is excavated width	=	2+ 0.15 B/ESR	
ESR =Excavation Support Ratio	=	1.3	For Highway Tunnel
Length of Rock Bolt Required	=	3.6	m
Provided Length of rock bolt	=	5.0 m	
characteristic compressive strength of shotcrete	=	35	N/mm^2
Yield strength of rock bolt (fy)	=	500	N/mm^2
Yield load of bolt ($f_y A_b$)	=	245.44 kN	
Factor of Safety for bolt	=	1.5	
Allowable load in bolt	=	163.62 kN	

1.1 Vertical Support Pressure for Crown

$$P_{ru} = \frac{2.0\, Q_{ru}^{-\frac{1}{3}} f}{J_r}$$ kg/cm^2 As per clause 3.5.1.1a of IS-13365 (Part2): 1992

Where

P ru = Ultimate roof support pressure

Q ru = Ultimate rock mass quality = Q

J r = Barton's joint roughness coefficient.

H= Over burden above crown in tunnel.

f = maximum of (1 , 1+(H-320)/800)

For the present case H varies from 50 m to 500 m for Tunnel , adopted value of H is

H = 500 m

f= 1.23

1.2 Ultimate Wall Support Pressure

As per clause 3.5.1.2b of IS: 13365 (Part-2) 1992,

Type of rock	**Q value**	**Q wu**
Very Good to Extremely Good	Q >10	5.00 Q

The ultimate wall support pressure P_{wu}

$$P_{wu} = \frac{2.0\, Q_{wu}^{-\frac{1}{3}} f}{J_r}$$ kg/cm^2

Pwu = Ultimate wall support pressure

Qwu = Ultimate wall rock mass quality

1.3 Roof and wall support pressure

S.No.	**Rock Mass Type**	**Q**	**Qru (for Roof)**	**Q_{wu} (for Wall)**	**J_r**	**Support roof pressure (kN/m^2)**	**Support wall pressure (kN/m^2)**
1	Very Good to Extremely Good Rock	40	40	200	3	23.88	13.96

Design of Integrated support System for Good Rock

1.4 Load carried by Shotcrete

Shear strength	=	300	t/m^2
	=	3.00	N/mm^2
	=	30.00	Kg/cm^2
Thickness of shotcrete	=	50	mm

Resistance offered by shotcrete = $$\frac{2\, q_{sc}\, t_{sc}}{BF_{sc}}$$ As per Clause 10.4.1 of IS 15026:2002

Where qsc =Shear Strength of Shotcrete =3 N/mm2
tsc = thickness of Shotcrete =50 mm
Fsc = (0.6±0.05) = 0.65 for present case
B = Size of opening = 14.1m

Shear strength offered by 50 mm thick shotcrete = 0.327 Kg/cm^2

Load Taken by Shotcrete (50mm thick) = **Psc** = **32.73** **kN/m^2**

1.5 Load carried by Bolt

Diameter of Rock Bolt , d	=	25 mm	
Grade of steel used for Rock Bolt , f_y	=	Fe 500	
Grade of shotcrete	=	M 35	
Width of excavation (B)	=	14.10	m
Cross Sectional Area of Rock Bolt	=	490.87	mm^2
Yield load of bolt ($f_y A_b$)	=	245.435	kN
Factor of Safety of Bolt	=	1.5	

Load carrying capacity of Rock Bolt (P)	=	163.62	kN
Considering Spacing of Rock Bolt	=	2.50 m	m
Area of Influence of Rock Bolt (A)	=	6.25	m^2
Load carrying capacity of Bolt for given spacing =(P/A) =	=	**P bolt = 40.91**	**kN/m^2**

1.6 Support System Compability Equation Crown

Ultimate support pressure = Total capacity of the support system

$$u + p_{roof} = p_{sc} + p_{bolt}$$

u = Pore water pressure , in this case it is assumed as zero)

U+P roof = 23.88 **kN/m^2**

P sc+P bolt = 73.64 **kN/m^2**

Since 73.64 >>23.88 Hence OK

1.7 Support System Compability Equation Side Walls

P_{wall} = 13.965 **kN/m^2**

P_{sc} = 32.733 **kN/m^2**

No need of bolt in side wall

Summary of Results	
Diameter of Rock Bolt =	**25 mm**
Length of Rock Bolts =	**5 m**
Spacing of Rock Bolt =	**Only spot bolting**
Thickness of Shotcrete =	**50 mm**

ANNEXURE -1B

TUNNEL ROCK SUPPORT DESIGN FOR CLASS B ROCK, Q=10-40

1 ASSUMPTIONS:-

Finished Width of Tunnel	=	13.00 m	
Lining Thickness	=	400.00	mm
Payline	=	100	mm
Thickness of shotcrete tc	=	75	mm
Excavated height of Tunnel	=	9.90 m	
Excavated Width of Tunnel	=	14.15 m	

	Q	J_r	Considering Spacing of rock bolt in Crown	Considering Spacing of rock bolt in Wall
Good Rock	10	3	2.0 m	-

Diameter of rock bolt	=	25 mm	
Length of Rock Bolt	=	2+ 0.15 B/ESR	
Where B is excavated width			
ESR =Excavation Support Ratio	=	1.3	For Highway Tunnel
Length of Rock Bolt Required	=	3.6	m
Provided Length of rock bolt	=	5.0 m	
characteristic compressive strength of shotcrete	=	35	N/mm^2
Yield strength of rock bolt (fy)	=	500	N/mm^2
Yield load of bolt (f_y A_b)	=	245.44 kN	
Factor of Safety of Bolt	=	1.5	
Allowable load in bolt	=	163.62 kN	

1.1 Vertical Support Pressure for Crown

$$P_{ru} = \frac{2.0\, Q_{ru}^{-\frac{1}{3}} f}{J_r}$$

kg/cm^2 As per clause 3.5.1.1a of IS-13365 (Part2): 1992

Where

P ru = Ultimate roof support pressure

Q ru = Ultimate rock mass quality = Q

J r = Barton's joint roughness coefficient.

H= Over burden above crown in tunnel.

f = maximum of (1 , 1+(H-320)/800)

For the present case H varies from 50 m to 500 m for Tunnel , adopted value of H is

H = 500 m

f= 1.23

1.2 Ultimate Wall Support Pressure

As per clause 3.5.1.2b of IS: 13365 (Part-2) 1992,

Type of rock	**Q value**	**Q wu**
Good	Q >10	5.00 Q

The ultimate wall support pressure P_{wu}

$$P_{wu} = \frac{2.0 Q_{wu}^{-\frac{1}{3}} f}{J_r}$$ kg/cm^2

Pwu = Ultimate wall support pressure

Qwu = Ultimate wall rock mass quality

1.3 Roof and wall support pressure

S. No.	Rock Mass Type	Q	Qru (for Roof)	Q_{wu} (for Wall)	J_r	Support roof pressure (kN/m^2)	Support wall pressure (kN/m^2)
1	Good Rock	10	10	50	3	37.91	22.17

Design of Integrated support System for Good Rock

1.4 Load carried by Shotcrete

Shear strength	=	300	t/m^2
	=	3.0	N/mm^2
	=	30.00	Kg/cm^2
Thickness of shotcrete	=	75	mm

Resistance offered by shotcrete

$$\frac{2 q_{sc} t_{sc}}{BF_{sc}}$$

As per Clause 10.4.1 of IS 15026:2002

=

Where qsc =Shear Strength of Shotcrete =3 N/mm2
tsc = thickness of Shotcrete =75mm
Fsc = (0.6±0.05) = 0.65 for present case
B = Size of opening = 14.15m

Shear strength offered by 75 mm thick shotcrete =			0.489	Kg/cm^2
Load Taken by Shotcrete (75 mm thick) =	**Psc**	=	**48.93**	**kN/m^2**

1.5 Load carried by Bolt

Diameter of Rock Bolt , d	=	25 mm	
Grade of steel used for Rock Bolt , f_y	=	Fe 500	
Grade of shotcrete	=	M 35	
Width of excavation (B)	=	14.15	m
Cross Sectional Area of Rock Bolt	=	490.87	mm^2
Yield load of bolt (fy Ab)	=	245.435	kN
Factor of Safety of Bolt	=	1.5	
Load carrying capacity of Rock Bolt (P)	=	163.62	kN
Considering Spacing of Rock Bolt	=	2.00 m	m

Area of Influence of Rock Bolt (A)	=	4	m^2
Load carrying capacity of Bolt for given spacing =(P/A) =	=	P bolt = 40.91	kN/m^2

1.6 Support System Compability Equation Crown

Ultimate support pressure = Total capacity of the support system

$$u + p_{roof} = p_{sc} + p_{bolt}$$

u = Pore water pressure , in this case it is assumed as zero)

U+P roof = 37.91 kN/m^2

P sc+P bolt = 89.83 kN/m^2

Since 89.83 >>37.91 Hence OK

1.7 Support System Compability Equation Side Walls

P_{wall} = 22.168 kN/m^2

P_{sc} = 48.926 kN/m^2

No need of bolt in side walls

Summary of Results	
Diameter of Rock Bolt =	**25 mm**
Length of Rock Bolts =	**5 m**
Spacing of Rock Bolt =	**2 m Longitudinal Spacing at crown only**
Thickness of Shotcrete =	**75 mm thick shotcrete at crown and wall**

ANNEXURE -1C

TUNNEL ROCK SUPPORT DESIGN FOR CLASS C ROCK , Q = 4-10

1 ASSUMPTIONS:-

Finished Width of Tunnel	=	13.0 m
Lining Thickness	=	400.0 mm
Payline	=	100 mm
Thickness of shotcrete tc	=	100 mm

Excavated height of Tunnel	=	9.900 m				
Excavated Width of Tunnel	=	14.200 m				
		Q	Jr		Considering Spacing of rock bolt in Crown	Considering Spacing of rock bolt in Wall
Fair Rock		4.0	2.00		1.5 m	1.5 m
Diameter of rock bolt	=		25 mm			
Length of Rock Bolt	=		2+ 0.15 B/ESR			
Where B is excavated width						
ESR =Excavation Support Ratio	=		1.3	For Highway Tunnel		
Length of Rock Bolt Required	=		3.6 m			
Provided Length of rock bolt	=		5.0 m			
characteristic compressive strength of shotcrete	=		35	N/mm2		
Yield strength of rock bolt (fy)	=		500.00	N/mm2		
Factor of Safety of Bolt	=		1.5			

1.1 Vertical Support Pressure for Crown

$$P_{ru} = \frac{2.0\, Q_{ru}^{-\frac{1}{3}}\, ff'}{J_r}$$ kg/cm²

As per clause 3.5.1.1a of IS-13365 (Part2): 1992

Where

P ru = Ultimate roof support pressure

Q ru = Ultimate rock mass quality = Q

J r = Barton's joint roughness coefficient.

H= Over burden above crown in tunnel.

f = maximum of (1 , 1+(H-320)/800)

For the present case H varies from 50 m to 500 m for Tunnel , adopted value of H is

H =	500	
f=	1.23	
f' =	1.00	squeezing factor

1.2 Ultimate Wall Support Pressure

As per clause 3.5.1.2b of IS: 13365 (Part-2) 1992,

Type of rock	Q value	Q wu
Fair	Q <10	2.50 Q

The ultimate wall support pressure P_{wu}

$$P_{wu} = \frac{2.0 Q_{wu}^{-\frac{1}{3}} f}{J_r}$$ kg/cm^2

Pwu = Ultimate wall support pressure

Qwu = Ultimate wall rock mass quality

1.3 Roof and wall support pressure

S. No.	Rock Mass Type	Q	Q_{ru}	Q_{wu}	J_r	Support roof pressure (kN/m^2)	Support wall pressure (kN/m^2)
1	Fair Rock	4.00	4	10	2	77.17	56.86

Design of Integrated support System for Fair Rock

1.4 Load carried by Shotcrete

Shear strength	=	300	t/m^2
		3.00	N/mm^2
		30.00	Kg/cm^2
Thickness of shotcrete	=	100 mm	

Resistance offered by shotcrete $\frac{2\, q_{sc}\, t_{sc}}{BF_{sc}}$ = As per Clause 10.4.1 of IS 15026:2002

Where qsc =Shear Strength of Shotcrete=3 N/mm2
tsc = thickness of Shotcrete =100mm
Fsc = (0.6±0.05) =0.65 for present case
B = Size of opening= 14.2m

Shear strength of shotcrete =			0.650	Kg/cm^2
Load taken by shotcrete (100mm thick)=	Psc	=	**65.01**	kN/m2

1.5 Load carried by Bolt

Diameter of Rock Bolt	=	25	mm
Grade of steel used for rock bolt , f_y	=	Fe 500	
Grade of shotcrete	=	M 35	
Width of excavation (B)	=	14.20	m
Cross Sectional Area of Rock Bolt	=	490.9	mm^2
Yield load of bolt (fy Ab)	=	245.44	kN
Factor of Safety of Bolt	=	1.5	
Load carrying capacity of Rock Bolt (P)	=	163.62	kN
	=		
Considering Spacing of Rock Bolt	=	1.50	m
Area of Influence of Rock Bolt (A)	=	2.25	m^2
Load carrying capacity of Bolt for given spacing =(P/A) =	**P bolt =**	**72.72**	kN/m^2

1.6 Support System Compability Equation

Ultimate support pressure = Total capacity of the support system

$$u + p_{roof} = p_{sc} + p_{bolt}$$

u = Pore water pressure , in this case it is assumed as zero)

U+P roof =	77.17	kN/m^2
P sc+P bolt =	137.73	kN/m^2
	Safe	

1.7 Support System Compability Equation Side Walls

P_{wall} = 57 kN/m²

P sc+P bolt = 137.7 kN/m²

Safe

Summary of Results	
Diameter of Rock Bolt =	**25 mm**
Length of Rock Bolts =	**5 m**
Spacing of Rock Bolt =	1.5 m Staggered Bothways at crown and wall
Thickness of Shotcrete =	**100mm thick shotcrete at crown and wall**

ANNEXURE -1D

TUNNEL ROCK SUPPORT DESIGN FOR CLASS D ROCK , Q = 1-4 (With Rib)

1 ASSUMPTIONS:-

Finished Width of Tunnel = 13.0 m

Lining Thickness = 400 mm

Payline = 100 mm

Thickness of shotcrete tc = 100 mm

Excavated height of Tunnel = 9.900 m

Excavated Width of Tunnel = 14.200 m

	Q	Jr	Considering Spacing of rock bolt in Crown	Considering Spacing of rock bolt in Wall
Very Poor Rock	1.00	1.00	1.5 m	1.5 m

Diameter of rock bolt = 25 mm

Length of Rock Bolt = 2+0.15 B/ESR

Where B is excavated width

ESR =Excavation Support Ratio = 1.3 For Highway Tunnel

Length of Rock Bolt Required = 3.6 m

Provided Length of rock bolt	=	6.0 m	
characteristic compressive strength of shotcrete	=	35	N/mm2
Yield strength of rock bolt (fy)	=	500.00	N/mm2
Factor of Safety of Bolt	=	1.5	
Allowable load in bolt	=	163.62	kN

1.1 Vertical Support Pressure for Crown

$$P_{ru} = \frac{2.0 Q_{ru}^{-\frac{1}{3}} f f'}{J_r}$$ kg/cm²

As per clause 3.5.1.1a of IS-13365 (Part2): 1992

Where

P ru =	Ultimate roof support pressure
Q ru =	Ultimate rock mass quality = Q
J r =	Barton's joint roughness coefficient.
H=	Over burden above crown in tunnel.
f =	maximum of (1 , 1+(H-320)/800)
f' =	Sqeezing Factor

For the present case H varies from 70 m to 500 m for Tunnel , adopted value of H is

H =	500	
f=	1.225	
f' =	1.18	sqeezing factor

1.2 Ultimate Wall Support Pressure

As per clause 3.5.1.2b of IS: 13365 (Part-2) 1992,

Type of rock	Q value	Q wu
Very Poor	Q <0.1	2.50 Q

The ultimate wall support pressure P_{wu}

$$P_{wu} = \frac{2.0 Q_{wu}^{-\frac{1}{3}} f}{J_r}$$

kg/cm^2

Pwu = Ultimate wall support pressure

Qwu = Ultimate wall rock mass quality

1.3 Roof and wall support pressure

S.No.	Rock Mass Type	Q	Q_{ru}	Q_{wu}	J_r	Support roof pressure (kN/m^2)	Support wall pressure (kN/m^2)
1	Poor Rock	1.00	1	2.5	1	289.10	213.01

Design of Integrated support System for Fair Rock

1.4 Load carried by Shotcrete

Shear strengh = 550 t/m^2

5.50 N/mm^2

55.00 Kg/cm2

Thickness of shotcrete = 100 mm

Resistance offered by shotcrete $$\frac{2\, q_{sc}\, t_{sc}}{BF_{sc}}$$ As per Clause 10.4.1 of IS 15026:2002

=

Where qsc =Shear Strength of Shotcrete=5.5 N/mm2
tsc = thickness of Shotcrete= 100 mm
Fsc = (0.6±0.05) =0.65 for present case
B = Size of opening= 14.2 m
Shear strength of shotcrete = 1.192 Kg/cm^2

	Load taken by 100mm thick shotcrete = Psc	=	**119.18**	kN/m^2	
1.5	**Load carried by Bolt**				
	Diameter of Rock Bolt	=	25 mm	mm	
	Grade of steel used for rock bolt , f_y	=	Fe 500		
	Grade of shotcrete	=	M 35		
	Width of excavation (B)	=	14.20	m	
	Cross Sectional Area of Rock Bolt	=	490.9	mm^2	
	Yield load of bolt (fy Ab)	=	245.44	kN	
	Factor of Safety of Bolt	=	1.5		
	Load carrying capacity of Rock Bolt (P)	=	163.62	kN	
	Considering Spacing of Rock Bolt	=	1.50	m	
	Area of Influence of Rock Bolt (A)	=	2.25	m^2	
	Load carrying capacity of Bolt for given spacing =(P/A) =	**P bolt =**	**72.72**	kN/m^2	
1.6	**Load carried by Steel rib**				
	Cross Sectional Area of Steel rib	**=**	**4750.00**	mm^2	
	Yeild Strength of Steel Rib (fy)	**=**	**250.00**	N/mm^2	
	Compression Carrying Capacity of Steel Rib (0.6 fy *ARib)	**=**	**712.50**	kN	As per cluse 5.1 of IS 800:1984

1.7 Support System Compability Equation

U+Uro of = Psc+P bol +PRib

u = Pore water pressure , in this case it is assumed as zero)

Design of Steel Rib As per clause 12.4 of IS: 15026 2002,

S_{Rib} =Spacing of Steel Rib (m),	S_{Rib}	$=P_{Rib}/P_{roof}$

P_{Rib} =Steel Rib Capacity =		712.50 kN	
B = size of opening (m)	=	14.20 m	m
U+P roof	=	289.10	kN/m^2
P_{sc} + P_{bolt}	=	191.90	kN/m^2
Load taken by Steel Rib	=	97.20	kN/m^2
Required Spacing of Steel Rib	**S_{Rib} =**	**1.032 m c/c**	
Provided Spacing of Steel Rib	=	**1.00 m c/c**	

Summary of Results	
Diameter of Rock Bolt =	**25 mm**
Length of Rock Bolts =	**6 m**
Spacing of Rock Bolt =	1.5 m Staggered Bothways at crown and wall
Thickness of Shotcrete =	**100 mm thick Fiber Reinforced Shotcrete at crown and wall**
Steel Rib =	**ISMB250 250 Grade Steel Rib @ 1 m c/c**

m Staggered Bothways at crown and wall

ANNEXURE -1E

TUNNEL ROCK SUPPORT DESIGN FOR CLASS E ROCK , Q =1.0-0.1

1 ASSUMPTIONS:-

Finished Width of Tunnel	=	13.0 m
Lining Thickness	=	400.0 mm
Payline	=	100 mm
Thickness of shotcrete tc	=	100 mm

Excavated height of Tunnel = 9.900 m

Excavated Width of Tunnel = 14.200 m

	Q	Jr	Considering Spacing of rock bolt in Crown	Considering Spacing of rock bolt in Wall
Extremely Poor Rock	0.10	1.00		

characteristic compressive strength of shotcrete = 35 N/mm2

1.1 Vertical Support Pressure for Crown

As per clause 3.5.1.1a of IS-13365 (Part2): 1992

$$P_{ru} = \frac{2.0 Q_{ru}^{-\frac{1}{3}} f f'}{J_r} \text{ kg/cm}^2$$

Where

P ru = Ultimate roof support pressure

Q ru = Ultimate rock mass quality = Q

J r = Barton's joint roughness coefficient.

H= Over burden above crown in tunnel.

f = maximum of (1 , 1+(H-320)/800)

f' = Sqeezing Factor

For the present case H varies from 30 m to 500 m for Tunnel , adopted value of H is

H = 500

f= 1.225

f' = 1 squeezing factor

1.2 Ultimate Wall Support Pressure

As per clause 3.5.1.2b of IS: 13365 (Part-2) 1992,

Type of rock	**Q value**	**Q wu**

Extremely Poor	Q <0.1	1.0 0 Q

The ultimate wall support pressure P_{wu}

$$P_{wu} = \frac{2.0 Q_{wu}^{-\frac{1}{3}} f}{J_r} \text{ kg/cm}^2$$

Pwu =	Ultimate wall support pressure
Qwu =	Ultimate wall rock mass quality

1.3 Roof and wall support pressure

S. No.	Rock Mass Type	Q	Q_{ru}	Q_{wu}	J_r	Support roof pressure (kN/m²)	Support wall pressure (kN/m²)
1	Extremely Poor Rock	0.10	0.1	0.1	1	527.84	527.84

Design of Integrated support System for Fair Rock

1.4 Load carried by Shotcrete

Shear strengh	=	550	t/m²
		5.50	N/mm²
		55.00	Kg/cm2
Thickness of shotcrete	=	100 mm	

Resistance offered by shotcrete $= \frac{2 q_{sc} t_{sc}}{BF_{sc}}$ As per Clause 10.4.1 of IS 15026:2002

Where qsc =Shear Strength of Shotcrete=5.5 N/mm2
tsc = thickness of Shotcrete= 100 mm
Fsc = (0.6±0.05) =0.65 for present case

	B = Size of opening= 14.2m				
	Shear strength of shotcrete =		1.192	Kg/cm^2	
	Load taken by 100mm thick shotcrete =	Psc =	**119.18**	kN/m^2	
1.5	**Load carried by Grouted Arch**				
	Capacity of Grouted Arch =	pgt =	=(2 x q_{gt} x l_{gt})/(B x Fgt)		
	Uniaxial Compressive Strength of grouted rock mass =	q_{gt} =	**2500**	kN/m^2	
	Thickness of grouted arch =	l_{gt} =	**3.20**	m	
	Size of Opening	**B =**	**14.20**	m	
	Mobilisation Factor of Grouted Arch	F_{gt} =	9.5 (p_{roof})^(-0.35)		
		F_{gt} =	**2.37**		
	Capacity of Grouted Arch =	**pgt =** **=**	**475**	kN/m2	
1.6	**Load carried by Steel Rib**				
	Cross Sectional Area of Lattice Girder (Arib)	**=**	**4750.00**	mm^2	ISMB 250
	Yeild Strength of Steel Rib (fy)	**=**	**250.00**	N/mm^2	
	Compression Carrying Capacity of Lattice Girder (0.6 f_y *A_{rib})	**=**	**712.50**	kN	As per cluse 5.1 of IS 800:1984

1.7 Support System Compability Equation

$U+U_{roof} = P_{sc} + Prib + P_{grout}$

u = Pore water pressure	=(2 x Diameter of Tunnel Head)	=	**260**	kN/m^2

Design of Steel Rib As per clause 12.4 of IS: 15026 2002,

$$S_{rib} = \frac{p_{rib}}{B p_{roof}}$$

Srib =Spacing of Steel Rib (m),	=		
Prib =Steel Rib Capacity =		712.50 kN	
B = size of opening (m)	=	14.200 m	m
U+P roof	=	787.84	kN/m^2
P sc +P_{grout}	=	594.49	kN/m^2
Load taken by Steel Rib	=	193.34	kN/m^2
Required Spacing of Steel Rib	**Srib =**	**0.519 m c/c**	
Provided Spacing of Steel Rib	=	**0.500 m c/c**	

Summary of Results	
Thickness of Shotcrete =	**100 mm thick Fibre Reinforced Shotcrete at crown and wall**
Steel Rib =	**ISMB 250 (250 Grade) @ 0.5m c/c**
Misc.	**Pipe roofing**

Silkyara Bend – BarkotRoad Tunnel
Design of Tunnel Lining
(A part of Detailed Project Report)

Of

2 Lane/ 2 Lane upgradation proposal of Highway between Km 144.00 (Dharasu) and Km 220.00 (Yamunotri) falling along NH - 94 and 123 in the State of Uttarakhand

Submitted to

Ministry of Road Transport & Highways
(Government of India)

By

M/s TECHNOCRATES ADVISORY SERVICES PVT.LTD.
(Earlier M/s MC Consulting Engineers Pvt. Ltd.)

JV with

G.E.S. & Association with S.I.P.L.

Contents

1 INTRODUCTION

1.1 General

The Ministry of Road Transport and Highways (MORT&H) is poised to develop all remote and strategically important roads in hilly terrains to perennial routes. In continuation to these developments National Highways And Infrastructure Development Corporation has been appointed by MORT&H, to implement the projects.

NHIDCL have appointed the M/s TECHNOCRATES ADVISORY SERVICES PVT.LTD. .in Joint Venture with G.E.S. and in association with S.I.P.L, lndia, as consultants to carry out the detailed design, for the Silkyara Bend – Barkot Tunnel of the NH-94, between Dharasu and Barkot section (CH.25.400 to CH.51.00), in the State of Uttarakhand.

1.2 Proposed Silkyara Bend – Barkot Tunnel Alignment

This tunnel is aligned to reduce the distance between Silkyara Bend (CH. 25.400) and Barkot(CH. 51.000) on NH-94, a total of 25.6km to less than 5.0 km. In current scenario this distance through road can be covered by crossing almost 5 hairpin bends with an ascending journey from approx. EL.1720 to EL.2250 and then again a descending journey to EL. 1500. The upper reaches of this ridge receive heavy snowfall during winters and as a result the highway gets blocked for one-two weeks every year.

2 Scope of Present Report

The present report deals with the design of internal concrete lining fortunnel. The analysis of the lining has been carried out in STAAD.Pro, whereas the design of the lining has been carried out using spreadsheets developed as per relevant codes and manuals.

3 References

The following references are used in the design of the tunnels lining.

[1] Engineering and Design: Tunnels and Shafts in Rock. U.S Army Corps of Engineers, Washington, DC 20314-1000, Manual No: EM 1110-2-2901.

[2] IS 456 – 2000: Plain and Reinforced Concrete – Code of Practice.

[3] IRC: 6-2014-Standard specifications and code of practice for road bridges.

[4] IS 1893 (Part1) - 2002: Criteria for Earthquake resistance design of structures.

[5] IS 4880 (Part IV) – 1971: Code of Practice for Design in Tunnels Conveying Water-Structural design of Concrete lining in Rock.

[6] IS 3370(Part 2):2009- Concrete structures for storage of liquids-code of practice.

[7] Contract agreement and schedules (Volume 1) - Schedule D.

[8]Commercial STAAD.Pro software. Website link http://www.bentley.com/en-US/Products/STAAD.Pro/

[9] Book on Reinforced Concrete, 6th Edition by Ashok K. Jain.

[10] Book on Reinforced Concrete Design, Second Edition by S Pillai and Devdas Menon.

4 Design Data

4.1 Geometrical Parameters

No. of tunnels : 1 nos.

Finished radius (above springing line) : **5.50m**

Center line modelling is carried out in STAAD.Pro for tunnel sections with invert section. The typical tunnel sections are shown below:-

5 Material Properties

5.1 Rock properties

The rock parameters estimated from the available reports for tunnel are presented below:

Rock type	Rock Class	RMR	Deformation modulus (GPa)	Poisson's ratio	Angle of friction (°)
Very good	A	81-100	18.96	0.20	52.278
Good	B	61-80	11.366	0.20	46.406
Fair	C	41-60	4.99	0.20	40.186
Poor	D	21-40	1.107	0.25	40.65
Very Poor	E	0-20	0.692	0.30	37.33

5.2 Concrete Properties

Concrete of M-30 grade with the following properties shall be used for the lining.

a. Grade of concrete : M-40

b. Young's modulus : 31622 MPa

c. Poisson's ratio : 0.2

d. Permissible bending stress in compression : 16MPa

e. Permissible direct stress in compression : 10MPa

f. Permissible bending stress in tension : 4.74MPa

g. Permissible direct stress in tension : 4 MPa

6 Loads

6.1 Design loads

The following loads acting on the concrete lining are considered for the structural analysis and design of the concrete lining:

6.1.1 Dead load

The self-weight of concrete lining based on unit weight of concrete i.e. 24.5 kN/$m^3$is considered in the lining analysis and design. The weight of Booster fans is assumed as 5.0kN each at the support location at spacing of 1.0m c/c. Both these loads are applied in the self-weight in STAAD.Pro.

6.1.2 Rock Load

After the excavation of the tunnels primary supports will be provided as required. Displacements will be monitored during the excavation and after the excavation also. Deformation monitoring system will be provided in the drawings. The lining shall be placed after the deformation stabilizes and the displacements reduce to nearly zero. As there will not be any further stress in the lining due to rock deformations, no rock load shall be considered in the lining.

However, for rock classes- III, IV, &V, 20%, 25%, and 25% of the total rock load is considered in the lining design. Refer Annexure-II for rock load calculations.

6.1.3 Seismic load

In the underground tunnel, seismic loading is not generally considered, unlessany fault is passing through the tunnel. Seismic loadings are not considered in the analysis due to sufficientextent of topographical cover when compared to the size of the tunnel, and the rockmass itself around the tunnel has enough stiffness to resist the seismic loads.

However, to be on the conservative side seismic loading is considered on the tunnel lining for all classes of rock. The seismic effect is considered on the self-weight of lining. The horizontal earthquake coefficient is calculated based on IS 1893 (Part 1):2002 as follows.

$$Ah = \frac{ZISa}{2Rg}$$

Ah= horizontal earthquake coefficient

Z= Zone factor (0.24 for Zone-IV)

I= importance factor (1.5)

R= Response reduction factor (2.5)

Sa/g= spectral acceleration coefficient (2.5)

So,

$$Ah = \frac{0.24 * 1.5 * 2.5}{2 * 2.5} = 0.18$$

6.1.4 External Water Pressure

This load is due to the static pressure of water in the concrete lining around its periphery acting from outside.

30mm thick water proofing membranewill be provided in the periphery of the concrete lining and the water shall be drained through the longitudinal tunnel drainage. Hence, the external water pressure build up is not considered in the concrete lining design, and the tunnel lining is designed for drained condition.

6.1.5 Vehicular traffic load

Vehicular traffic of class-A, 70R tracked load, & 70R wheeled load are considered at the invert of the tunnel lining based on IRC standards. The traffic load is considered for the tunnel with invert section only. Refer Annexure-III for traffic load calculation.

6.1.6 Pavement dead load

The dead load of the pavement is considered in the tunnel with invert lining. Approximate density of 25kN/m^3isconsidered for the pavement materials.

6.1.7 Grouting pressure

As no internal pressure is there in the road tunnels, grouting is generally not carried out. So, no grouting load is anticipated in the tunnel lining at this stage. However, during the construction phase site engineer may decide on this.

6.2 Loads in STAAD.Pro

For rock Classes-A, B,C, D, &E (Tunnel with invert)

Primary load cases

Load case 1- Earthquake in +X direction
Load case 2- Self weight
Load case 3- Rock load
Load case 4- Pavement load
Load case 5- Traffic load

Load combinations

Load case 101- Earthquake + Self weight
Load case 102 – Earthquake + Self weight+ Rock load
Load case 103 – Earthquake + Self weight+ Rock load+ pavement load
Load case 104 – Earthquake + Self weight+ Rock load+ pavement load + traffic load
Load case 105 –Self weight+ Rock load
Load case 106 –Self weight+ Rock load+ pavement load
Load case 107 –Self weight+ Rock load+ pavement load + traffic load

As the lining is designed using working stress method (WSM), no partial load factor is considered.

7 Analysis and Design

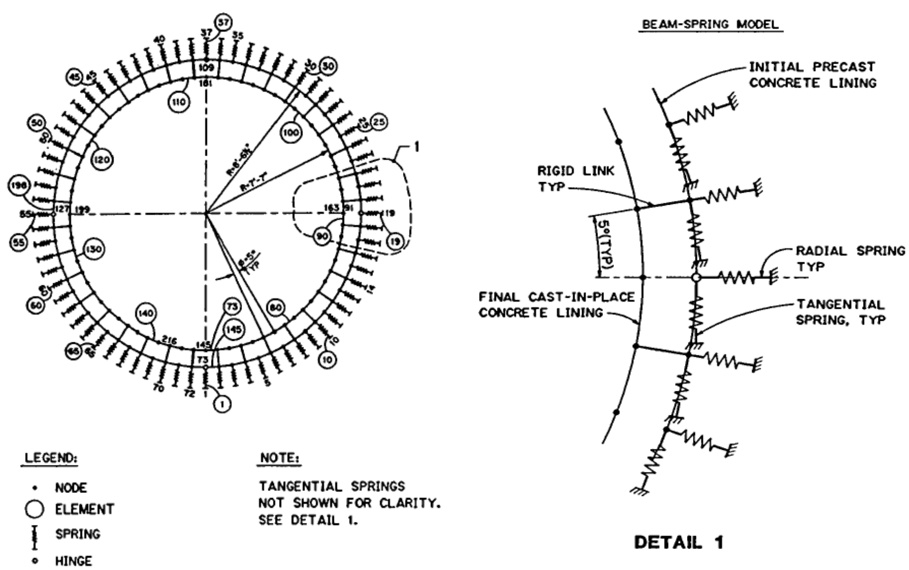
7.1 Analysis approach

- For rock Classes –A & E tunnels with invert lining is considered as ring closure is also required for good rock classes.

- The concrete lining has been modelled in STAAD.Pro considering the centre line of the lining.
- 5.0m length of concrete lining is considered along the length in the model in STAAD.Pro.
- The lining is divided in to plate elements and length of each plate is kept approximately 1m. The angel subtended at the centre by each plate is calculated (approx.) and the stiffness is calculated accordingly.
- The tangential and radial springs are applied at each node to simulate elastic interaction between the lining and the rock. The interface between lining and rock cannot withstand tension; therefore, interface elements (springs) are deactivated in tension.
- In case of tunnel without invert lining, pin support is applied at the ends of lining.

7.1.1 Calculation of spring constant

The radial and tangential spring constants are calculated using manual on Engineering and Design: Tunnels and Shafts in Rock. U.S Army Corps of Engineers, Washington, DC 20314-1000, Manual No: EM 1110-2-2901. The below figure shows a circular lining with springs applied radially.



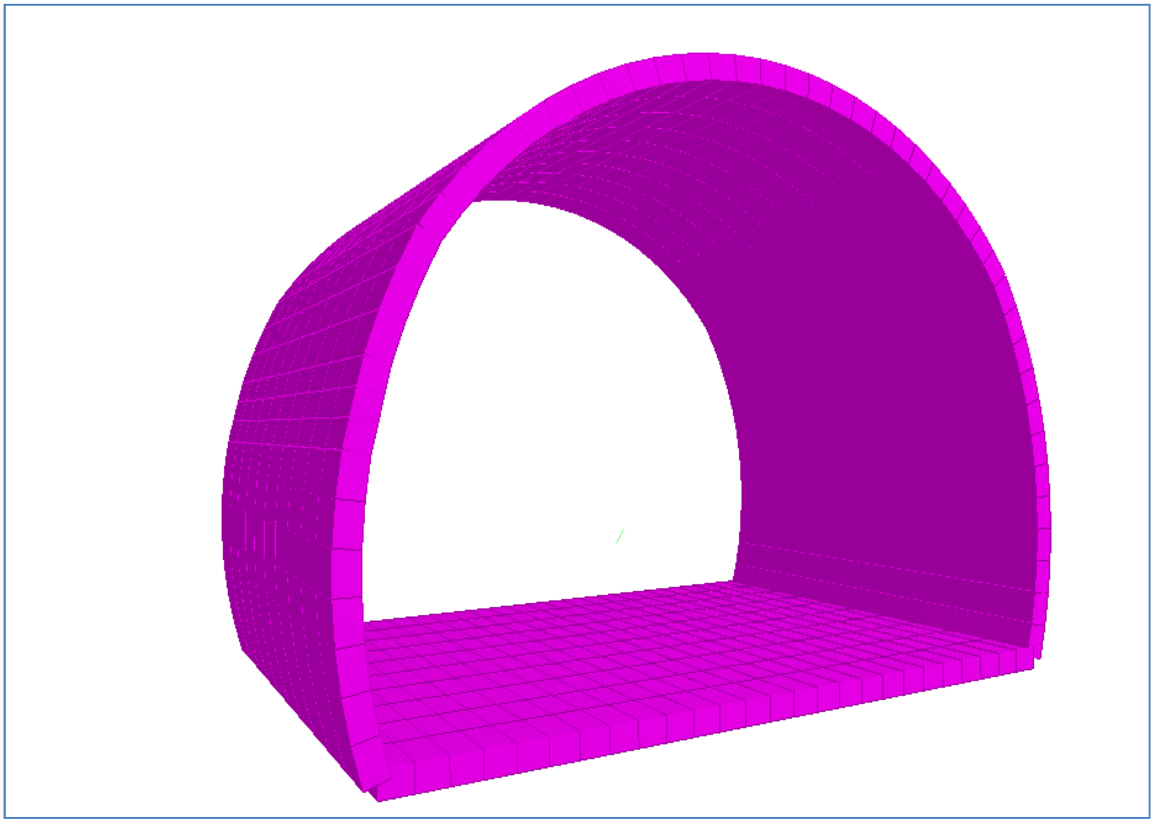
$$k_r = \frac{E_r b \theta}{(1+\nu_r)} \qquad k_t = \frac{k_r G}{E_r} = \frac{0.5 k_r}{(1+\nu_r)}$$

K_r= radial spring stiffness
Kt= Tangential spring stiffness
Er=Deformation modulus of rock
b=length of the element considered
$\nu_{r=}$ Poisson’s ratio

Refer Annexure-I for detail calculation.

7.1.2 Staad Pro analysis

Concrete linings for all the rock classes are analyzed using STAAD.Pro and the reactions (i.e. bending moment, axial force, and shear stress) obtained are used in the design of the lining. Refer Annexure IV to VIII for detailed analysis report from STAAD.Pro. A 3D model created in STAAD Pro has been attached below.



7.2 Design

- The lining is designed based on working stress method (WSM).
- For PCC lining, support capacity plots are developed based on interaction equations for "axial force+ compression due to bending ", and the maximum tension is compared with the permissible tension.
- The PCC lining is designed as un-cracked section.
- Refer Annexure IV to VIII for detailed design of the lining.

8 Conclusion

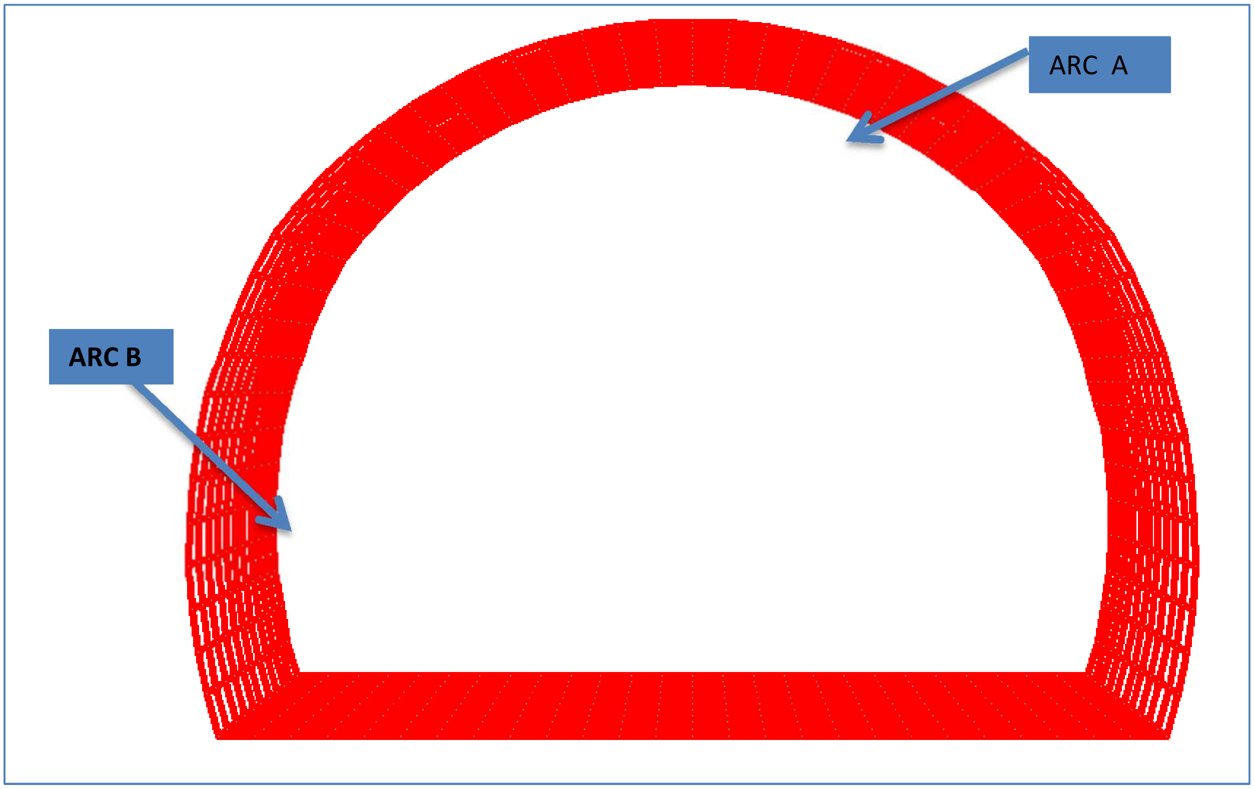
The proposed lining thickness of 400mm for all classes of rock will be able to withstand the loads coming on it.

ANNEXURE-I

SPRING STIFFNESS CALCULATION:

The concrete lining of the tunnels is approximated to a circular lining for the purpose of calculation of spring stiffness.

In the STAAD.Pro analysis center line modeling is carried out for the lining. For all curves inclined spring support have been provided in STAAD.Pro accordingly.



TUNNELS WITH INVERT (FOR ROCK CLASSES-A TO E)

As per EM 1110-2-2901: Engineer Manual (U.S. Army Corps)-Tunnels and Shafts in Rock.

$$k_r = \frac{E_r b \theta}{(1+\nu_r)}$$

$$k_t = \frac{k_r G}{E_r} = \frac{0.5 k_r}{(1+\nu_r)}$$

k_r = radial spring stiffness

k_t = tangential spring stiffness

E_r = Deformation modulus

b = length of element considered for stiffness calculation

θ = arc subtended by the element at center (radian)

ν_r = Poisson's ratio

Radius of the center line of equivalent circle		=	8.8158	m
Length of lining considered for stiffness calculation	b	=	1	m
(As the plate elements are of 0.5m length, one support will carry the load of 0.5m width)				
Angle subtended at center by the single element	Θ_A	=	4.12	°

As the length of each element for arc 'B' is approximately equal to that of 'A', same spring stiffness has been applied for all the arcs with different reference points.

For Rock Class-A

Deformation modulus for class-A rock	E_r	=	18996000	Kn/m^2
Poisson's ratio for class-A rock	ν_r	=	0.20	
Radial spring stiffness	k_{ra}	=	1137021.59	kN/m
Tangential spring stiffness	k_{ta}	=	473759.00	kN/m

For Rock Class-B

Deformation modulus for class-B rock	E_r	=	11366000	kN/m^2
Poisson's ratio for class-B rock	ν_r	=	0.20	
Radial spring stiffness	k_{ra}	=	680321.51	kN/m
Tangential spring stiffness	k_{ta}	=	283467.30	kN/m

For Rock Class-C

Deformation modulus for class-C rock	E_r	=	4990000	kN/m^2
Poisson's ratio for class-C rock	ν_r	=	0.20	
Radial spring stiffness	k_{ra}	=	298680.66	kN/m
Tangential spring stiffness	k_{ta}	=	124450.27	kN/m

For Rock Class-D

Deformation modulus for class-D rock	E_r	=	1107000	kN/m^2
Poisson's ratio for class-D rock	ν_r	=	0.25	
Radial spring stiffness	k_{ra}	=	63610.00	kN/m
Tangential spring stiffness	k_{ta}	=	25444.00	kN/m

For Rock Class-E

Deformation modulus for class-E rock	E_r	=	692000	kN/m^2
Poisson's ratio for class-E rock	ν_r	=	0.30	
Radial spring stiffness	k_{ra}	=	38234.07	kN/m
Tangential spring stiffness	k_{ta}	=	14705.41	kN/m

ANNEXURE-II

EXTERNAL ROCK LOAD CALCULATION (FOR ROCK CLASS-C,D, &E):

For rock classes C, D, & E, rock load of 20%, 25%, & 25% of total load is considered on the internal concrete lining design. For rock classes A & B no rock road is considered.

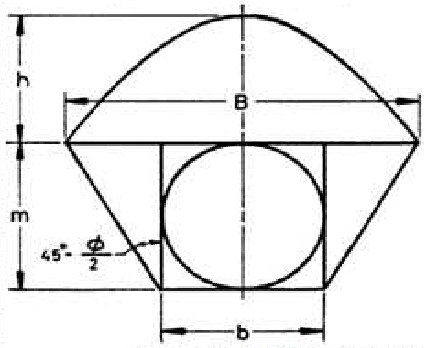
Class-C				
Deformation modulus	E	=	4990000	kN/m^2
Angle of internal friction of surrounding rock	ø	=	40.186	°
Cohesion of surrounding rock	c	=	0	KPa
Poisson's ratio	v	=	0.2	
Class-D				
Deformation modulus	E	=	1107000	kN/m^2
Angle of internal friction of surrounding rock	ø	=	40.65	°
Cohesion of surrounding rock	c	=	0	KPa
Poisson's ratio	v	=	0.25	
Class-E				
Deformation modulus	E	=	692000	kN/m^2
Angle of internal friction of surrounding rock	ø	=	37.33	°
Cohesion of surrounding rock	c	=	0	KPa
Poisson's ratio	v	=	0.3	

Reference : IS 4880 (Part IV):1971Code of Practice for Design of Tunnels conveying water, Structural design of concrete lining in Rock.

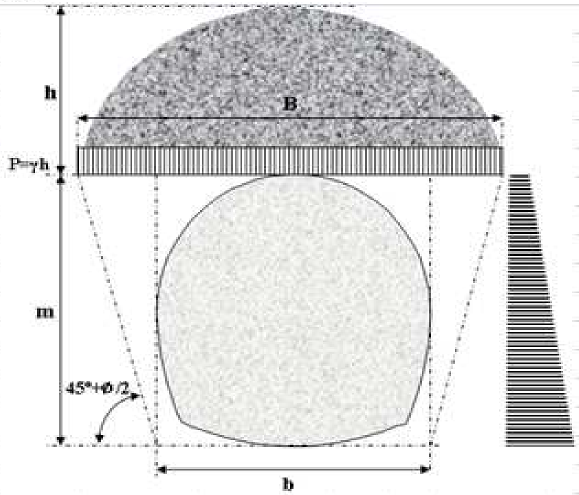
Load calculation as per cl. B-3.1.3

The rock load may be taken as that for rock area enclosed by the parabola starting from intersection points of the rupture planes with horizontal length down to crown of tunnel section. The dimensions of parabola are given below.

The rock load may be taken as that for rock area enclosed by the parabola starting from intersection points of the rupture planes with horizontal length down to crown of tunnel section. The dimensions of parabola are given below.



ASSUMED ROCK LOAD



$$h = \frac{B}{2f}$$

$$B = b + 2\,m \tan(45° - \phi/2)$$

where

ϕ = the angle of repose of the soil.

f = the strength factor

Calculate

Width of cavity	b	=	11.70	m
Height of cavity	m	=	10.35	m
Unit weight of rock	γ_{sub}	=	27.00	kN/m^3

<u>Class-C</u>

Strength factor as per IS 4880 (Prat-4):1971 table-2 for ClassIII	f	=	8	
Height of Parabola	h	=	1.33	m
Pressure width at the crest of cavity	B	=	21.31	m

$$B = b + 2m\tan(45^{\circ} - \phi/2)$$

Pressure on the Roof of Cavity

U.D.L. at the top of cavity	p_1	=	**35.96**	**kN/m/m**

Pressure on the side wall of Cavity

Pressure on side wall at the top of cavity = **7.8** kN/m/m

$$e_1 = p_1 \tan^2(45-\phi/2) - 2c\tan(45-\phi/2)$$

Pressure on side wall at the bottom of cavity = **68.0** kN/m/m

$$e_2 = (p_1 + H\gamma')\tan^2(45-\phi/2) - 2c\tan(45-\phi/2)$$

Class-D

Strength factor as per IS 4880 (Prat-4):1971 table-2 for ClassII	f	=	4	
Height of Parabola	h	=	2.65	m
Pressure width at the crest of cavity	B	=	21.21	m

$$B = b + 2m\tan(45^\circ - \phi/2)$$

Pressure on the Roof of Cavity

U.D.L. at the top of cavity p_1 = **71.58** kN/m/m

Pressure on the side wall of Cavity

Pressure on side wall at the top of cavity = **15.1** kN/m/m

$$e_1 = p_1 \tan^2(45-\phi/2) - 2c\tan(45-\phi/2)$$

Pressure on side wall at the bottom of cavity = **74.1** kN/m/m

$$e_2 = (p_1 + H\gamma')\tan^2(45-\phi/2) - 2c\tan(45-\phi/2)$$

Class-E

Strength factor as per IS 4880 (Prat-4):1971 table-2 for ClassIII	f	=	3	
Height of Parabola	h	=	3.66	m
Pressure width at the crest of cavity	B	=	21.95	m

$$B = b + 2m\tan(45^\circ - \phi/2)$$

Pressure on the Roof of Cavity

U.D.L. at the top of cavity p_1 = **98.76** kN/m/m

Pressure on the side wall of Cavity

Pressure on side wall at the top of cavity = **24.2** kN/m/m

$$e_1 = p_1 \tan^2(45-\phi/2) - 2c\tan(45-\phi/2)$$

Pressure on side wall at the bottom of cavity = **92.7** kN/m/m

$$e_2 = (p_1 + H\gamma')\tan^2(45-\phi/2) - 2c\tan(45-\phi/2)$$

Sl. No	Rock class	Vertical pressure (kN/m^2)	lateral pressure (kN/m^2)		% of rock load considered
			Start	End	
1	C	7.19	1.6	13.6	20
2	D	17.9	3.8	18.5	25
3	E	24.7	6.0	23.2	25

ANNEXURE-III

TRAFFIC LOAD CALCULATION ON TUNNEL INVERT (FOR ROCK CLASS-A,B,C ,D & E):

1 Input:-

Effective Span	=	10.5	m	
Length	=	10	m	
Thickness of pavement	=	1	m	
Effective depth of pavement	=	1.00	m	

2 Live Load

2.1 Class A Wheeled Load IRC 6 Cl. 204.1

Length of Load (Longitudinal Direction) c/c	=	1.20	m	
Tyre contact area (Longitudinal Direction)	=	0.25	m	
Tyre contact area (Transverse Direction)	=	0.50	m	
Overall track width (Transverse Direction) c/c	=	1.80	m	
Clearance between two Class A Vehicles	=	1.20	m	
Clearance	=	0.15	m	
Kerb	=	0	m	
Axle Load	=	11.4	t	
Impact Factor	=	27.27	%	IRC 6 Cl. 208.2
Dispersed Width of load in longitudinal direction	=	2.25	m	
	>	1.20	m	
		Dispersed area overlap		
Dispersed Width of load in longitudinal direction	=	3.450	m	
Total Axle Load two Class A Vehicles (side by side)	=	22.8	t	

(i) For a single concentrated load, the effective width may be calculalted in accordance with the following equation :

$$b_{ef} = \alpha_a \left(1 - \frac{a}{lo}\right) + b_1$$

Where b_{ef} = the effective width of slab on which the load acts,

l_o = the effective span as indicated in Clause 305.4,

a = the distance of the centre of gravity of the concentrated load from the nearer support,

b_1 = the breadth of concentration area of the load, i.e., the dimension of the tyre or track contact area over the road surface of the slab in a direction at right angles to the span plus twice the thickness of the wearing coat or surface finish above the structural slab, and

α = a constant having the following values depending upon the ratio $\frac{b}{l_o}$ where b is the width of the slab

Dispersed Width of load in Transverse direction

l0 (Length)	=	10.50	m
a	=	4.65	m

bi	=	0.5	m	
b (Width)	=	10.0	m	
b/lo	=	1.0		
alpha	=	2.60		IRC 21 Cl.305.16.1
bef (single wheel)	=	7.24	m	
bef	=	9.32	m	

Intensity of Load	=	0.90	t/m^2	……..(i)

2.2 Class 70R tracked Load — IRC 6 Cl. 204.1

Breadth of Track (Longitudinal Direction)	=	4.57	m	
Width of Track (Transverse Direction)	=	0.84	m	
Overall vehicle Length (Transverse Direction) c/c	=	2.06	m	
Clearance	=	1.2	m	
Kerb	=	0	m	
Total Load	=	70	t	
Impact Factor	=	25	%	IRC 6 Cl. 208.3
Dispersed Width of load in longitudinal direction	=	6.57	m	
Dispersed Width of load in Transverse direction				

l0 (Length)	=	10.50	m	
a	=	5.3	m	
bi	=	0.84	m	
b (Width)	=	10.0	m	
b/lo	=	1.0		
alpha	=	2.60		IRC 21 Cl.305.16.1
bef for one wheel	=	7.67	m	
bef	=	7.51	m	

Intensity of Load	=	1.77	t/m^2	………(ii)

2.3 70R Wheeled Load — IRC 6 Cl. 204.1

Length of Load (Longitudinal Direction) c/c	=	1.22	m	
Tyre contact area (Longitudinal Direction)	=	0.15	m	
Tyre contact area (Transverse Direction)	=	0.86	m	
Overall vehicle Length (Transverse Direction)	=	1.93	m	
Clearance	=	1.2	m	
Kerb	=	0	m	
Axle Load	=	20	t	
Impact Factor	=	25	%	IRC 6 Cl. 208.3
Dispersed Width of load in longitudinal direction	=	2.15	m	

	>	1.20	m	
		Dispersion area overlaps		
Dispersed Width of load in longitudinal direction	=	3.350	m	
Total Axle Load	=	40	t	
Dispersed Width of load in Transverse direction	=			
l0 (Length)	=	7.85	m	
a	=	3.315	m	
bi	=	0.86	m	
b (Width)	=	20.0	m	
b/lo	=	2.55		
alpha	=	2.60		IRC 21 Cl.305.16.1
bef (single wheel)	=	5.84	m	
bef	=	6.48	m	
Intensity of Load	=	2.30	t/m^2	……..(iii)
Live load udl (max of (i), (ii), (iii))		**2.30**	**t/m^2**	
Traffic load value taken for design		**2.40**	**t/m^2**	**OK**

ANNEXURE-IV
CONCRETE LINING DESIGN FOR ROCK CLASS-A

Material Data:

Grade of concrete		=	M-40	
Characteristic strength of concrete	f_{ck}	=	40	MPa

Design Input:

Lining thickness considered	D	=	400	mm
Length of the tunnel considered	b	=	1000	mm

The design of concrete lining is carried out by considering it as an independent structural member. The lining is designed based on working stress method.

PCC LINING

Design criteria

Member Subjected to Combined Axial Load and Bending

Refer clause B-4.1,IS 456:2000- Plain and Reinforced Concrete- code of practice, for uncracked section a member subjected to axial compressive load and bending shall be considered safe provided the following conditions are satisfied:

$$\frac{\sigma_{cc,cal}}{\sigma_{cc}} + \frac{\sigma_{cbc,cal}}{\sigma_{cbc}} \leq 1 \quad \text{------------------------------} \quad A$$

Where

$\sigma_{cc,cal}$ = calculated direct compressive stress in concrete

σ_{cc} = permissible axial compressive stress in concrete

$\sigma_{cbc,cal}$ = calculated bending compressive stress in concrete considering biaxial bending

σ_{cbc} = permissible bending compressive stress in concrete

Refer clause 6.3 (b), IS 3370(Part 2):2009- Concrete structures for storage of liquids-code of practice, for uncracked section a member subjected to axial tension load and bending shall be considered safe provided the following conditions are satisfied:

$$\frac{\sigma_{ct,cal}}{\sigma_{ct}} + \frac{\sigma_{cbt,cal}}{\sigma_{cbt}} \leq 1 \quad \text{------------------------------} \quad B$$

Where

$\sigma_{ct,cal}$ = calculated direct tensile stress in concrete

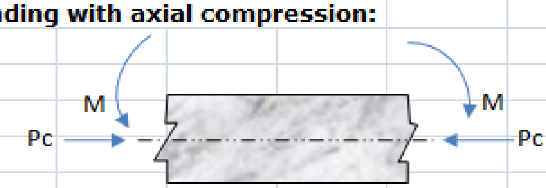
σ_{ct} = permissible direct tensile stress in concrete

$\sigma_{cbt,cal}$ = calculated tensile stress due to bending in concrete considering biaxial bending

σ_{cbt} = permissible tensile stress due to bending in concrete

Permissible bending stress in compression	σ_{cbc}	=	13.00	MPa
Permissible direct stress in compression	σ_{cc}	=	10.00	MPa
Permissible bending stress in tension	σ_{cbt}	=	4.74	MPa
Permissible direct stress in tension	σ_{ct}	=	4.00	MPa

Bending with axial compression:



The moment 'M' in a member during bending with axial compression will cause compression in one face while tension in opposite face at the same time. Hence, the moment capacity of the section has to be checked for both permissible bending stress in compression and tension at the same time.

Axial compressive force with compression due to bending:

Considering Eqn. 'A' $\frac{\sigma_{cc,cal}}{\sigma_{cc}} + \frac{\sigma_{cbc,cal}}{\sigma_{cbc}} \leq 1$

$\frac{P_c}{A\sigma_{cc}} + \frac{6M}{bD^2\sigma_{cbc}} \leq 1$	X at normal condition	=	4000.00	kN
$\frac{P_c}{x} + \frac{M}{y} \leq 1$	Y at normal condition	=	346.67	kN-m

where $x = A\sigma_{cc}$ are constants.

$y = \frac{bD^2\sigma_{cbc}}{6}$

Bending with Axial tension

Axial tensile force with tension due to bending:

Considering Eq. 'B' $\frac{\sigma_{ct,cal}}{\sigma_{ct}} + \frac{\sigma_{cbt,cal}}{\sigma_{cbt}} \leq 1$

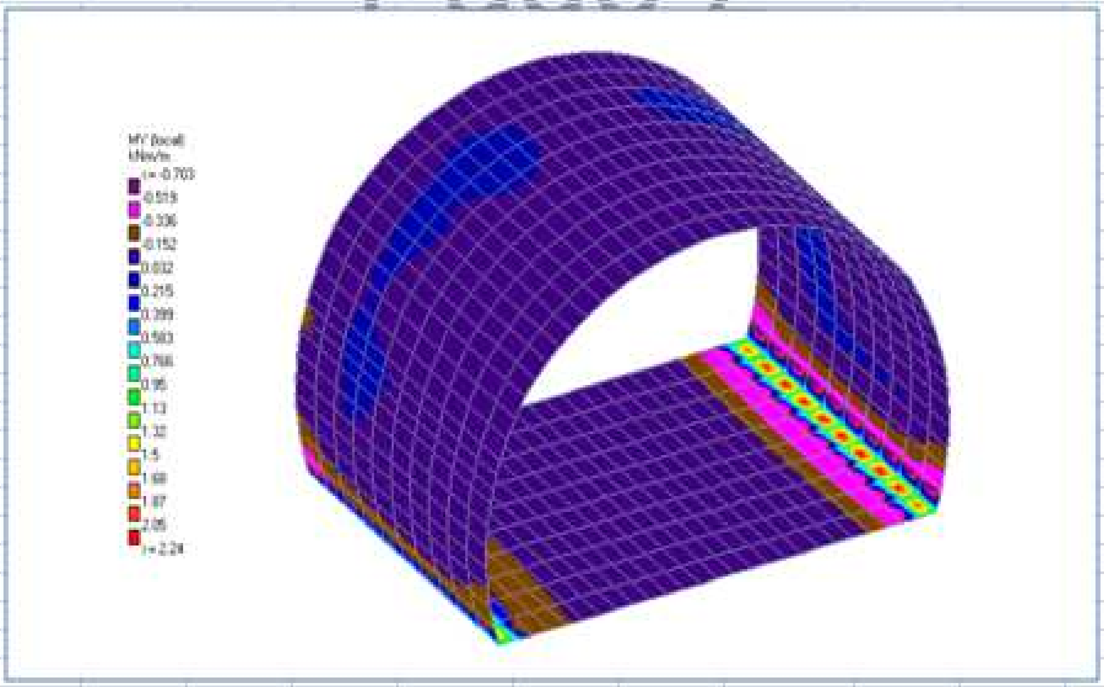
$\frac{P_t}{A\sigma_{ct}} + \frac{6M}{bD^2\sigma_{bt}} \leq 1$	where $x = A\sigma_{ct}$	X at normal condition	=	1600.00	kN
$\frac{P_t}{x} + \frac{M}{y} \leq 1$	$y = \frac{bD^2\sigma_{bt}}{6}$	Y at normal condition	=	126.40	kNm

The moment 'M' in a member during bending with axial tension will cause compression in one face while tension in opposite face at the same time. Hence, the moment capacity of the section has to be checked for both permissible bending stress in compression and tension at the same time. However as the face with tension due to bending and tension due to axial force will be critical, this face has been

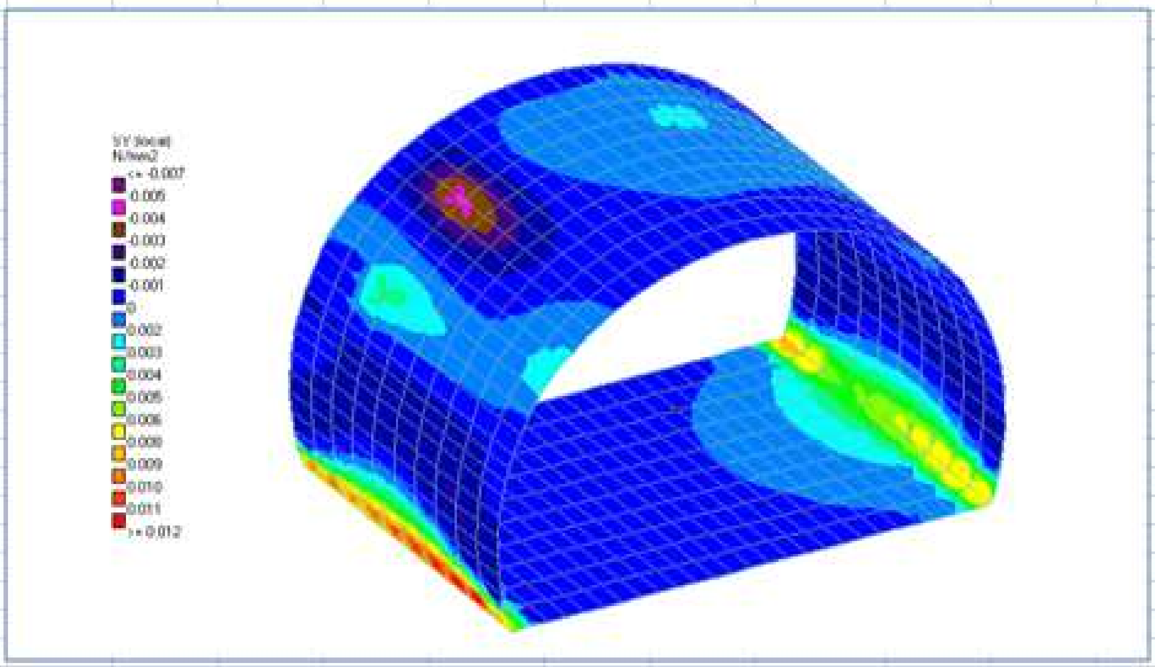
Load Cases

Load Case 1:	Earthquake (+X)
Load Case 2:	Self weight
Load Case 3:	Pavement load
Load Case 4:	Traffic load
Load Case 101:	Earthquake+Self weight
Load Case 102:	Earthquake+Self weight+Pavement load
Load Case 103:	Earthquake+Self weight+Pavement load+Traffic load
Load Case 104:	Self weight+Pavement load
Load Case 105:	Self weight+Pavement load+Traffic load

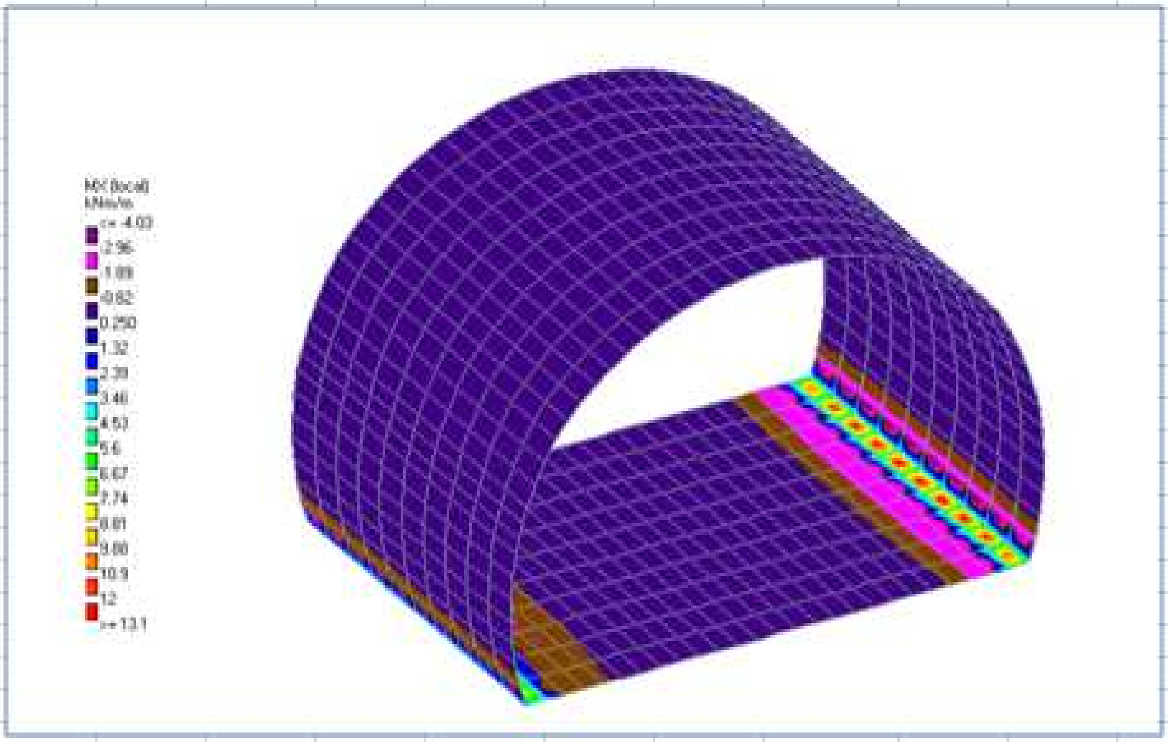
STAAD OUTPUT



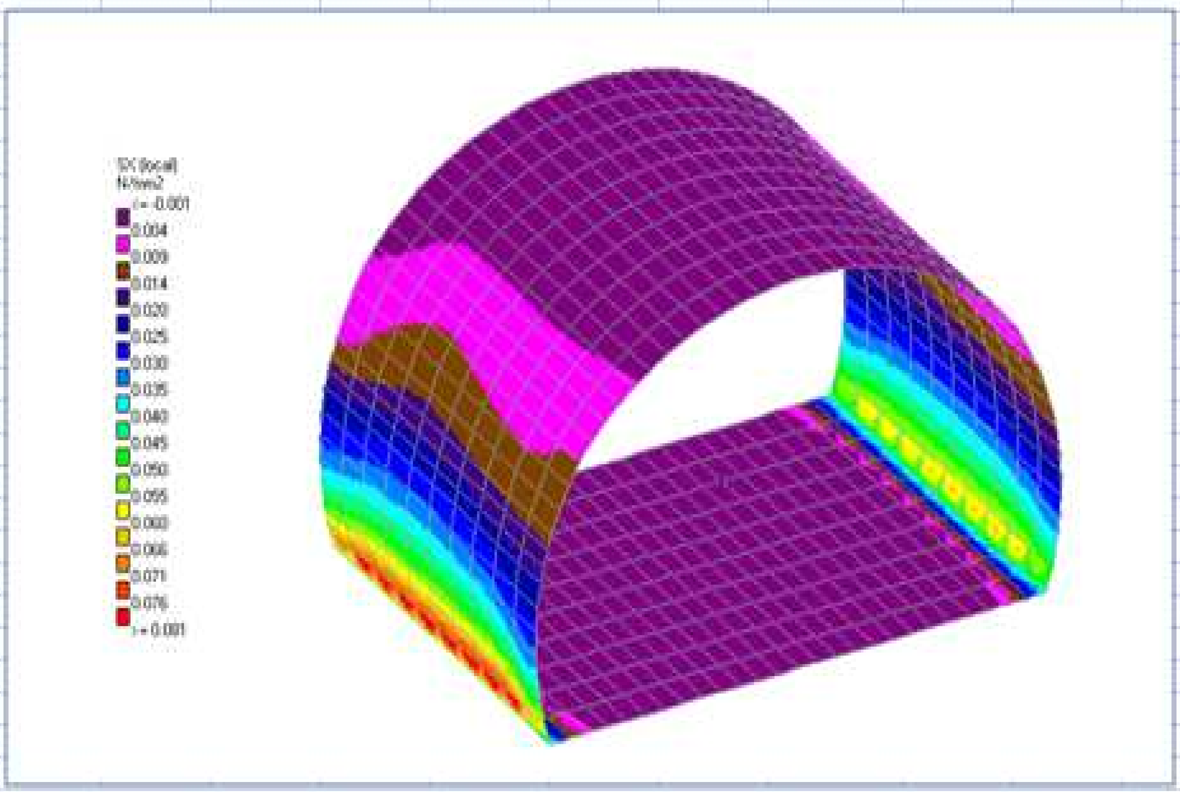
Load case 105: Bending moment (My)



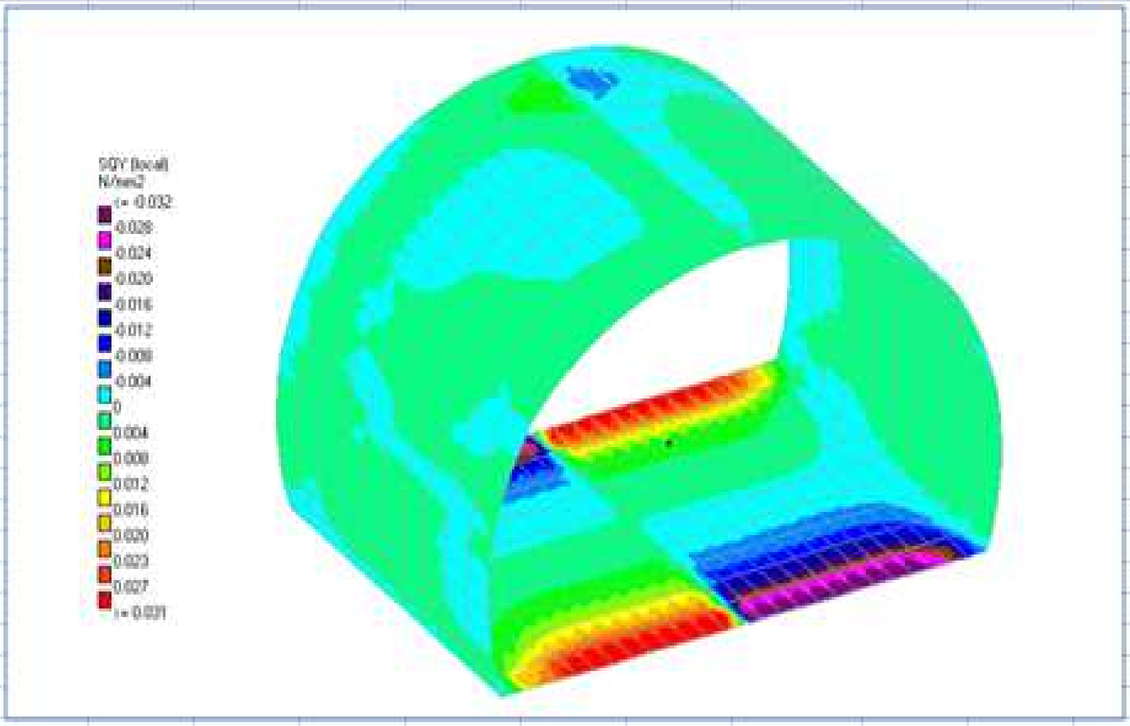
Load case 105: Axial stress (Sy)



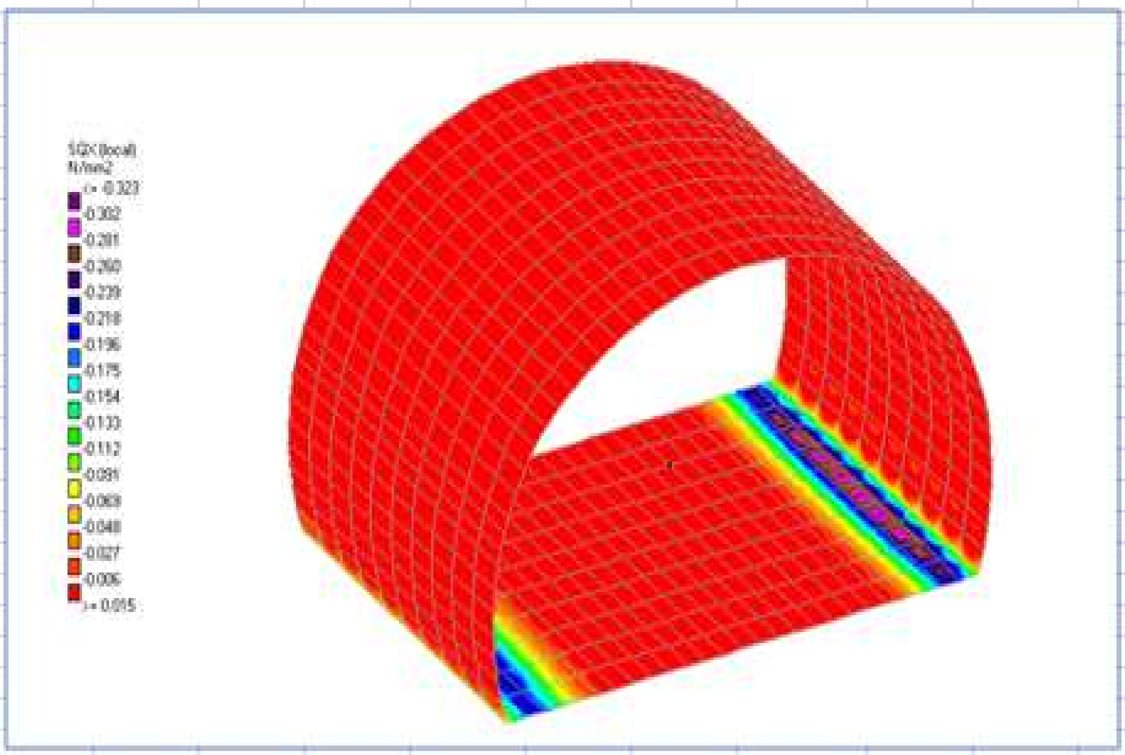
Load case 105: Bending moment (Mx)



Load case 105: Axial stress (Sx)



Load case 105: Shear stress (Sqy)



Load case 101: Shear stress (Sqx)

It is observed from the above STAAD.Pro results that the concrete lining has compressive membrane stresses in all the load cases and hence it is not checked for tensile membrane stresses.

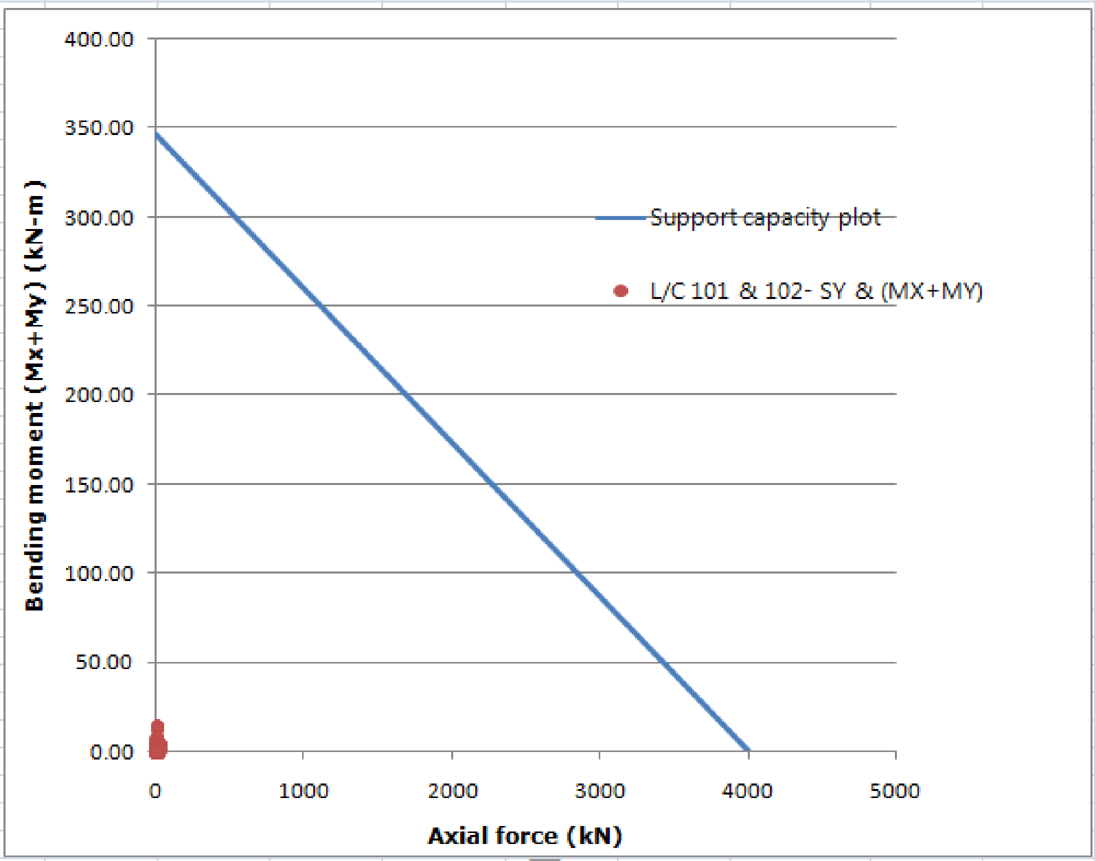
LOAD CASES: LC 101 , 102,103,104 &105										
Description	Plate	L/C	Sqx (N/mm^2)	Sqy (N/mm^2)	Mx (kN-m)	My (kN-m)	Mxy (kN-m)	Sx (N/mm^2)	Sy (N/mm^2)	Sxy (N/mm^2)
Max.My	1180	103	-0.228	0	13.279	**2.268**	0.041	0.032	0.006	0.067
Max.Sy	1609	105	-0.006	0.001	-2.167	-0.331	0.038	0.081	**0.012**	0
Max.Mx	1180	103	-0.228	0	**13.279**	2.268	0.041	0.032	0.006	0.067
Max.Sx	531	103	-0.009	0.001	-3.253	-0.619	-0.405	**0.082**	0.009	-0.006
Max.Sqy	1816	105	0	**0.031**	-0.328	-0.056	-0.005	0	0	-0.002
Max.Sqx	288	103	**0.027**	0.003	-3.464	-0.452	0.312	0.019	0.002	0
Max. My+Mx	289	103	0.006	-0.001	-0.687	-0.37	0.549	0.02	0	-0.004

DESIGN OF CONCRETE LINING

The axial stress is converted to axial force by multiplying the cross-sectional area.

Axial compression+Compression due to bending

Lining thickness	Axial force	Bending moment
(mm)	(kN)	(kN-m)
400	4000	0.00
400	0	346.67



Axial compression+Tension due to bending

Resultant stress ' -' = compression
Resultant stress '+' = tension

L/C	Axial Force kN	Bending moment kN-m	Resultant stress (MPa)	Tension /Compression	Check
103	2.40	**15.55**	0.58	Tension	O.K
105	4.80	**2.50**	0.08	Tension	O.K
103	2.40	**15.55**	0.58	Tension	O.K
103	3.60	**3.87**	0.14	Tension	O.K
105	0.00	**0.38**	0.01	Tension	O.K
103	0.80	**3.92**	0.14	Tension	O.K
103	0.00	**1.06**	0.04	Tension	O.K

Since all the points corresponding to the maximum axial load (compression) and bending moment are lying within the "Support capacity plot" the section considered for the design is SAFE.

DESIGN -SHEAR CHECK

Percentage of tensile reinforcement provided = 0
Permissible shear stress = 0.20 MPa
Multiplying factor for shear stress for members subjected to axial compression
(Refer Clause B-5.2.2 , IS 456:2000- Plain and Reinforced Concrete- Code of Practice.)

$$\delta = 1 + 5P/(A_g f_{ck})$$

P = axial compressive force
A_g = gross are of the concrete section

δ = 1.00
Hence, permissible shear stress taking the effect of axial compression = 0.20 MPa
Design shear stress = 0.031 MPa
For the calculation of increased shear stress the axial force of the element having maximum shear stress is considered.
Hence, the section is safe in shear.

ANNEXURE-V
CONCRETE LINING DESIGN FOR ROCK CLASS-B

Material Data:

Grade of concrete		=	M-40	
Characteristic strength of concrete	f_{ck}	=	40	MPa

Design Input:

Lining thickness considered	D	=	400	mm
Length of the tunnel considered	b	=	1000	mm

The design of concrete lining is carried out by considering it as an independent structural member. The lining is designed based on working stress method.

PCC LINING

Design criteria

Member Subjected to Combined Axial Load and Bending

Refer clause B-4.1,IS 456:2000- Plain and Reinforced Concrete- code of practice, for uncracked section a member subjected to axial compressive load and bending shall be considered safe provided the following conditions are satisfied:

$$\frac{\sigma_{cc,cal}}{\sigma_{cc}} + \frac{\sigma_{cbc,cal}}{\sigma_{cbc}} \leq 1 \quad \text{------------------ A}$$

Where

$\sigma_{cc,cal}$ = calculated direct compressive stress in concrete

σ_{cc} = permissible axial compressive stress in concrete

$\sigma_{cbc,cal}$ = calculated bending compressive stress in concrete considering biaxial bending

σ_{cbc} = permissible bending compressive stress in concrete

Refer clause 6.3 (b), IS 3370(Part 2):2009- Concrete structures for storage of liquids-code of practice, for uncracked section a member subjected to axial tension load and bending shall be considered safe provided the following conditions are satisfied:

$$\frac{\sigma_{ct,cal}}{\sigma_{ct}} + \frac{\sigma_{cbt,cal}}{\sigma_{cbt}} \leq 1 \quad \text{------------------ B}$$

Where

$\sigma_{ct,cal}$ = calculated direct tensile stress in concrete

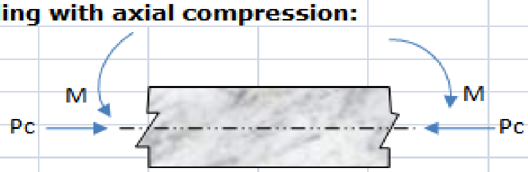
σ_{ct} = permissible direct tensile stress in concrete

$\sigma_{cbt,cal}$ = calculated tensile stress due to bending in concrete considering biaxial bending

σ_{cbt} = permissible tensile stress due to bending in concrete

Permissible bending stress in compression	σ_{cbc}	=	13.00	MPa
Permissible direct stress in compression	σ_{cc}	=	10.00	MPa
Permissible bending stress in tension	σ_{cbt}	=	4.74	MPa
Permissible direct stress in tension	σ_{ct}	=	4.00	MPa

Bending with axial compression:



The moment 'M' in a member during bending with axial compression will cause compression in one face while tension in opposite face at the same time. Hence, the moment capacity of the section has to be checked for both permissible bending stress in compression and tension at the same time.

Axial compressive force with compression due to bending:

Considering Eqn. 'A' $\frac{\sigma_{cc,cal}}{\sigma_{cc}} + \frac{\sigma_{cbc,cal}}{\sigma_{cbc}} \leq 1$

$\frac{P_c}{A\sigma_{cc}} + \frac{6M}{bD^2\sigma_{cbc}} \leq 1$	X at normal condition	=	4000.00	kN
$\frac{P_c}{x} + \frac{M}{y} \leq 1$	Y at normal condition	=	346.67	kN-m

where $x = A\sigma_{cc}$ are constants.

$y = \frac{bD^2\sigma_{cbc}}{6}$

Bending with Axial tension

Axial tensile force with tension due to bending:

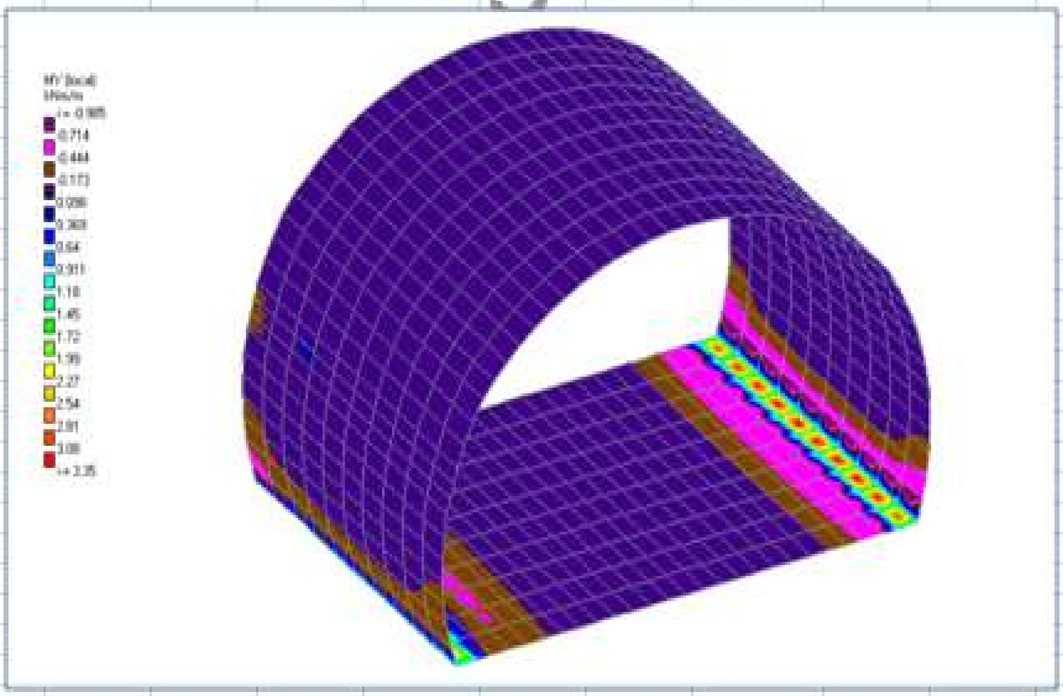
Considering Eq. 'B' $\frac{\sigma_{ct,cal}}{\sigma_{ct}} + \frac{\sigma_{cbt,cal}}{\sigma_{cbt}} \leq 1$

$\frac{P_t}{A\sigma_{ct}} + \frac{6M}{bD^2\sigma_{bt}} \leq 1$	where $x = A\sigma_{ct}$	X at normal condition	=	1600.00	kN
$\frac{P_t}{x} + \frac{M}{y} \leq 1$	$y = \frac{bD^2\sigma_{bt}}{6}$	Y at normal condition	=	126.40	kNm

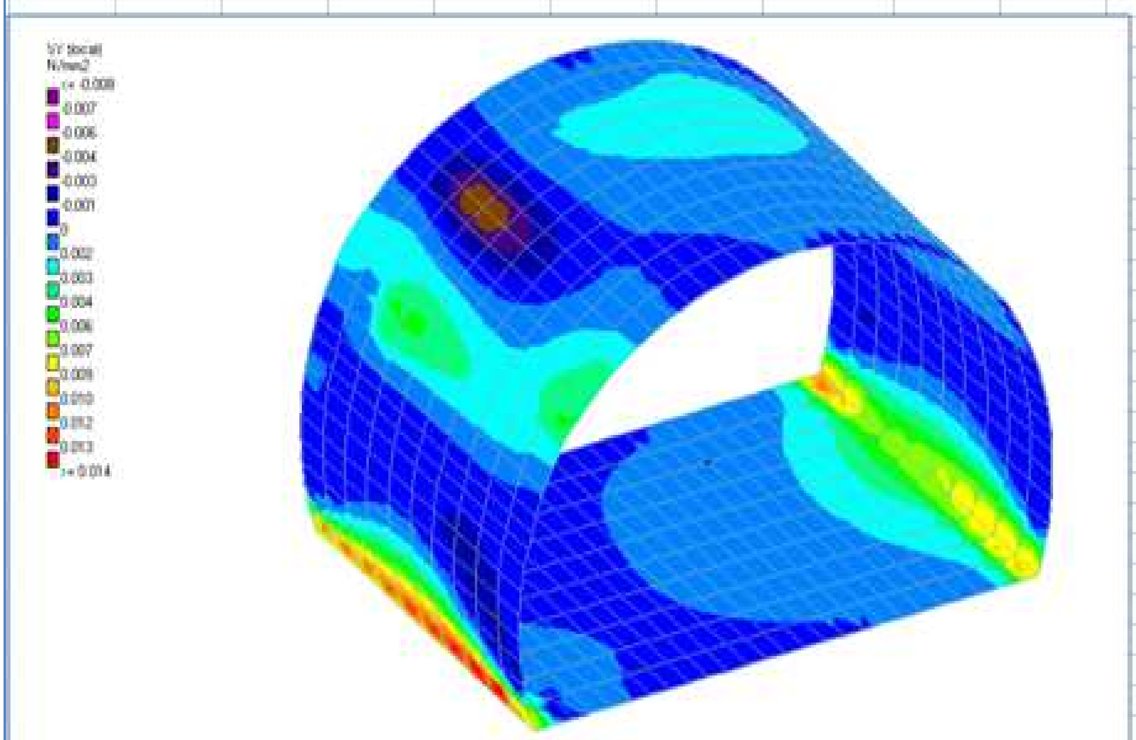
The moment 'M' in a member during bending with axial tension will cause compression in one face while tension in opposite face at the same time. Hence, the moment capacity of the section has to be checked for both permissible bending stress in compression and tension at the same time. However as the face with tension due to bending and tension due to axial force will be critical, this face has been

Load Cases	
Load Case 1:	Earthquake (+X)
Load Case 2:	Self weight
Load Case 3:	Pavement load
Load Case 4:	Traffic load
Load Case 101:	Earthquake+Self weight
Load Case 102:	Earthquake+Self weight+Pavement load
Load Case 103:	Earthquake+Self weight+Pavement load+Traffic load
Load Case 104:	Self weight+Pavement load
Load Case 105:	Self weight+Pavement load+Traffic load

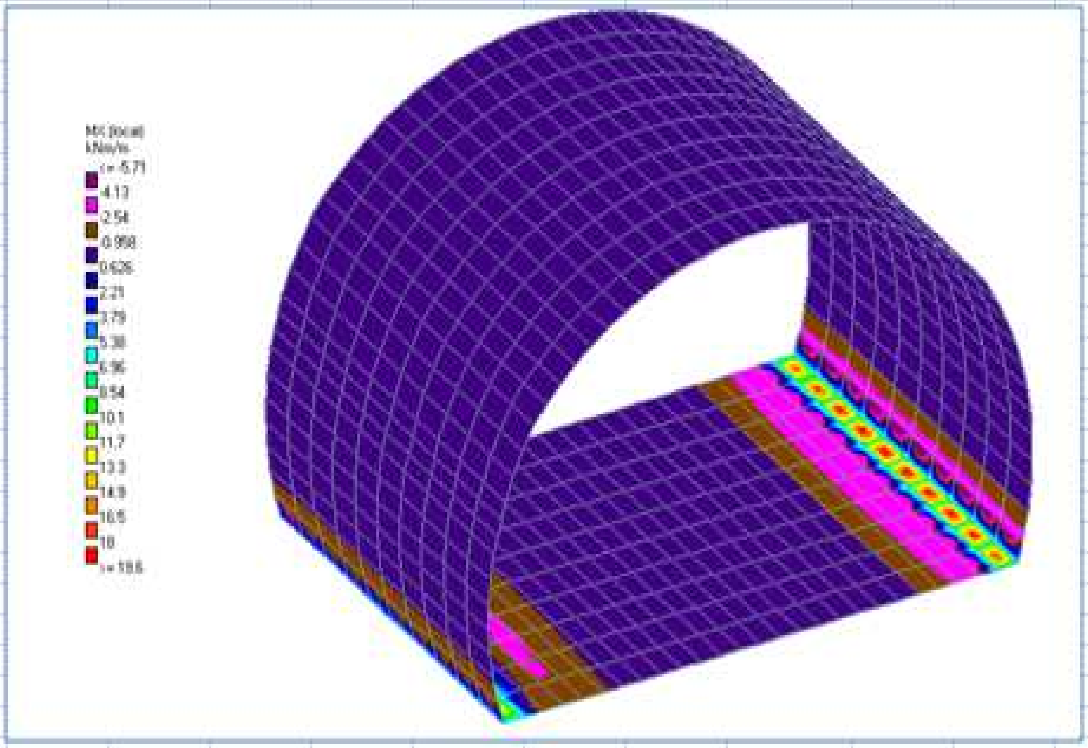
STAAD OUTPUT



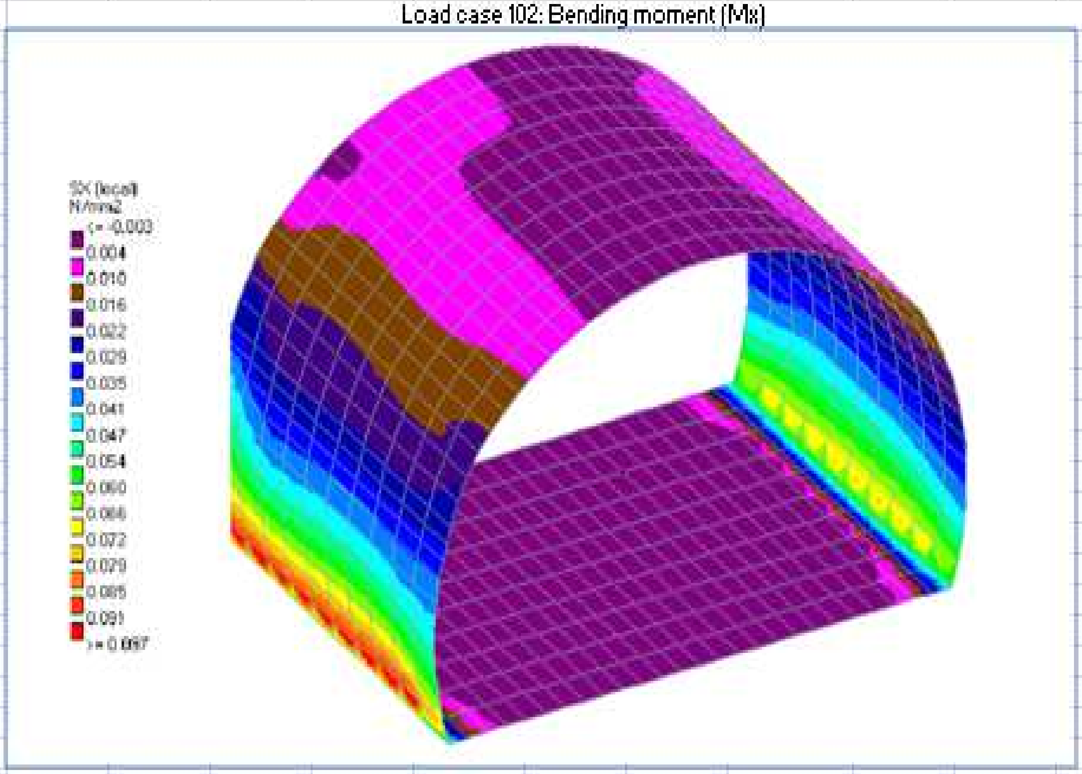
Load case 105: Bending moment (My)



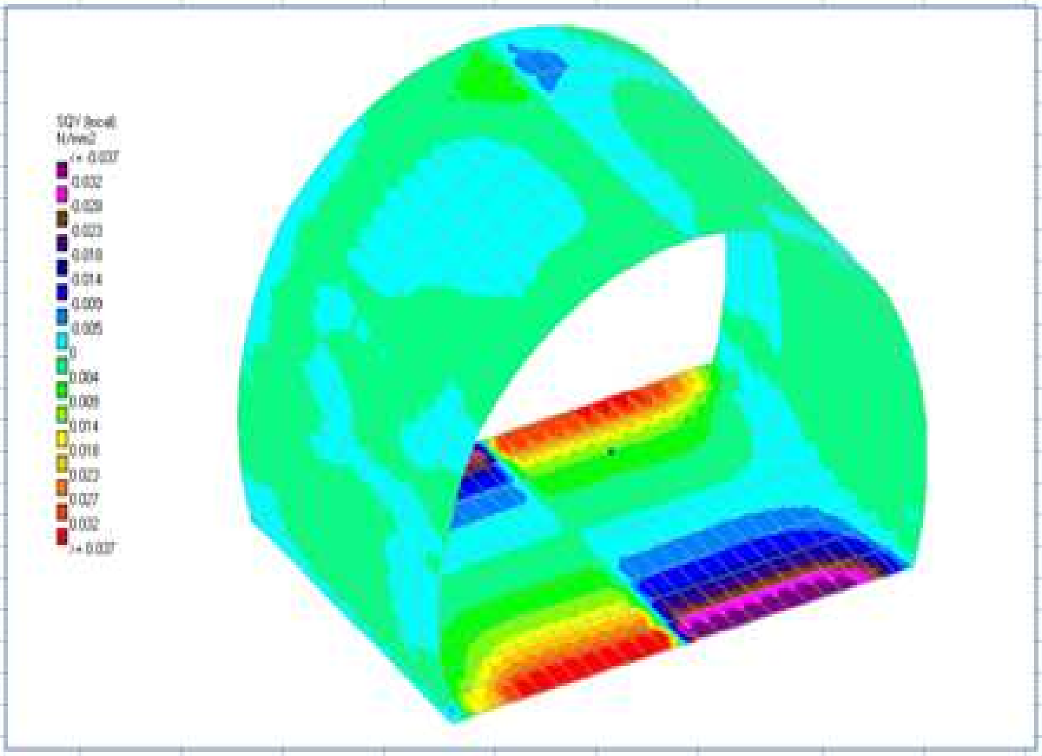
Load case 105: Axial stress (Sy)



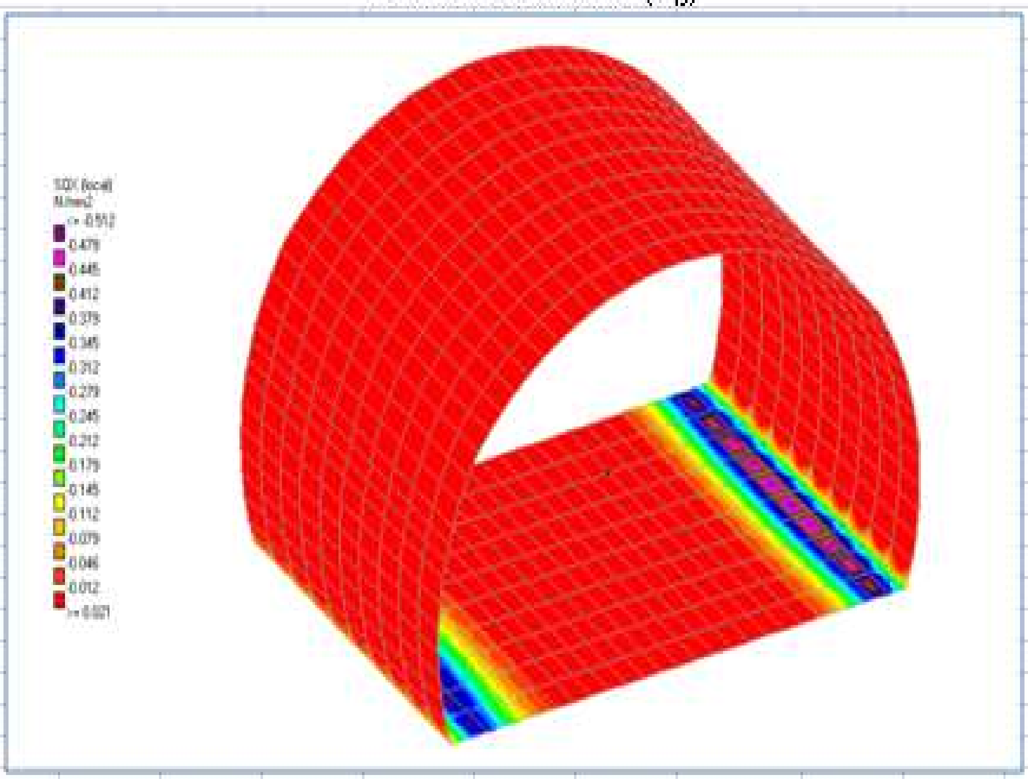
Load case 102: Bending moment (Mx)



Load case 103: Axial stress (Sx)



Load case 105: Shear stress (Sqy)



Load case 101: Shear stress (Sqx)

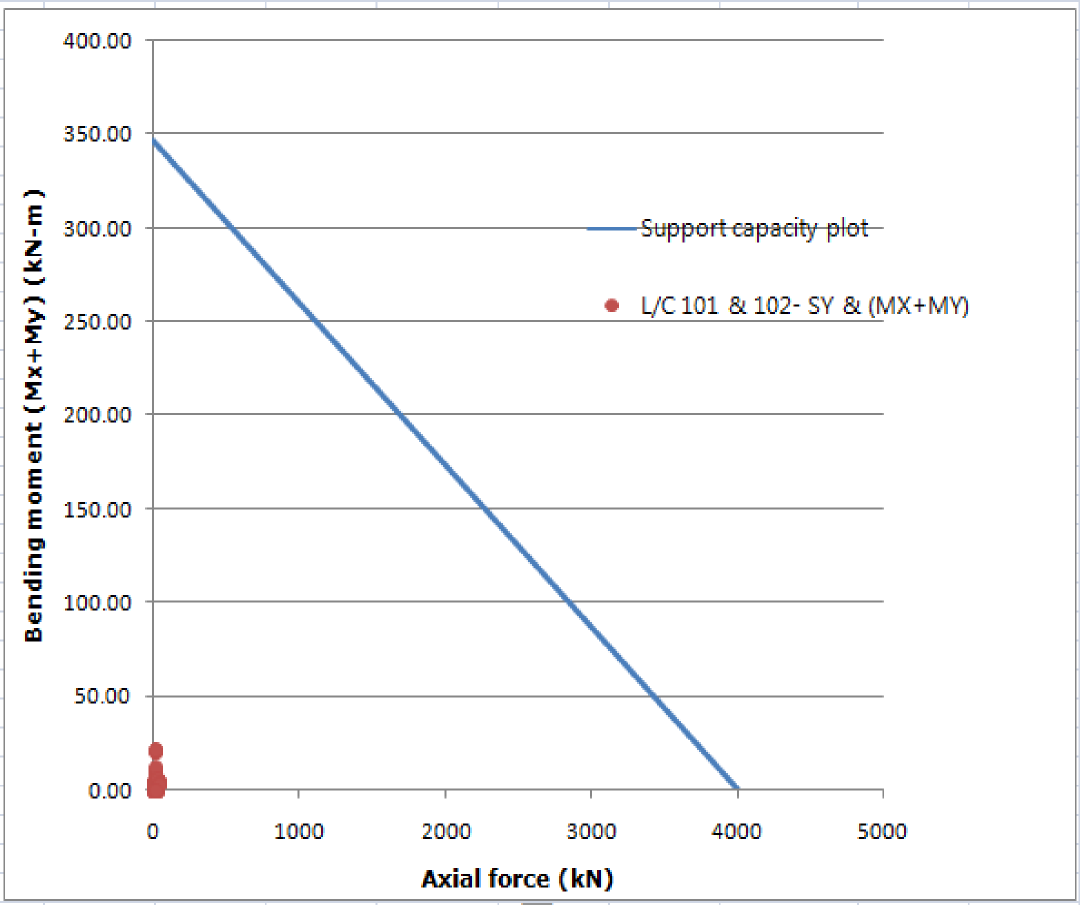
LOAD CASES: LC 101 , 102,103,104 &105										
Description	Plate	L/C	Sqx (N/mm^2)	Sqy (N/mm^2)	Mx (kN-m)	My (kN-m)	Mxy (kN-m)	Sx (N/mm^2)	Sy (N/mm^2)	Sxy (N/mm^2)
Max.My	1180	103	-0.329	-0.001	19.632	**3.349**	0.064	0.038	0.007	0.099
Max.Sy	1609	105	-0.005	0	-2.661	-0.427	0.037	0.097	**0.014**	0
Max.Mx	1180	103	-0.329	-0.001	**19.632**	3.349	0.064	0.038	0.007	0.099
Max.Sx	531	103	-0.008	0.001	-3.719	-0.701	-0.433	**0.097**	0.011	-0.008
Max.Sqy	1815	105	0.006	**0.037**	-0.334	-0.057	0	0	0	-0.002
Max.Sqx	288	103	**0.027**	0.003	-3.431	-0.453	0.33	0.024	0.003	0.001
Max. My+Mx	357	105	-0.276	-0.002	4.433	0.754	0.676	0.013	-0.008	-0.007

DESIGN OF CONCRETE LINING

The axial stress is converted to axial force by multiplying the cross-sectional area.

Axial compression+Compression due to bending

Lining thickness	Axial force	Bending moment
(mm)	(kN)	(kN-m)
400	4000	0.00
400	0	346.67



Axial compression+Tension due to bending

Resultant stress ' -' = compression
Resultant stress '+' = tension

L/C	Axial Force	Bending moment	Resultant stress	Tension	Check
	kN	kN-m	(MPa)	/Compression	
103	2.80	**22.98**	0.85	Tension	O.K
105	5.60	**3.09**	0.10	Tension	O.K
103	2.80	**22.98**	0.85	Tension	O.K
103	4.40	**4.42**	0.15	Tension	O.K
105	0.00	**0.39**	0.01	Tension	O.K
103	1.20	**3.88**	0.14	Tension	O.K
105	3.20	**5.19**	0.19	Tension	O.K

Since all the points corresponding to the maximum axial load (compression) and bending moment are lying within the "Support capacity plot" the section considered for the design is SAFE.

DESIGN -SHEAR CHECK

Percentage of tensile reinforcement provided = 0
Permissible shear stress = 0.20 MPa
Multiplying factor for shear stress for members subjected to axial compression
(Refer Clause B-5.2.2 , IS 456:2000- Plain and Reinforced Concrete- Code of Practice.)

$$\delta=1+5P/(A_g f_{ck})$$

P = axial compressive force
A_g = gross are of the concrete section

δ = 1.00

Hence, permissible shear stress taking the effect of axial compression = 0.20 MPa
Design shear stress = 0.037 MPa
For the calculation of increased shear stress the axial force of the element having maximum shear stress is considered.
Hence, the section is safe in shear.

ANNEXURE-VI

CONCRETE LINING DESIGN FOR ROCK CLASS-C

Material Data:

Grade of concrete		=	M-40	
Characteristic strength of concrete	f_{ck}	=	40	MPa

Design Input:

Lining thickness considered (excluding invert portion)	D	=	400	mm
Lining thickness considered (invert portion)	D	=	400	mm
Length of the tunnel considered	b	=	1000	mm

The design of concrete lining is carried out by considering it as an independent structural member. The lining is designed based on working stress method.

PCC LINING

Design criteria

Member Subjected to Combined Axial Load and Bending

Refer clause B-4.1,IS 456:2000- Plain and Reinforced Concrete- code of practice, for uncracked section a member subjected to axial compressive load and bending shall be considered safe provided the following conditions are satisfied:

$$\frac{\sigma_{cc,cal}}{\sigma_{cc}} + \frac{\sigma_{cbc,cal}}{\sigma_{cbc}} \le 1 \quad \text{------------ A}$$

Where

$\sigma_{cc,cal}$ = calculated direct compressive stress in concrete

σ_{cc} = permissible axial compressive stress in concrete

$\sigma_{cbc,cal}$ = calculated bending compressive stress in concrete considering biaxial bending

σ_{cbc} = permissible bending compressive stress in concrete

Refer clause 6.3 (b), IS 3370(Part 2):2009- Concrete structures for storage of liquids-code of practice, for uncracked section a member subjected to axial tension load and bending shall be considered safe provided the following conditions are satisfied:

$$\frac{\sigma_{ct,cal}}{\sigma_{ct}} + \frac{\sigma_{cbt,cal}}{\sigma_{cbt}} \le 1 \quad \text{------------ B}$$

Where

$\sigma_{ct,cal}$ = calculated direct tensile stress in concrete

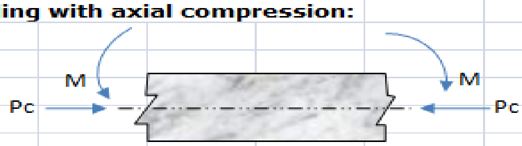
σ_{ct} = permissible direct tensile stress in concrete

$\sigma_{cbt,cal}$ = calculated tensile stress due to bending in concrete considering biaxial bending

σ_{cbt} = permissible tensile stress due to bending in concrete

Permissible bending stress in compression	σ_{cbc}	=	13.00	MPa
Permissible direct stress in compression	σ_{cc}	=	10.00	MPa
Permissible bending stress in tension	σ_{cbt}	=	4.75	MPa
Permissible direct stress in tension	σ_{ct}	=	4.00	MPa

Bending with axial compression:



The moment 'M' in a member during bending with axial compression will cause compression in one face while tension in opposite face at the same time. Hence, the moment capacity of the section has to be checked for both permissible bending stress in compression and tension at the same time.

Axial compressive force with compression due to bending:

Considering Eqn. 'A' $\dfrac{\sigma_{cc,cal}}{\sigma_{cc}} + \dfrac{\sigma_{cbc,cal}}{\sigma_{cbc}} \leq 1$

$$\frac{P_c}{A\sigma_{cc}} + \frac{6M}{bD^2\sigma_{cbc}} \leq 1$$

X at normal condition(for 400mm thick.)	=	4000.00	kN
	=	4000.00	kN

$$\frac{P_c}{x} + \frac{M}{y} \leq 1$$

Y at normal condition (for 400mm thick.	=	346.67	kN-m
	=	346.67	kN-m

where $x = A\sigma_{cc}$ are constants.

$$y = \frac{bD^2\sigma_{cbc}}{6}$$

Bending with Axial tension

Axial tensile force with tension due to bending:

Considering Eq. 'B' $\dfrac{\sigma_{ct,cal}}{\sigma_{ct}} + \dfrac{\sigma_{cbt,cal}}{\sigma_{cbt}} \leq 1$

$$\frac{P_t}{A\sigma_{ct}} + \frac{6M}{bD^2\sigma_{bt}} \leq 1$$

where $x = A\sigma_{ct}$

X at normal condition (for 400mm thick.	=	1600.00	kN
	=	1600.00	kN

$$\frac{P_t}{x} + \frac{M}{y} \leq 1 \qquad y = \frac{bD^2\sigma_{bt}}{6}$$

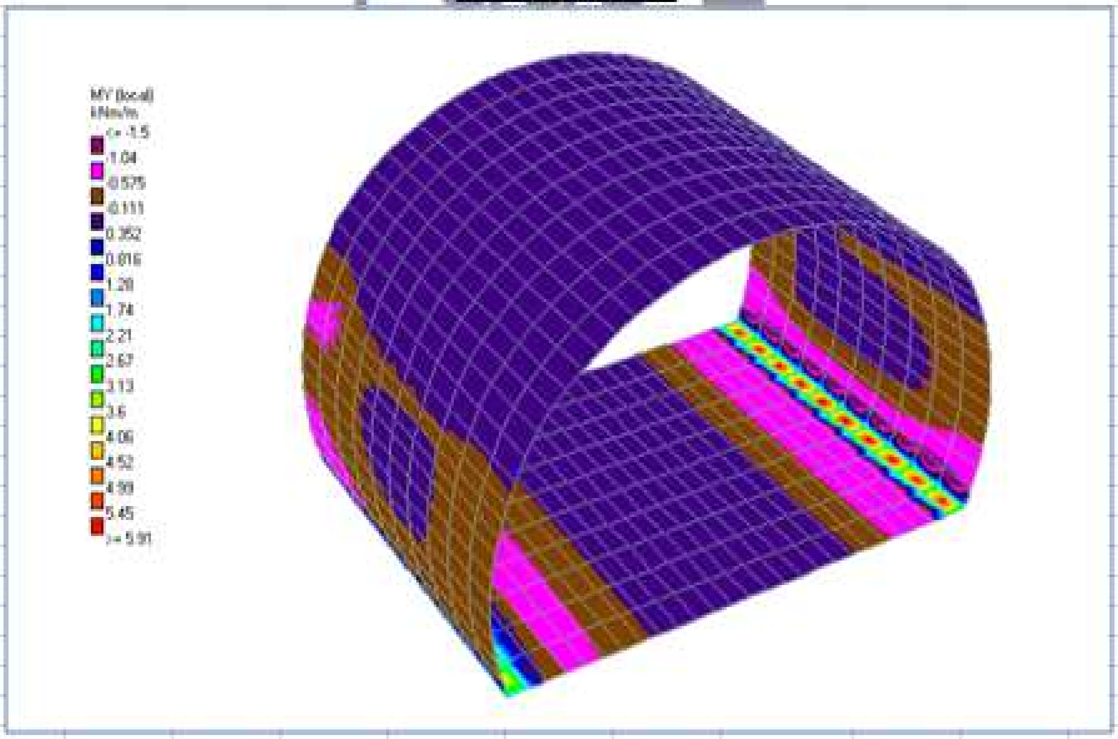
Y at normal condition (for 400mm thick.	=	126.67	kNm
	=	126.67	kNm

The moment 'M' in a member during bending with axial tension will cause compression in one face while tension in opposite face at the same time. Hence, the moment capacity of the section has to be checked for both permissible bending stress in compression and tension at the same time. However as the face with tension due to bending and tension due to axial force will be critical, this face has been

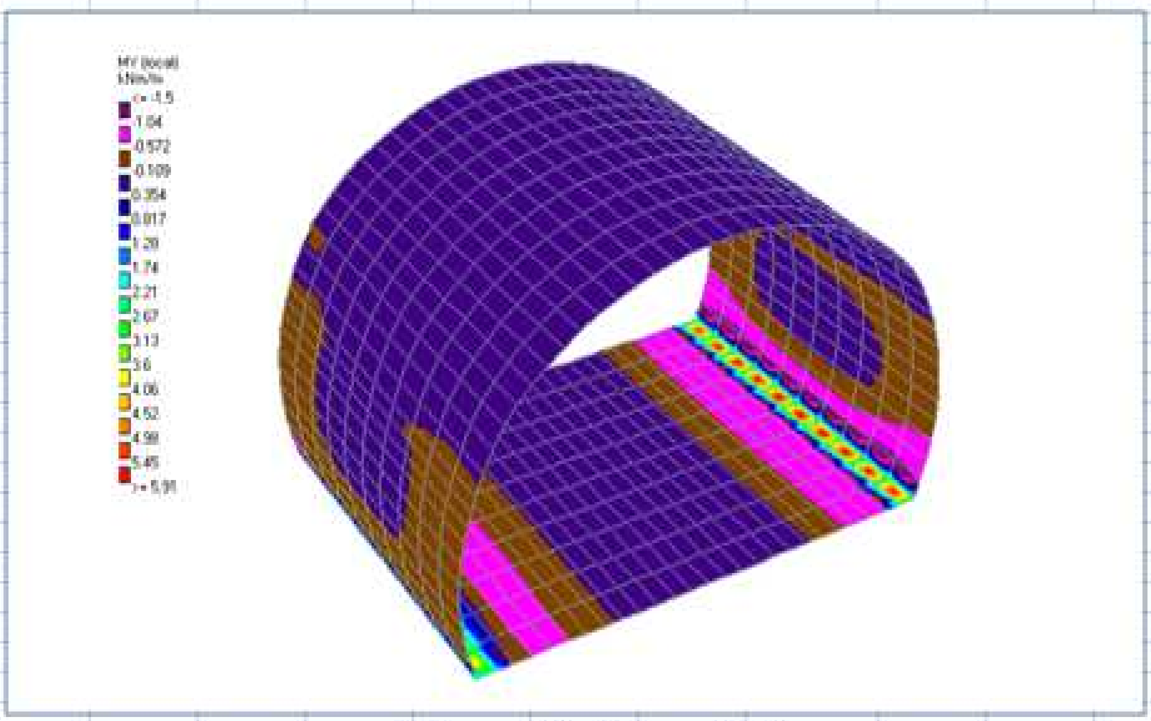
Load Cases

Load Case 1:	Earthquake (+X)
Load Case 2:	Self weight
Load Case 3:	Rock load
Load Case 4:	Pavement load
Load Case 5:	Traffic load
Load Case 101:	Earthquake+Self weight
Load Case 102:	Earthquake+Self weight+Rock load
Load Case 103:	Earthquake+Self weight+Rock load+Pavement load
Load Case 104:	Earthquake+Self weight+Rock load+Pavement load+Traffic load
Load Case 105:	Self weight+Rock load
Load Case 106:	Self weight+Rock load+Pavement load
Load Case 107:	Self weight+Rock load+Pavement load+Traffic load

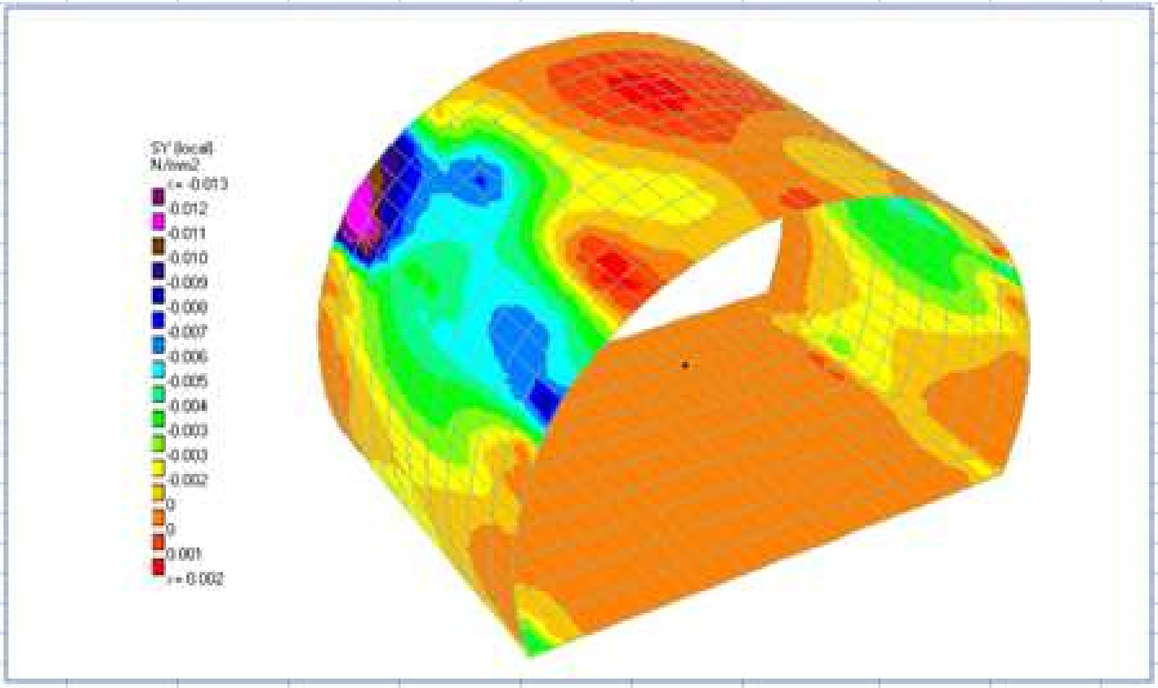
STAAD OUTPUT

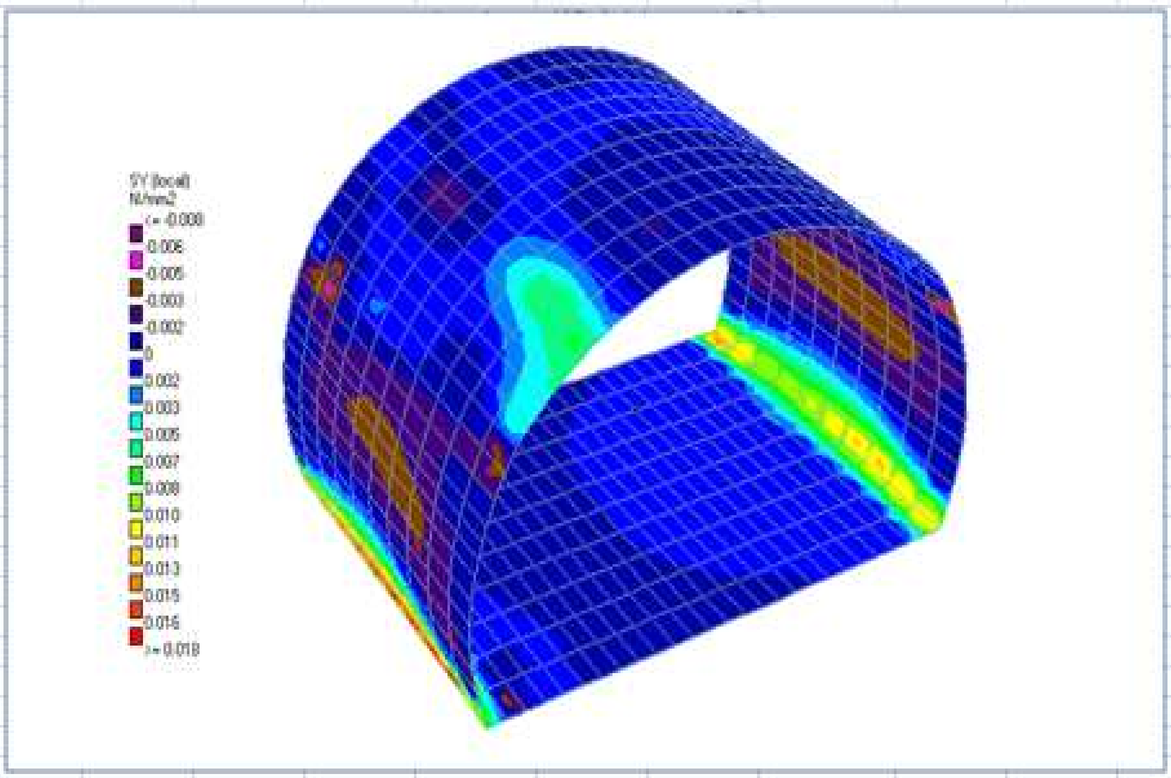


Load case 104: Bending moment (My)

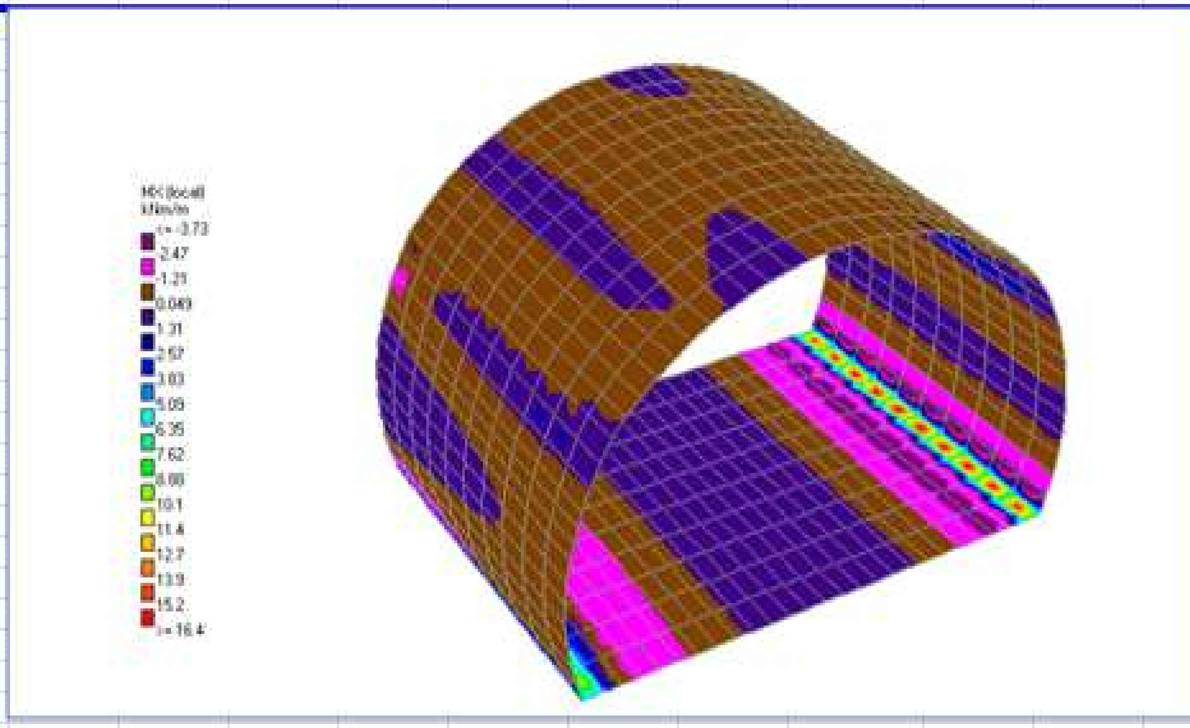


Load case 105: Bending moment (My)

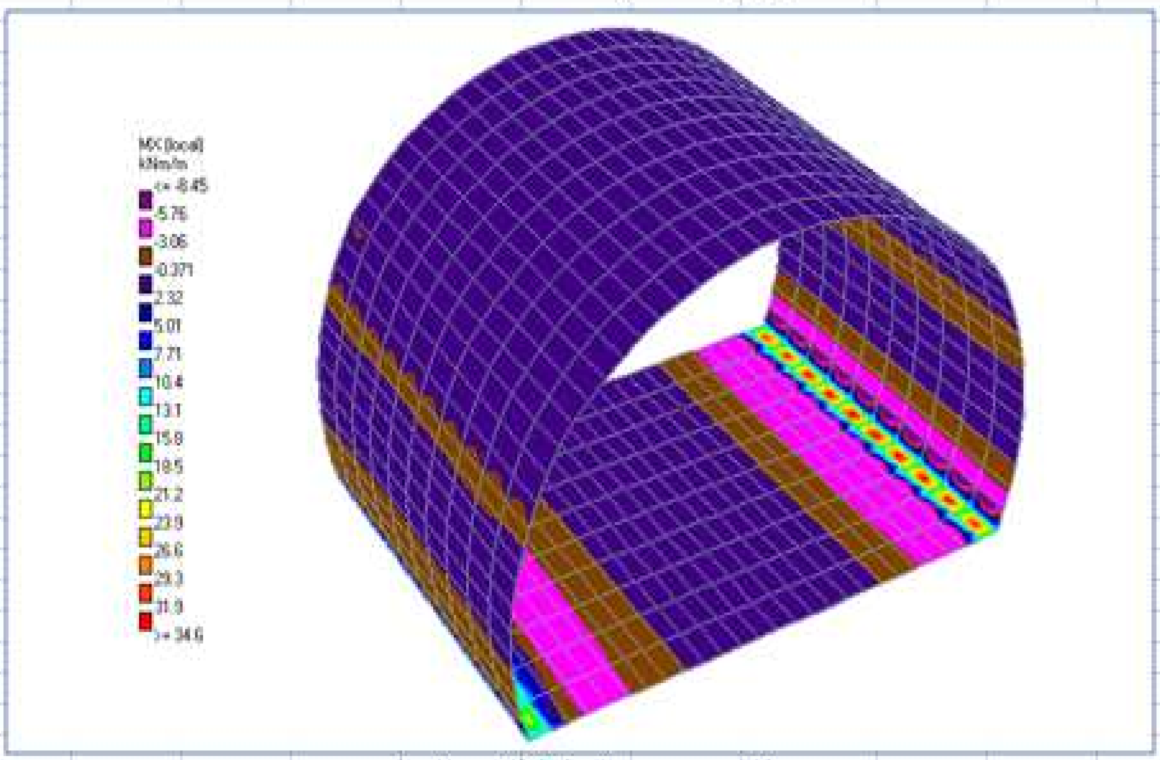




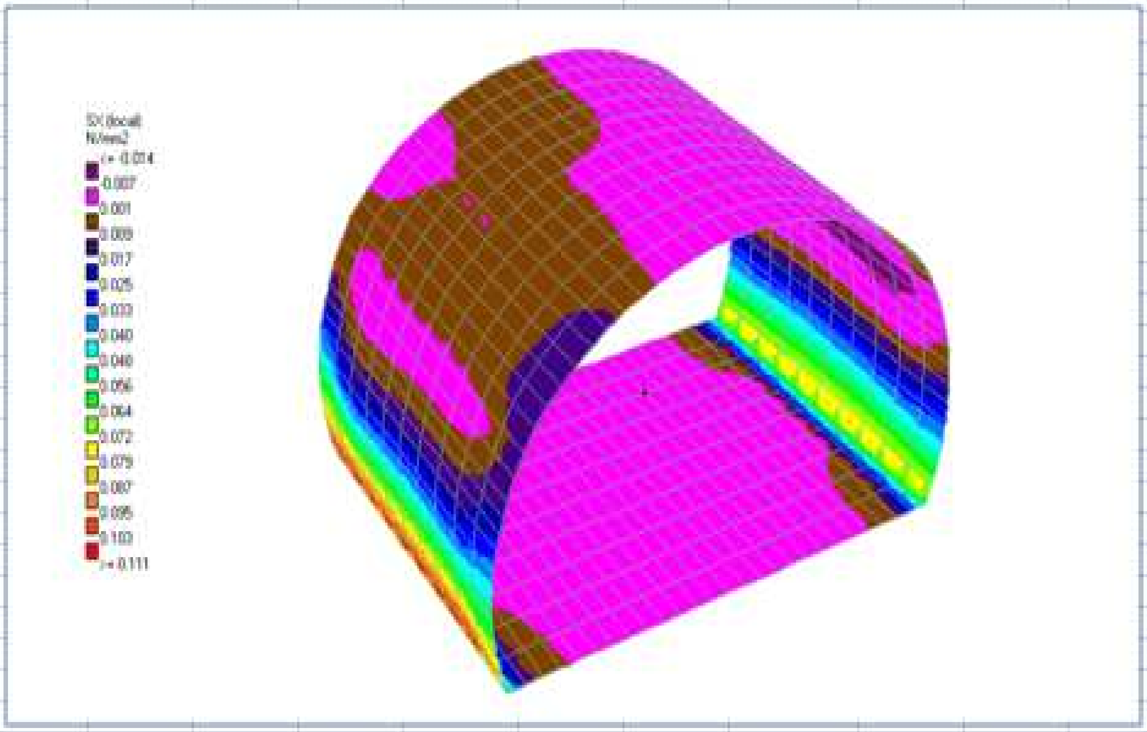
Load case 107: Axial stress (Sy)



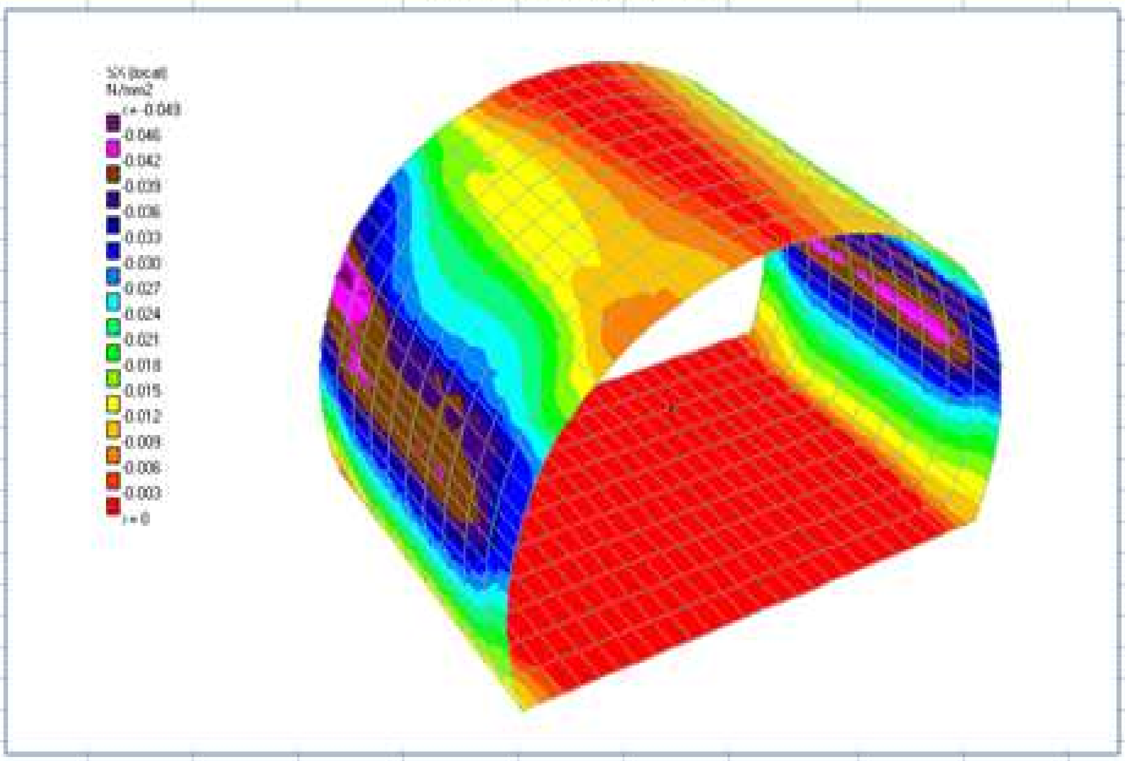
Load case 103: Bending moment (Mx)



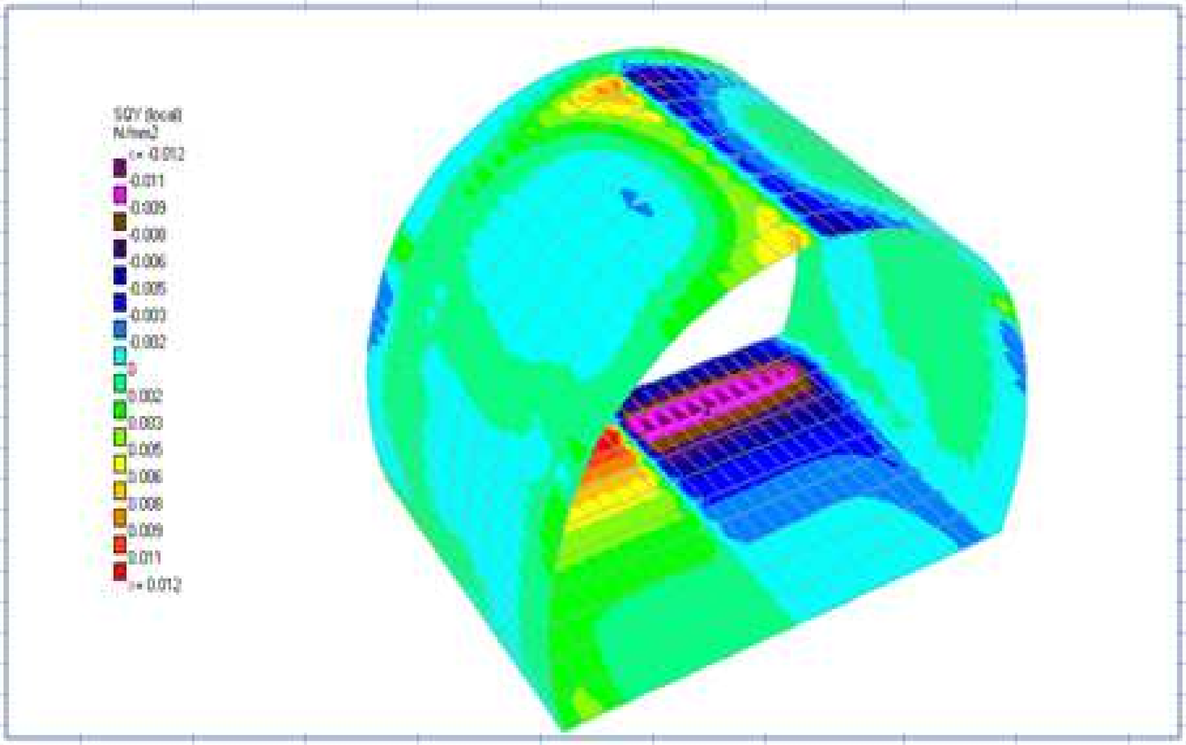
Load case 107: Bending moment (Mx)



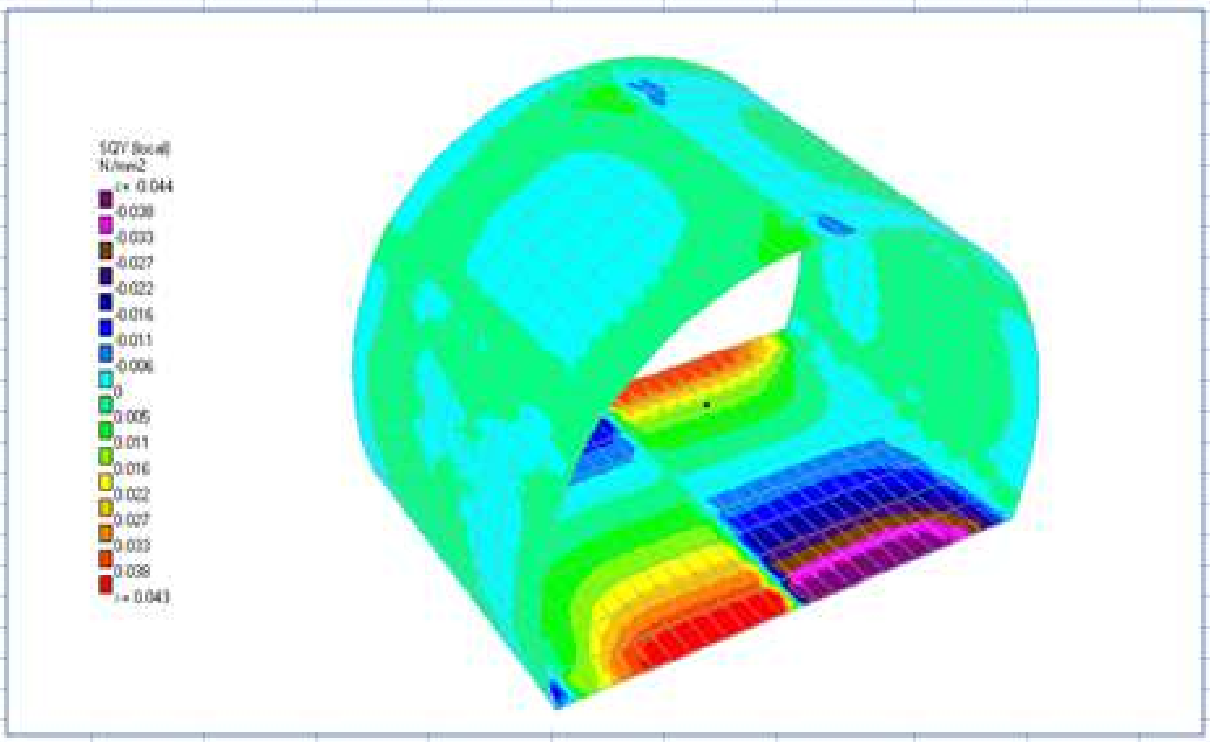
Load case 104: Axial stress (Sx)



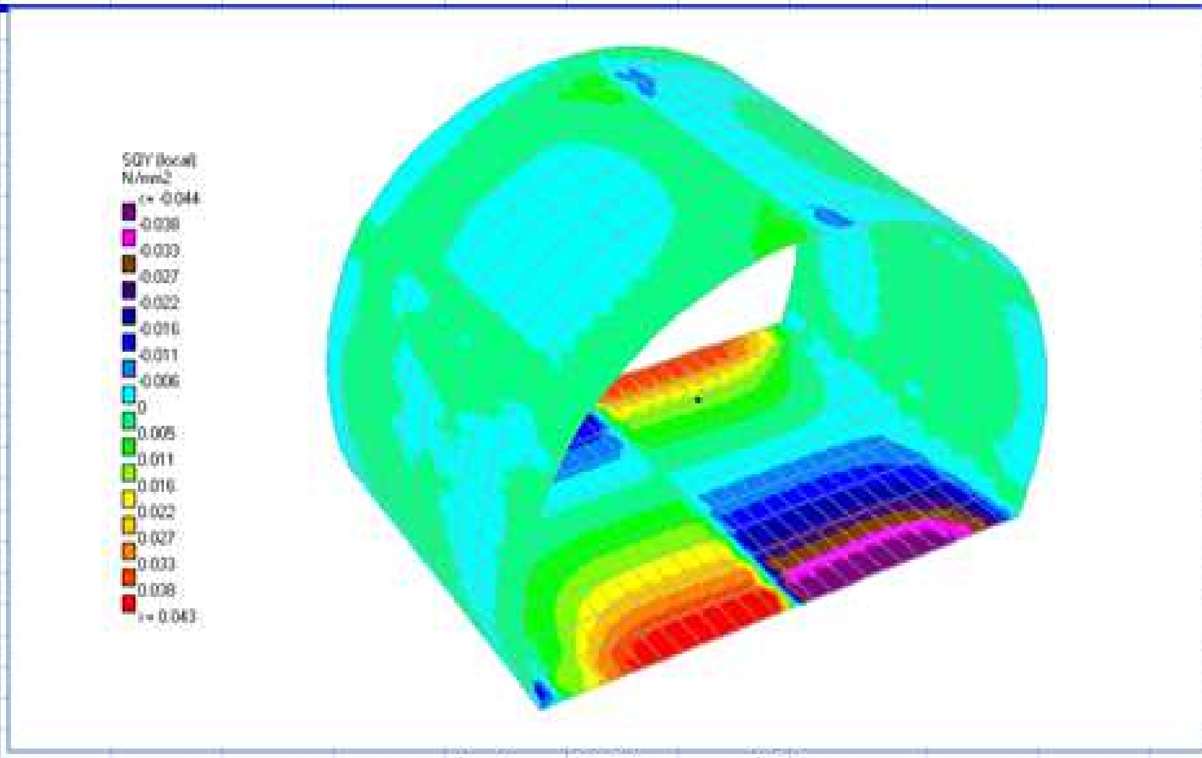
Load case 105: Axial stress (Sx)



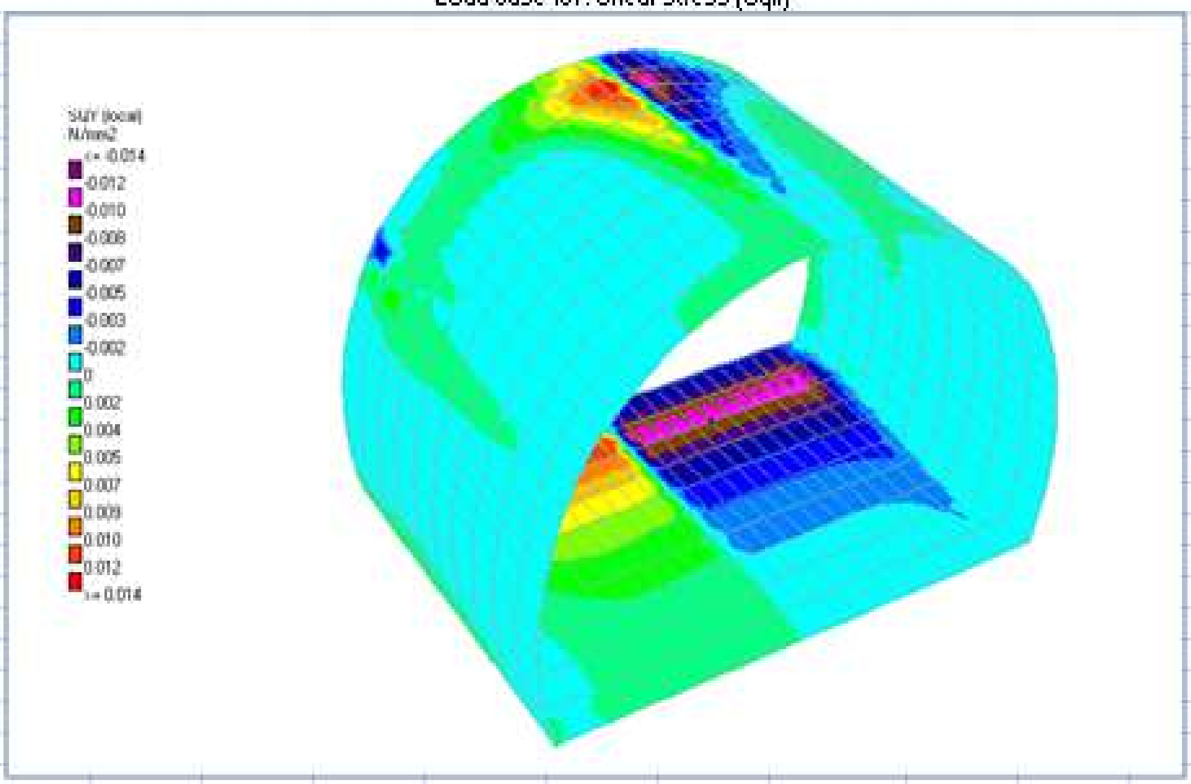
Load case 105: Shear stress (Sqy)



Load case 107: Shear stress (Sqy)



Load case 107: Shear stress (Sqx)



Load case 101: Shear stress (Sqx)

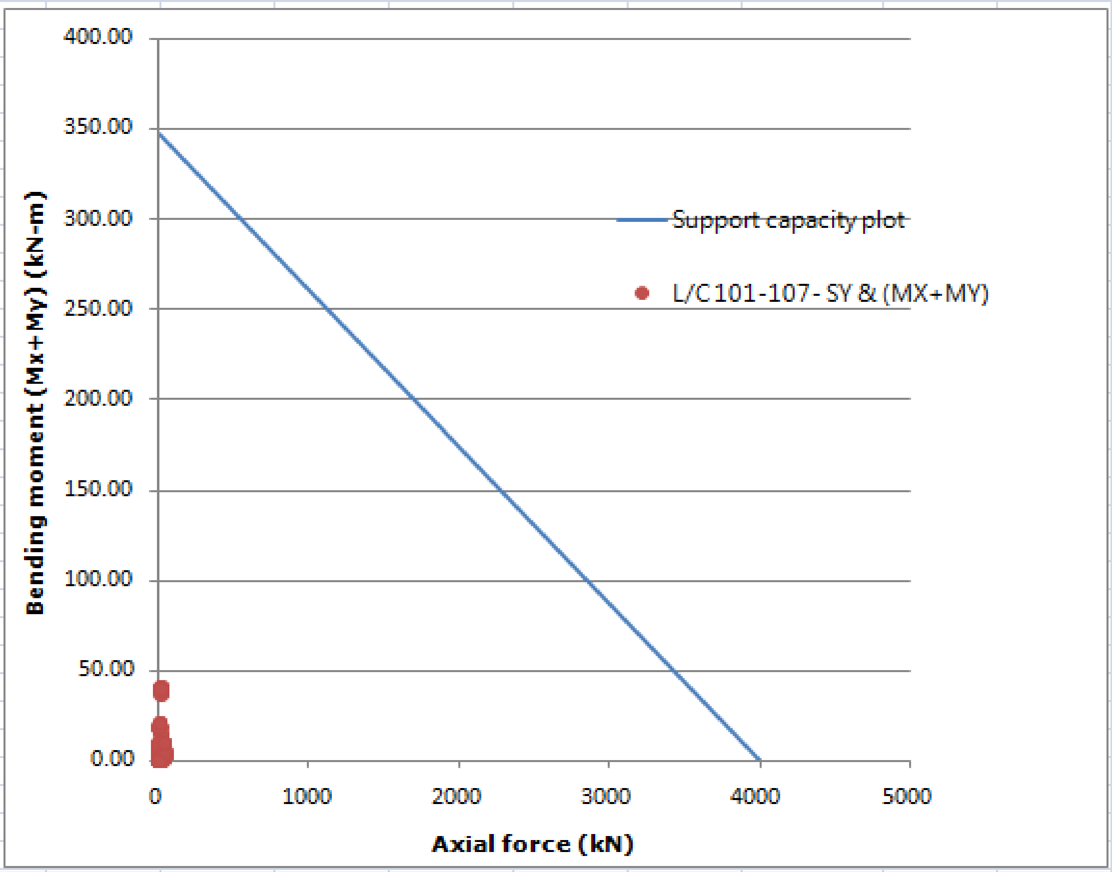
ROCK CLASS C										
LOAD CASES: LC 101 TO 107										
Description	Plate	L/C	Sqx (N/mm^2)	Sqy (N/mm^2)	Mx (kN-m)	My (kN-m)	Mxy (kN-m)	Sx (N/mm^2)	Sy (N/mm^2)	Sxy (N/mm^2)
Max.My	1180	104	-0.547	-0.002	34.653	**5.913**	0.135	0.04	0.007	0.179
Max.Sy	1609	107	0.001	-0.001	-2.825	-0.513	0.03	0.111	**0.018**	-0.005
Max.Mx	1180	104	-0.547	-0.002	**34.65**	5.913	0.135	0.04	0.007	0.179
Max.Sx	1609	107	0.001	-0.001	-2.825	-0.513	0.03	**0.111**	0.018	-0.005
Max.Sqy	1814	104	0.045	**0.043**	-0.677	-0.115	-0.002	0	0	-0.004
Max.Sqx	719	105	**0.103**	-0.008	-0.173	-0.029	0.002	-0.001	0	-0.004
Max. My+Mx	289	104	0.005	-0.004	-1.29	-0.404	0.863	0.009	-0.001	-0.002

DESIGN OF CONCRETE LINING

The axial stress is converted to axial force by multiplying the cross-sectional area.

Axial compression+Compression due to bending

Lining thickness	Axial force	Bending
(mm)	(kN)	(kN-m)
400	4000	0.00
400	0	346.67



Axial compression+Tension due to bending

Resultant stress ' -' = compression
Resultant stress '+' = tension

L/C	Axial Force kN	Bending moment kN-m	Resultant stress (MPa)	Tension /Compression	Check
104	2.80	**40.57**	1.51	Tension	O.K
107	7.20	**3.34**	0.11	Tension	O.K
104	2.80	**40.57**	1.51	Tension	O.K
107	7.20	**3.34**	0.11	Tension	O.K
104	0.00	**0.79**	0.03	Tension	O.K
105	0.00	**0.20**	0.01	Tension	O.K
104	0.40	**1.69**	0.06	Tension	O.K

Since all the points corresponding to the maximum axial load (compression) and bending moment are lying within the "Support capacity plot" the section considered for the design is SAFE.

DESIGN -SHEAR CHECK

Percentage of tensile reinforcement provided	=	0	
Permissible shear stress	=	0.20	MPa

Multiplying factor for shear stress for members subjected to axial compression
(Refer Clause B-5.2.2 , IS 456:2000- Plain and Reinforced Concrete- Code of Practice.)

P = axial compressive force
A_g = gross are of the concrete section

δ	=	1.00	
Hence, permissible shear stress taking the effect of axial compression	=	0.20	MPa
Design shear stress	=	0.04	MPa

For the calculation of increased shear stress the axial force of the element having maximum shear stress is considered.

Hence, the section is safe in shear.

ANNEXURE-VII

CONCRETE LINING DESIGN FOR ROCK CLASS-D

Material Data:

Grade of concrete		=	M-40	
Characteristic strength of concrete	f_{ck}	=	40	MPa

Design Input:

Lining thickness considered (excluding invert portion)	D	=	400	mm
Lining thickness considered (invert portion)	D	=	400	mm
Length of the tunnel considered	b	=	1000	mm

The design of concrete lining is carried out by considering it as an independent structural member. The lining is designed based on working stress method.

PCC LINING

Design criteria

Member Subjected to Combined Axial Load and Bending

Refer clause B-4.1,IS 456:2000- Plain and Reinforced Concrete- code of practice, for uncracked section a member subjected to axial compressive load and bending shall be considered safe provided the following conditions are satisfied:

$$\frac{\sigma_{cc,cal}}{\sigma_{cc}} + \frac{\sigma_{cbc,cal}}{\sigma_{cbc}} \le 1 \quad \text{------------ A}$$

Where

$\sigma_{cc,cal}$ = calculated direct compressive stress in concrete

σ_{cc} = permissible axial compressive stress in concrete

$\sigma_{cbc,cal}$ = calculated bending compressive stress in concrete considering biaxial bending

σ_{cbc} = permissible bending compressive stress in concrete

Refer clause 6.3 (b), IS 3370(Part 2):2009- Concrete structures for storage of liquids-code of practice, for uncracked section a member subjected to axial tension load and bending shall be considered safe provided the following conditions are satisfied:

$$\frac{\sigma_{ct,cal}}{\sigma_{ct}} + \frac{\sigma_{cbt,cal}}{\sigma_{cbt}} \le 1 \quad \text{------------ B}$$

Where

$\sigma_{cc,cal}$ = calculated direct compressive stress in concrete

σ_{cc} = permissible axial compressive stress in concrete

$\sigma_{cbc,cal}$ = calculated bending compressive stress in concrete considering biaxial bending

σ_{cbc} = permissible bending compressive stress in concrete

Refer clause 6.3 (b), IS 3370(Part 2):2009- Concrete structures for storage of liquids-code of practice, for uncracked section a member subjected to axial tension load and bending shall be considered safe provided the following conditions are satisfied:

$$\frac{\sigma_{ct,cal}}{\sigma_{ct}} + \frac{\sigma_{cbt,cal}}{\sigma_{cbt}} \le 1 \quad \text{------------ B}$$

Where

$\sigma_{ct,cal}$ = calculated direct tensile stress in concrete

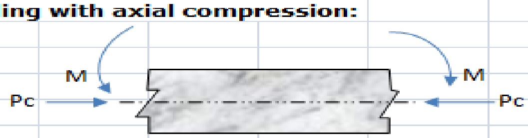
σ_{ct} = permissible direct tensile stress in concrete

$\sigma_{cbt,cal}$ = calculated tensile stress due to bending in concrete considering biaxial bending

σ_{cbt} = permissible tensile stress due to bending in concrete

Permissible bending stress in compression	σ_{cbc}	=	16.00	MPa
Permissible direct stress in compression	σ_{cc}	=	12.00	MPa
Permissible bending stress in tension	σ_{cbt}	=	4.74	MPa
Permissible direct stress in tension	σ_{ct}	=	4.00	MPa

Bending with axial compression:



The moment 'M' in a member during bending with axial compression will cause compression in one face while tension in opposite face at the same time. Hence, the moment capacity of the section has to be checked for both permissible bending stress in compression and tension at the same time.

Axial compressive force with compression due to bending:

Considering Eqn. 'A' $\frac{\sigma_{cc,cal}}{\sigma_{cc}} + \frac{\sigma_{cbc,cal}}{\sigma_{cbc}} \leq 1$

$\frac{P_c}{A\sigma_{cc}} + \frac{6M}{bD^2\sigma_{cbc}} \leq 1$	X at normal condition(for 400mm thick.)	=	4800.00	kN
		=	4800.00	kN
$\frac{P_c}{x} + \frac{M}{y} \leq 1$	Y at normal condition (for 400mm thick.	=	426.67	kN-m
		=	426.67	kN-m

where $x = A\sigma_{cc}$ are constants.

$y = \frac{bD^2\sigma_{cbc}}{6}$

Bending with Axial tension

Axial tensile force with tension due to bending:

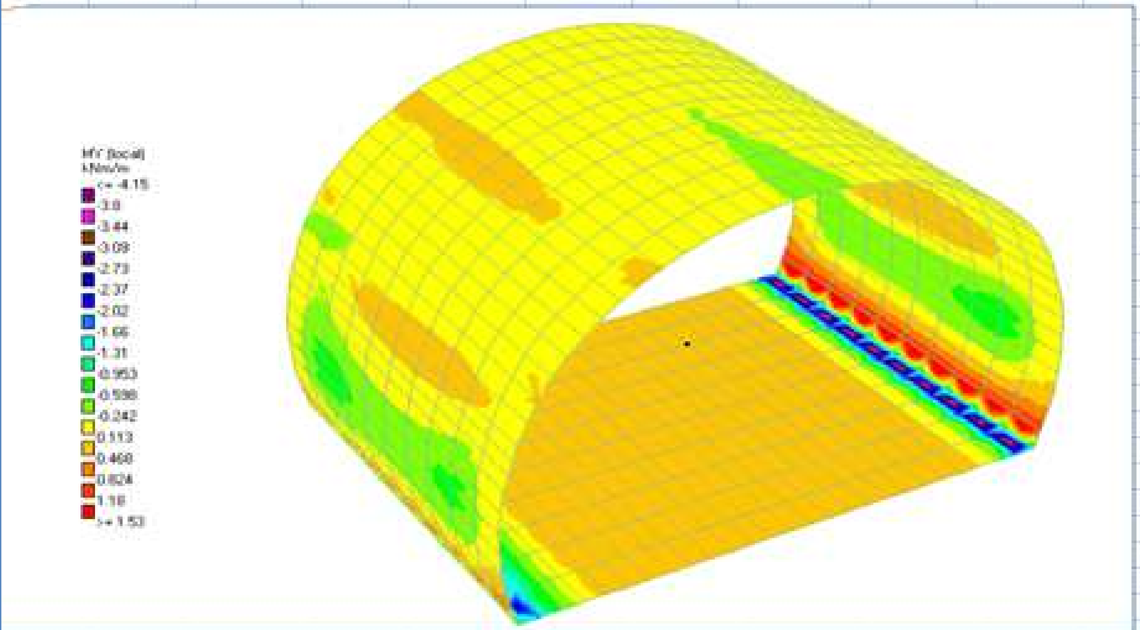
Considering Eq. 'B' $\frac{\sigma_{ct,cal}}{\sigma_{ct}} + \frac{\sigma_{cbt,cal}}{\sigma_{cbt}} \leq 1$

$\frac{P_t}{A\sigma_{ct}} + \frac{6M}{bD^2\sigma_{bt}} \leq 1$	where	X at normal condition (for 400mm thick.	=	1600.00	kN
	$x = A\sigma_{ct}$		=	1600.00	kN
$\frac{P_t}{x} + \frac{M}{y} \leq 1$	$y = \frac{bD^2\sigma_{bt}}{6}$	Y at normal condition (for 400mm thick.	=	126.49	kNm
			=	126.49	kNm

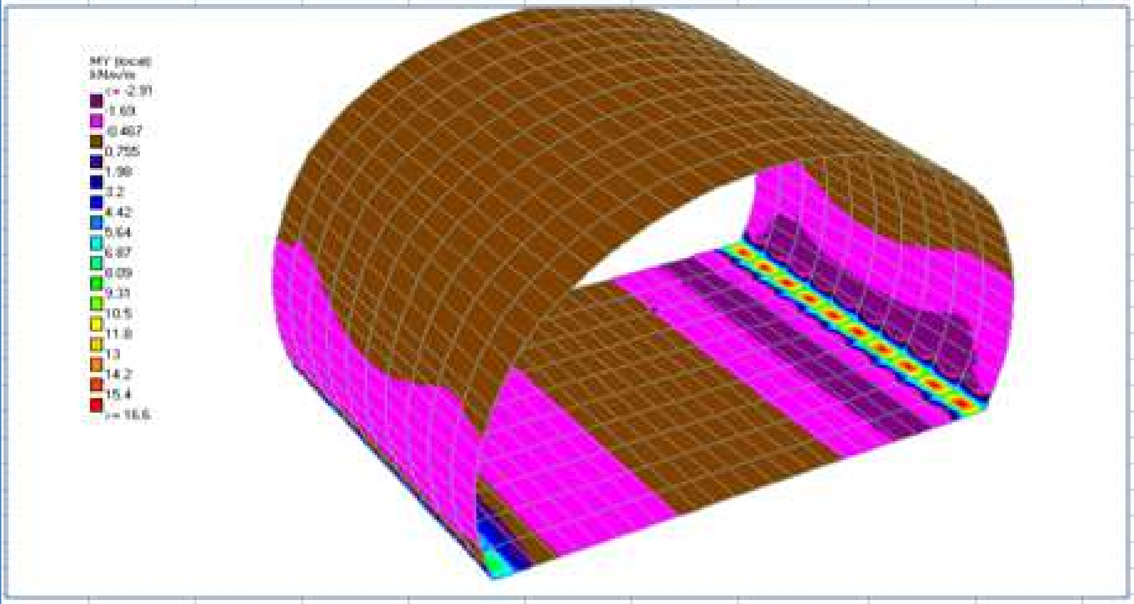
The moment 'M' in a member during bending with axial tension will cause compression in one face while tension in opposite face at the same time. Hence, the moment capacity of the section has to be checked for both permissible bending stress in compression and tension at the same time. However as the face with tension due to bending and tension due to axial force will be critical, this face has been

Load Cases	
Load Case 1:	Earthquake (+X)
Load Case 2:	Self weight
Load Case 3:	Rock load
Load Case 4:	Pavement load
Load Case 5:	Traffic load
Load Case 101:	Earthquake+Self weight
Load Case 102:	Earthquake+Self weight+Rock load
Load Case 103:	Earthquake+Self weight+Rock load+Pavement load
Load Case 104:	Earthquake+Self weight+Rock load+Pavement load+Traffic load
Load Case 105:	Self weight+Rock load
Load Case 106:	Self weight+Rock load+Pavement load
Load Case 107:	Self weight+Rock load+Pavement load+Traffic load

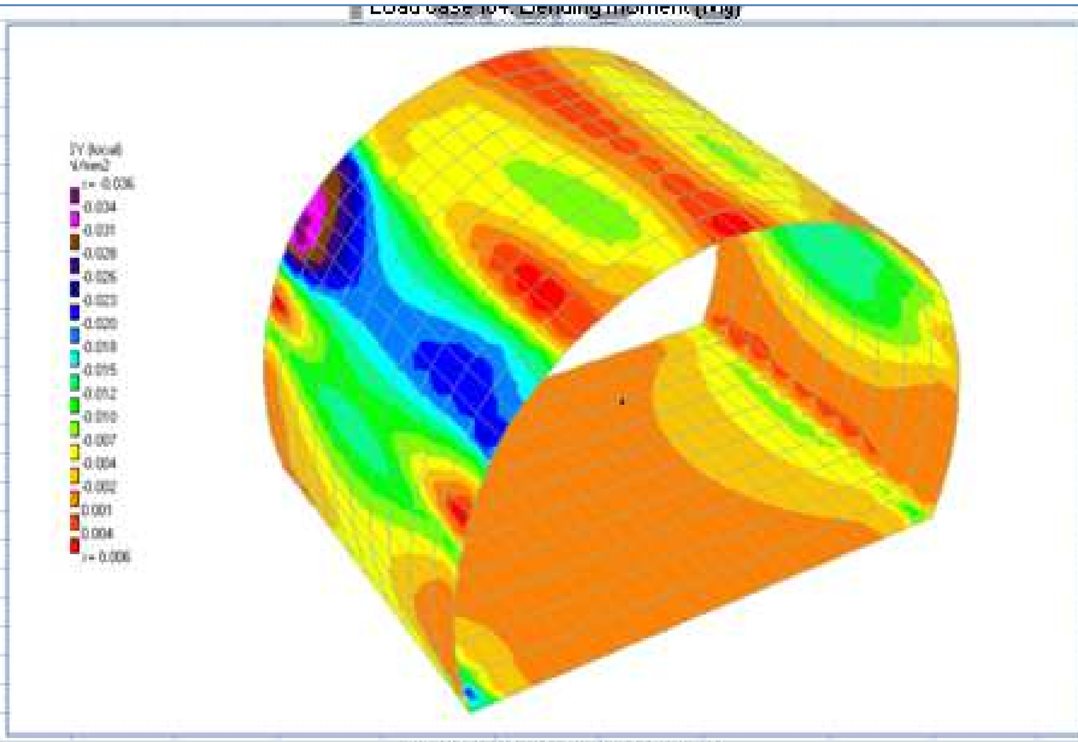
STAAD OUTPUT



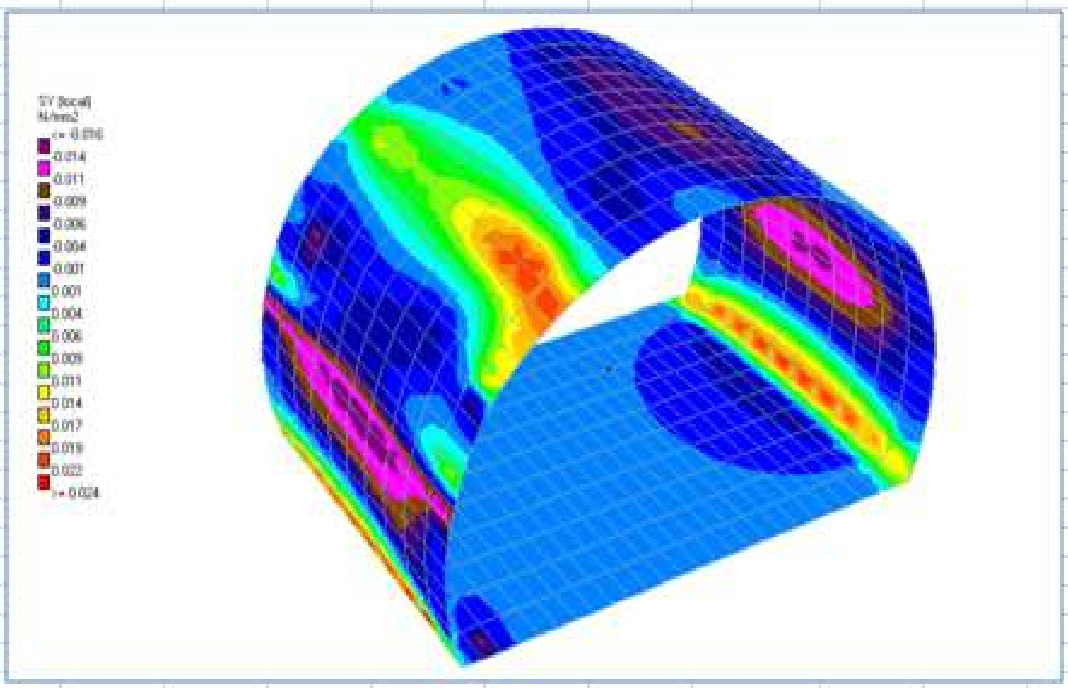
Load case 102: Bending moment (My)



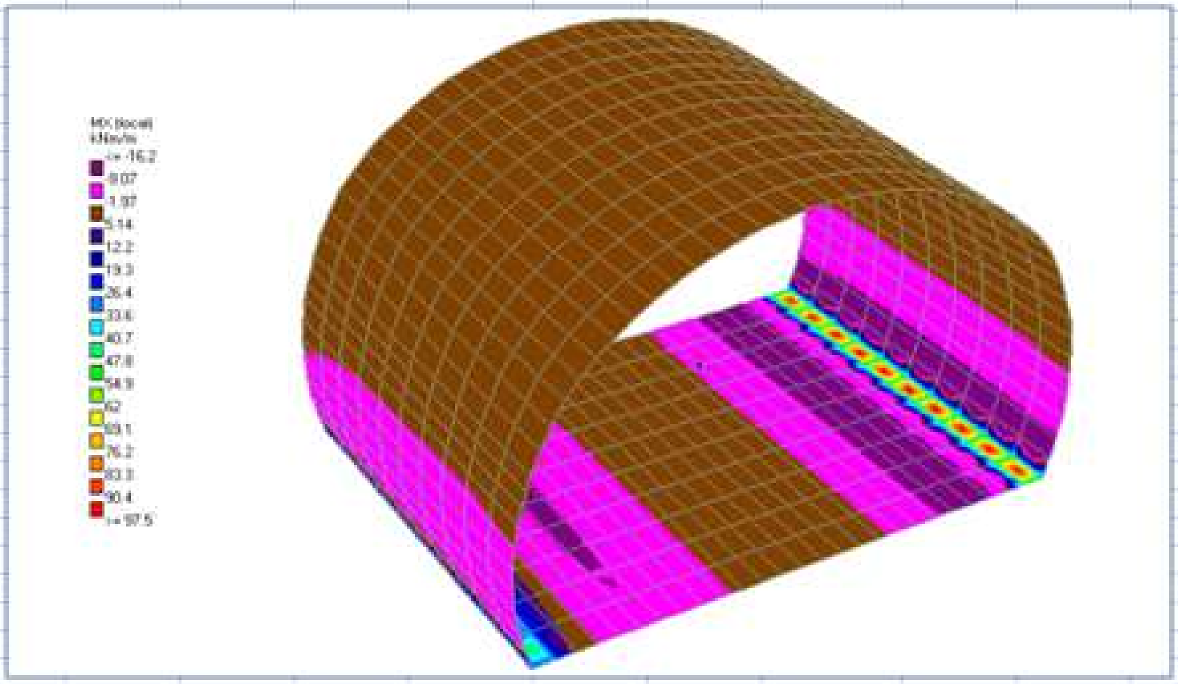
Load case 104: Bending moment (My)



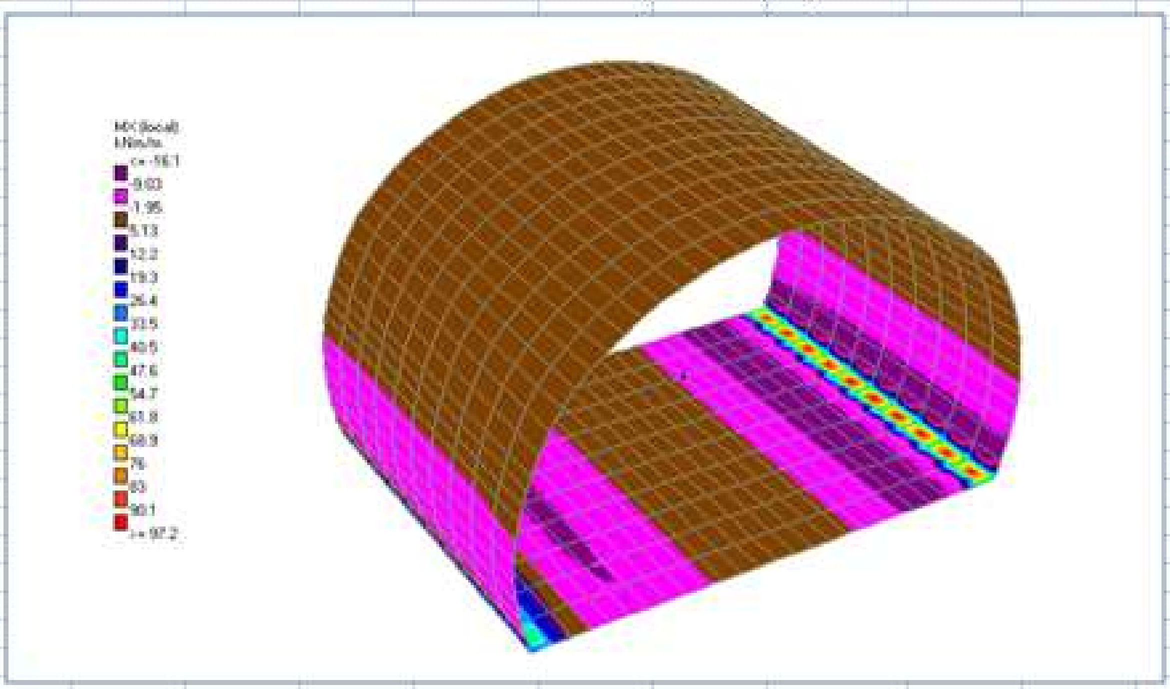
Load case 105: Axial stress (Sy)



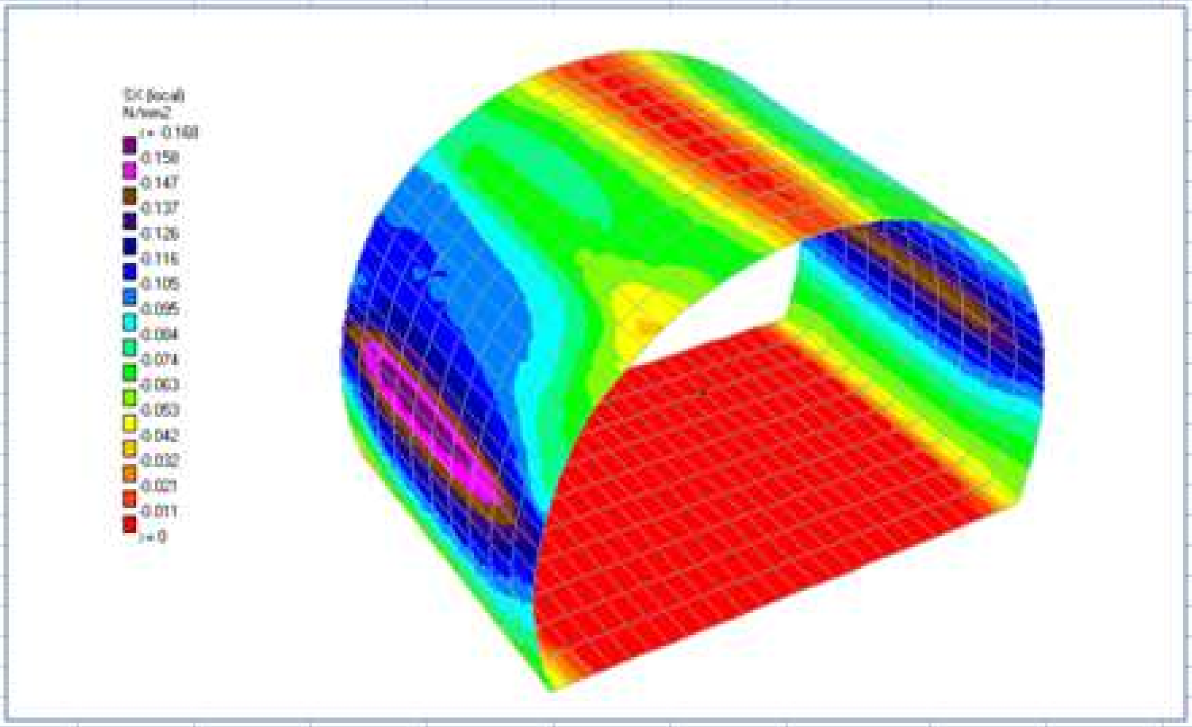
Load case 107: Axial stress (Sy)



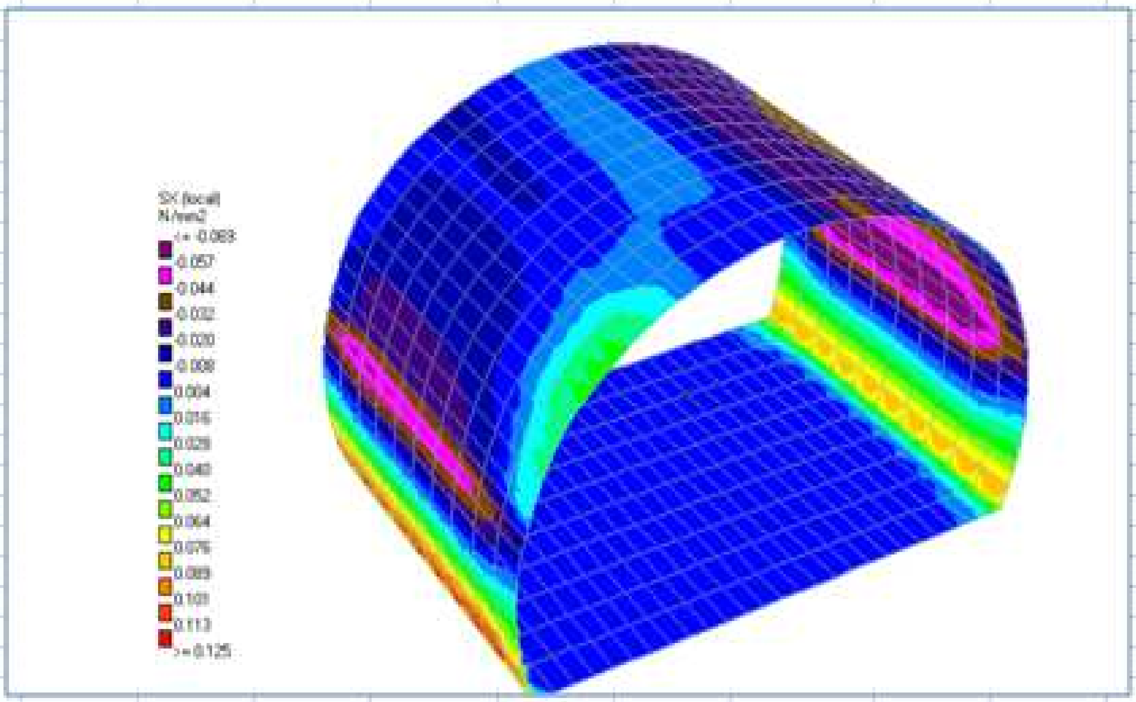
Load case 104: Bending moment (Mx)



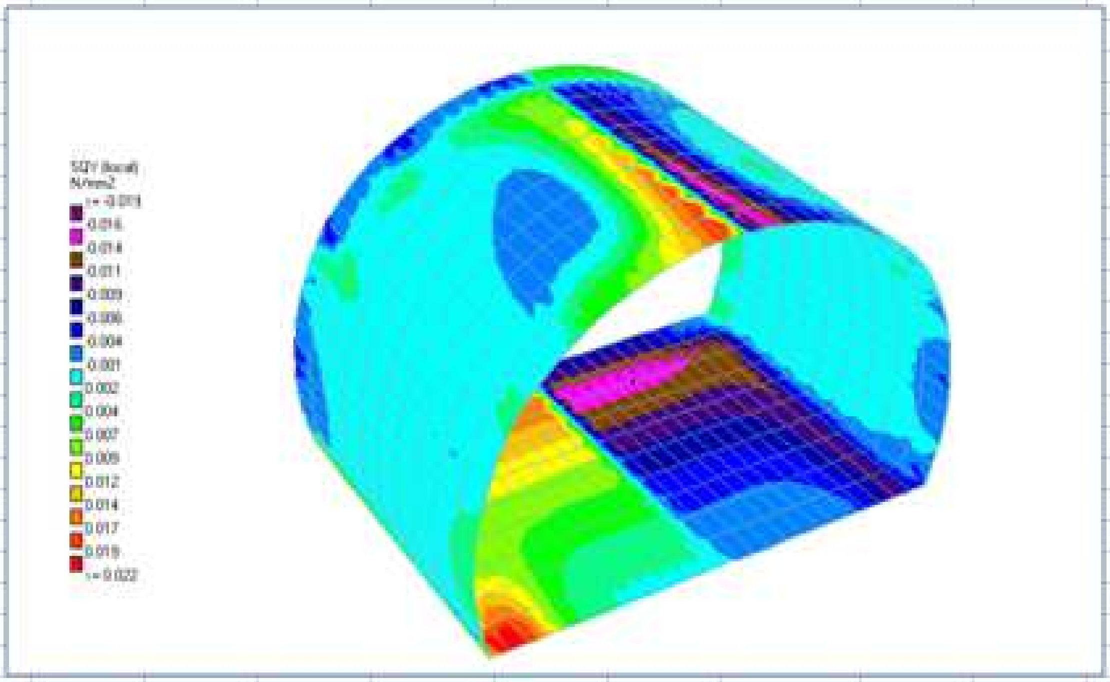
Load case 107: Bending moment (Mx)



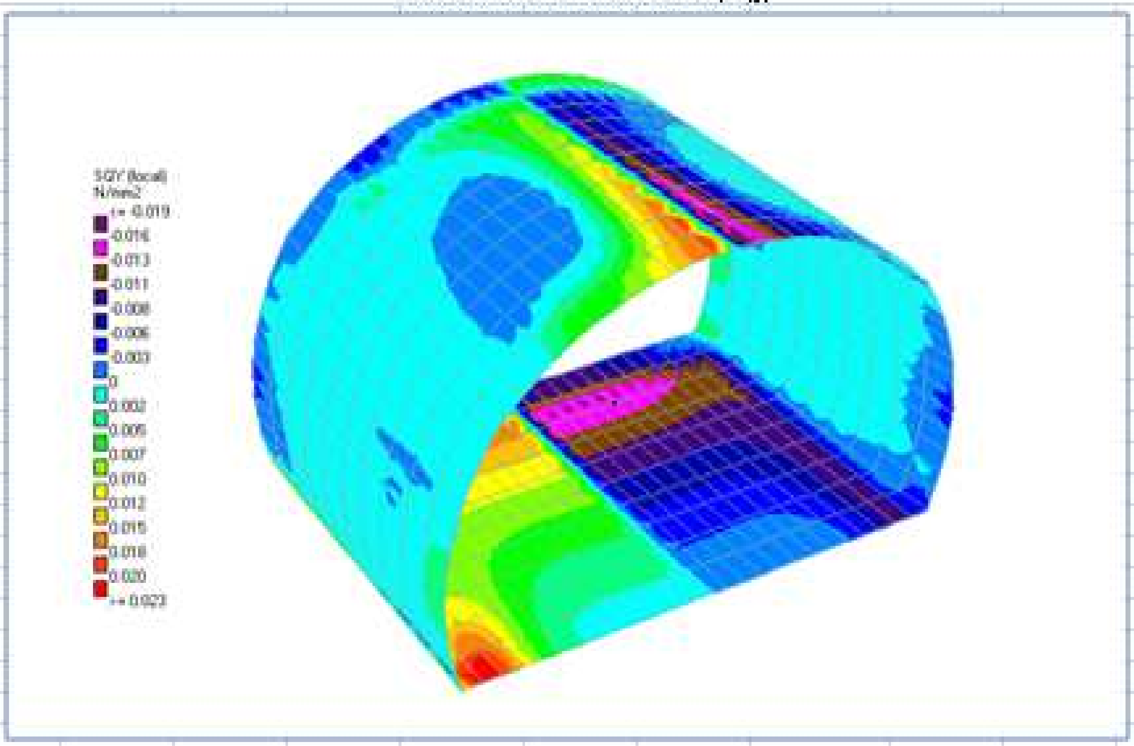
Load case 102: Axial stress (Sx)



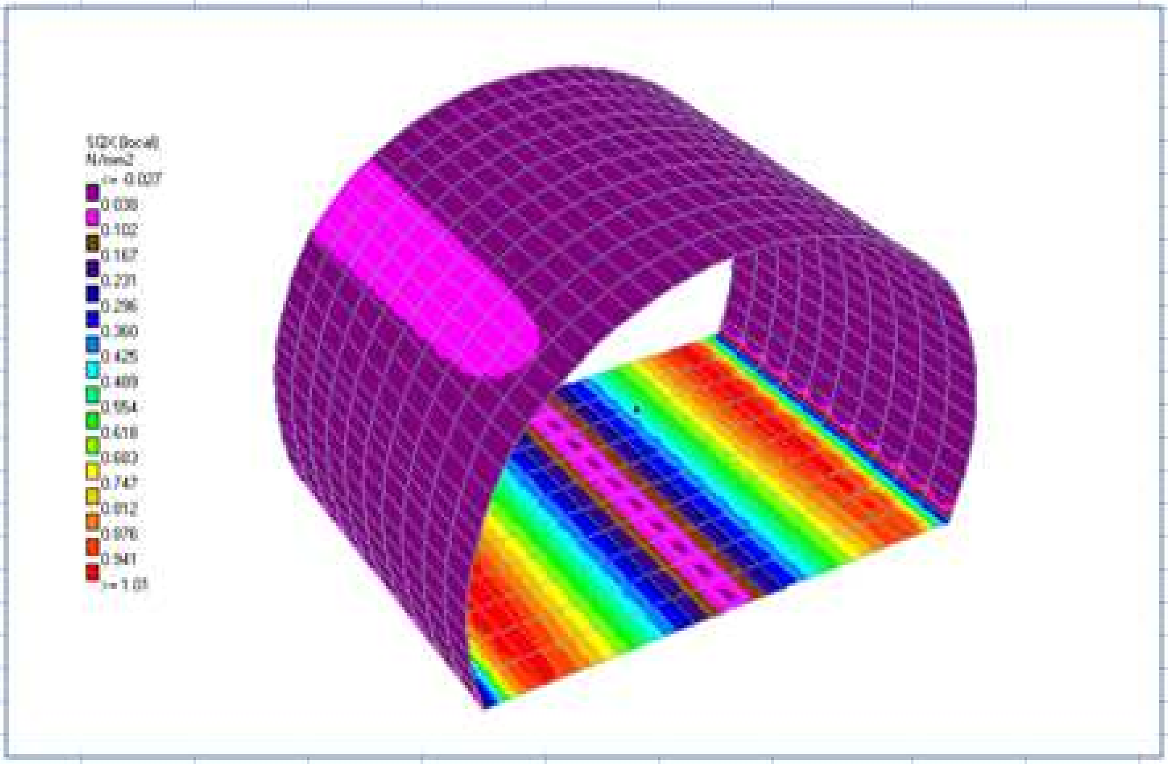
Load case 107: Axial stress (Sx)



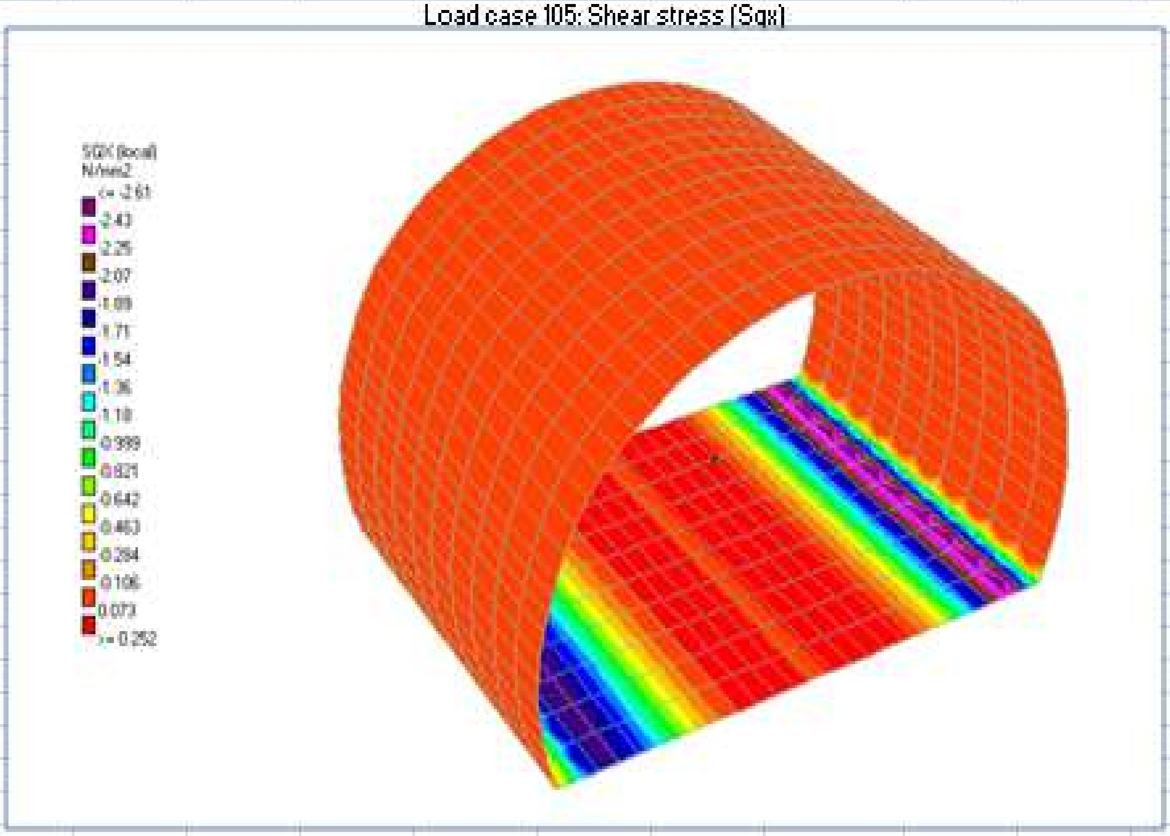
Load case 104: Shear stress (Sqy)



Load case 105: Shear stress (Sqy)



Load case 105: Shear stress (Sqx)



Load case 107: Shear stress (Sqx)

It is observed from the above STAAD.Pro results that the concrete lining has compressive membrane stresses in all the load cases and hence it is not checked for tensile membrane stresses.

Load case 104: Shear stress (Sqx)

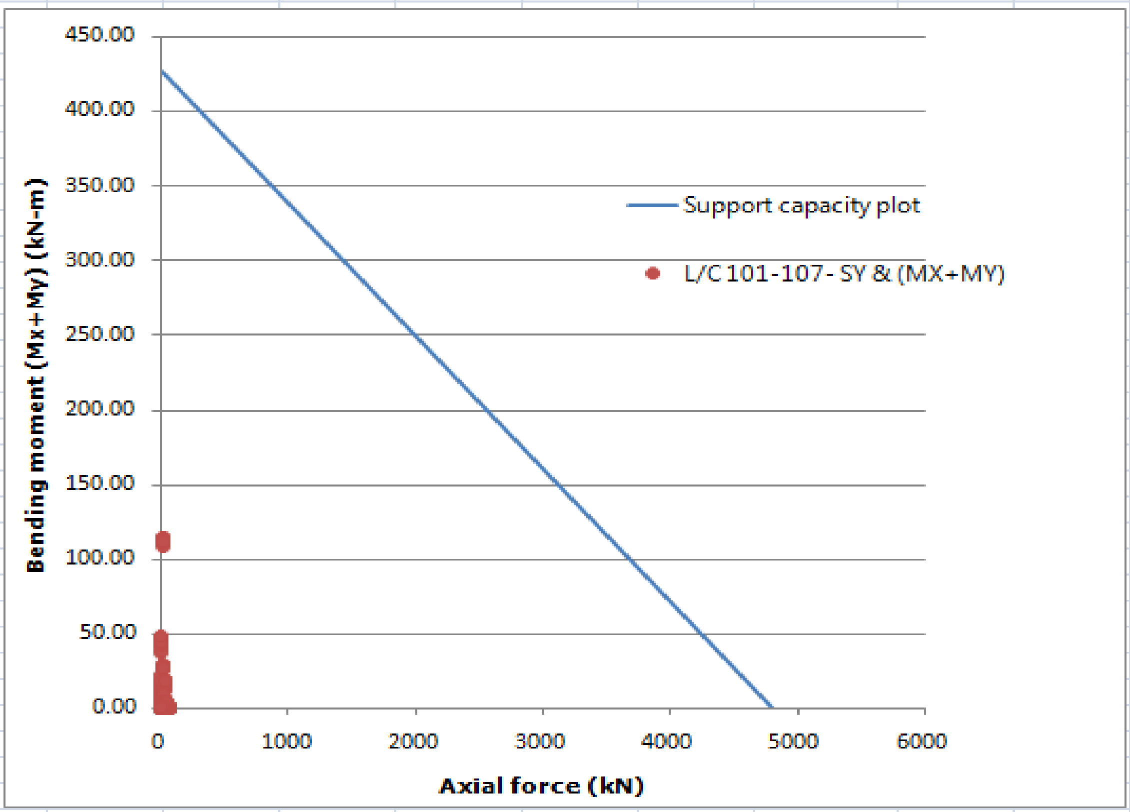
CLASS D : TYPE ROCK											
LOAD CASES: LC 101 TO 107											
Description	Plate	L/C	Sqx (N/mm^2)	Sqy (N/mm^2)	Mx (kN-m)	My (kN-m)	Mxy (kN-m)	Sx (N/mm^2)	Sy (N/mm^2)	Sxy (N/mm^2)
Max.My	1334	104	-1.39	-0.006	97.413	**16.64**	0.489	0.029	0.007	0.44
Max.Sy	1609	107	0.025	-0.003	-0.018	-0.08	-0.053	0.125	**0.024**	-0.019
Max.Mx	1180	104	-1.391	-0.005	**97.49**	16.638	0.368	0.03	0.006	0.428
Max.Sx	1609	107	0.025	-0.003	-0.018	-0.08	-0.053	**0.125**	0.024	-0.019
Max.Sqy	1809	104	0.064	**0.051**	1.962	0.333	-0.001	0	0	-0.008
Max.Sqx	1048	105	**1.005**	0.01	0.584	0.099	-0.004	-0.001	0	-0.009
Max. My+Mx	1820	107	-1.76	0.007	7.288	1.239	1.199	-0.006	-0.01	-0.005

DESIGN OF CONCRETE LINING

The axial stress is converted to axial force by multiplying the cross-sectional area.

Axial compression+Compression due to bending

Lining thickness	Axial force	Bending
(mm)	(kN)	(kN-m)
400	4800	0.00
400	0	426.67



Axial compression+Tension due to bending

Resultant stress ' -' = compression
Resultant stress '+' = tension

L/C	Axial Force kN	Bending moment kN-m	Resultant stress (MPa)	Tension /Compression	Check
104	2.80	**114.06**	4.27	Tension	O.K
107	9.60	**0.10**	-0.02	No Tension	O.K
104	2.40	**114.13**	4.27	Tension	O.K
107	9.60	**0.10**	-0.02	No Tension	O.K
104	0.00	**2.30**	0.09	Tension	O.K
105	0.00	**0.68**	0.03	Tension	O.K
107	4.00	**8.53**	0.31	Tension	O.K

Since all the points corresponding to the maximum axial load (compression) and bending moment are lying within the "Support capacity plot" the section considered for the design is SAFE.

DESIGN -SHEAR CHECK

Percentage of tensile reinforcement provided	=	0	
Permissible shear stress	=	0.20	MPa

Multiplying factor for shear stress for members subjected to axial compression
(Refer Clause B-5.2.2 , IS 456:2000- Plain and Reinforced Concrete- Code of Practice.)

P = axial compressive force
A_g = gross are of the concrete section

δ	=	1.00	
Hence, permissible shear stress taking the effect of axial compression	=	0.20	MPa
Design shear stress	=	0.05	MPa

For the calculation of increased shear stress the axial force of the element having maximum shear stress is considered.

Hence, the section is safe in shear.

ANNEXURE-VIII
CONCRETE LINING DESIGN FOR ROCK CLASS-E

Material Data:

Grade of concrete		=	M-40	
Characteristic strength of concrete	f_{ck}	=	40	MPa

Design Input:

Lining thickness considered (excluding invert portion)	D	=	400	mm
Lining thickness considered (invert portion)	D	=	400	mm
Length of the tunnel considered	b	=	1000	mm

The design of concrete lining is carried out by considering it as an independent structural member. The lining is designed based on working stress method.

PCC LINING

Design criteria

Member Subjected to Combined Axial Load and Bending

Refer clause B-4.1,IS 456:2000- Plain and Reinforced Concrete- code of practice, for uncracked section a member subjected to axial compressive load and bending shall be considered safe provided the following conditions are satisfied:

$$\frac{\sigma_{cc,cal}}{\sigma_{cc}} + \frac{\sigma_{cbc,cal}}{\sigma_{cbc}} \leq 1 \quad \text{A}$$

Where

$\sigma_{cc,cal}$ = calculated direct compressive stress in concrete

σ_{cc} = permissible axial compressive stress in concrete

$\sigma_{cbc,cal}$ = calculated bending compressive stress in concrete considering biaxial bending

σ_{cbc} = permissible bending compressive stress in concrete

Refer clause 6.3 (b), IS 3370(Part 2):2009- Concrete structures for storage of liquids-code of practice, for uncracked section a member subjected to axial tension load and bending shall be considered safe provided the following conditions are satisfied:

$$\frac{\sigma_{ct,cal}}{\sigma_{ct}} + \frac{\sigma_{cbt,cal}}{\sigma_{cbt}} \leq 1 \quad \text{B}$$

Where

$\sigma_{ct,cal}$ = calculated direct tensile stress in concrete

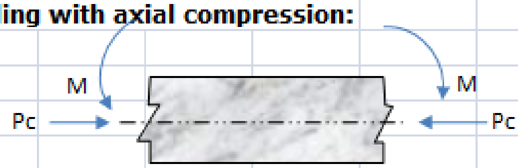
σ_{ct} = permissible direct tensile stress in concrete

$\sigma_{cbt,cal}$ = calculated tensile stress due to bending in concrete considering biaxial bending

σ_{cbt} = permissible tensile stress due to bending in concrete

Permissible bending stress in compression	σ_{cbc}	=	13.00	MPa
Permissible direct stress in compression	σ_{cc}	=	10.00	MPa
Permissible bending stress in tension	σ_{cbt}	=	4.74	MPa
Permissible direct stress in tension	σ_{ct}	=	4.00	MPa

Bending with axial compression:



The moment 'M' in a member during bending with axial compression will cause compression in one face while tension in opposite face at the same time. Hence, the moment capacity of the section has to be checked for both permissible bending stress in compression and tension at the same time.

Axial compressive force with compression due to bending:

Considering Eqn. 'A' $\frac{P_c}{A\sigma_{cc}} + \frac{6M}{bD^2\sigma_{cbc}} \le 1$

$x = A\sigma_{cc}$ $\quad \frac{P_c}{x} + \frac{M}{y} \le 1$

$y = \frac{bD^2\sigma_{cbc}}{6}$

X at normal condition(for 400mm thick.	=	4000.00	kN
(for 400mm thick.)	=	4000.00	kN
Y at normal condition (for 400mm thick	=	346.67	kN-m
(for 400mm thick.)	=	346.67	kN-m

where are constants.

Bending with Axial tension

Axial tensile force with tension due to bending:

Considering Eq. 'B'

$$\frac{\sigma_{ct,cal}}{\sigma_{ct}} + \frac{\sigma_{cbt,cal}}{\sigma_{cbt}} \le 1$$

$$\frac{P_t}{x} + \frac{M}{y} \le 1$$

where

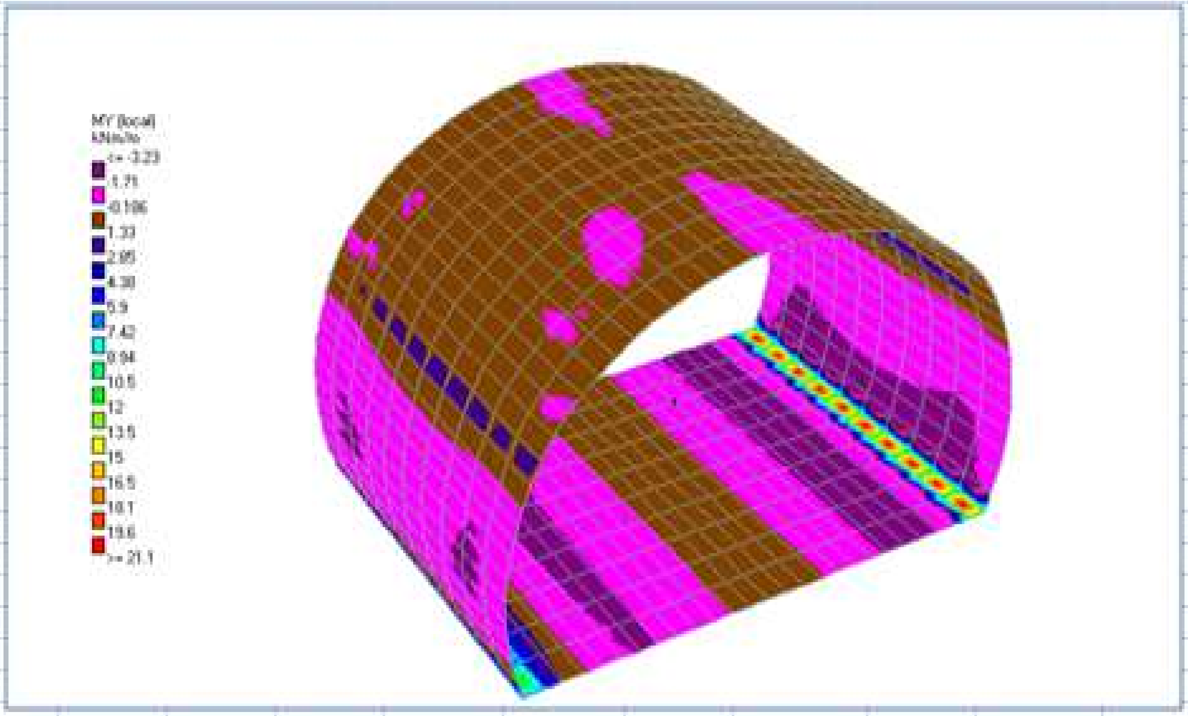
X at normal condition (for 400mm thick	=	1600.00	kN
	=	1600.00	kN
Y at normal condition (for 400mm thick	=	126.40	kNm
	=	126.40	kNm

The moment 'M' in a member during bending with axial tension will cause compression in one face while tension in opposite face at the same time. Hence, the moment capacity of the section has to be checked for both permissible bending stress in compression and tension at the same time. However as the face with tension due to bending and tension due to axial force will be critical, this

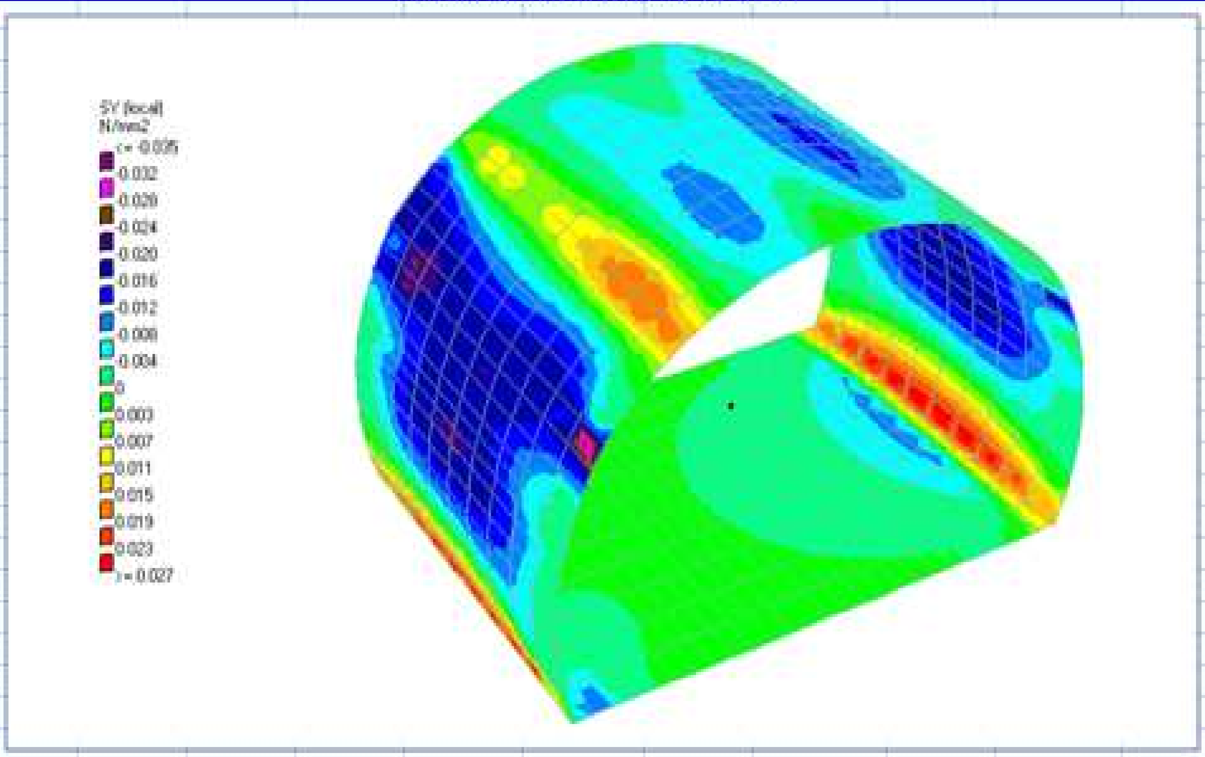
Load Cases

Load Case 1:	Earthquake (+X)
Load Case 2:	Self weight
Load Case 3:	Rock load
Load Case 4:	Pavement load
Load Case 5:	Traffic load
Load Case 101:	Earthquake+Self weight
Load Case 102:	Earthquake+Self weight+Rock load
Load Case 103:	Earthquake+Self weight+Rock load+Pavement load
Load Case 104:	Earthquake+Self weight+Rock load+Pavement load+Traffic load
Load Case 105:	Self weight+Rock load
Load Case 106:	Self weight+Rock load+Pavement load
Load Case 107:	Self weight+Rock load+Pavement load+Traffic load

STAAD OUTPUT

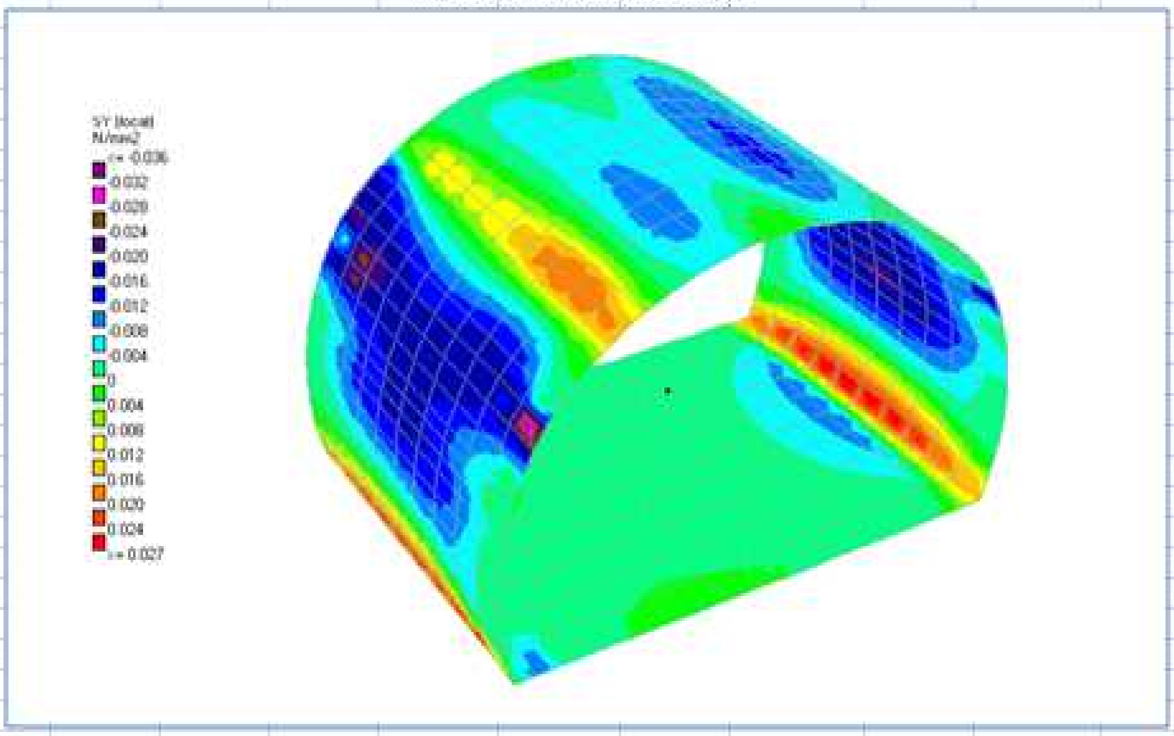


Load case 104: Bending moment (My)

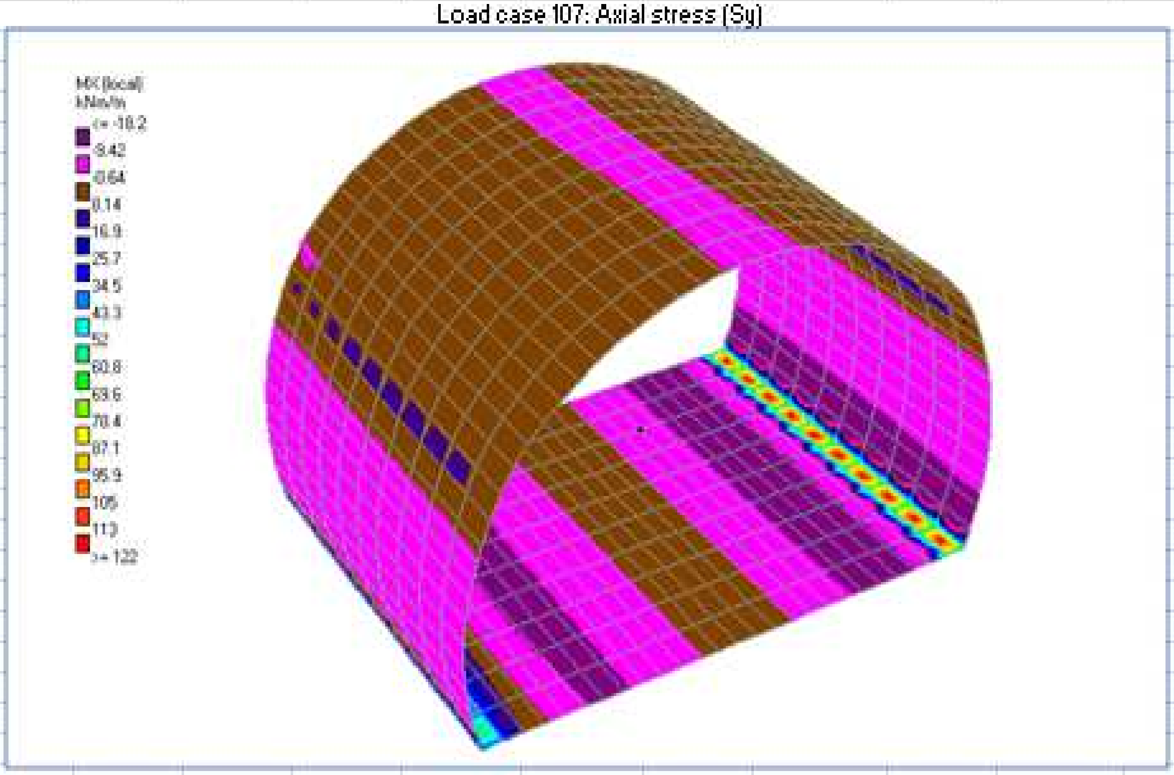


Load case 104: Axial stress (Sy)

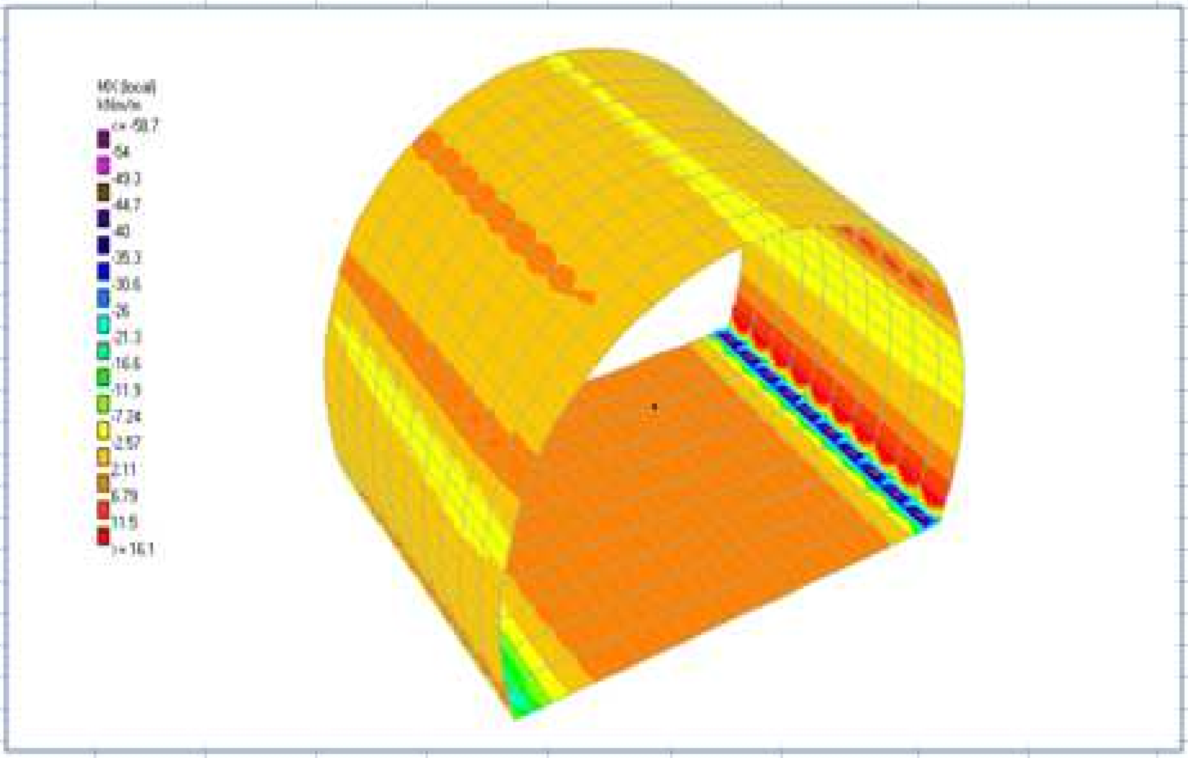
Load case 104: Axial stress (Sy)



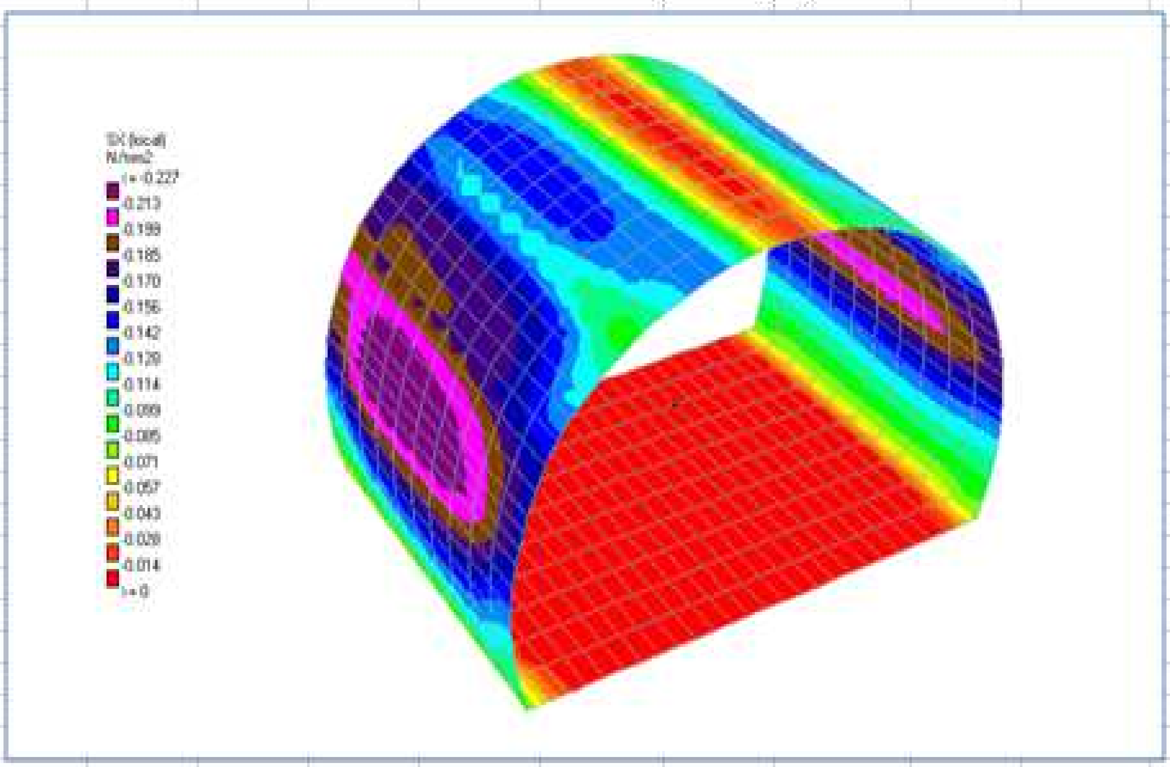
Load case 107: Axial stress (Sy)



Load case 104: Bending moment (Mx)

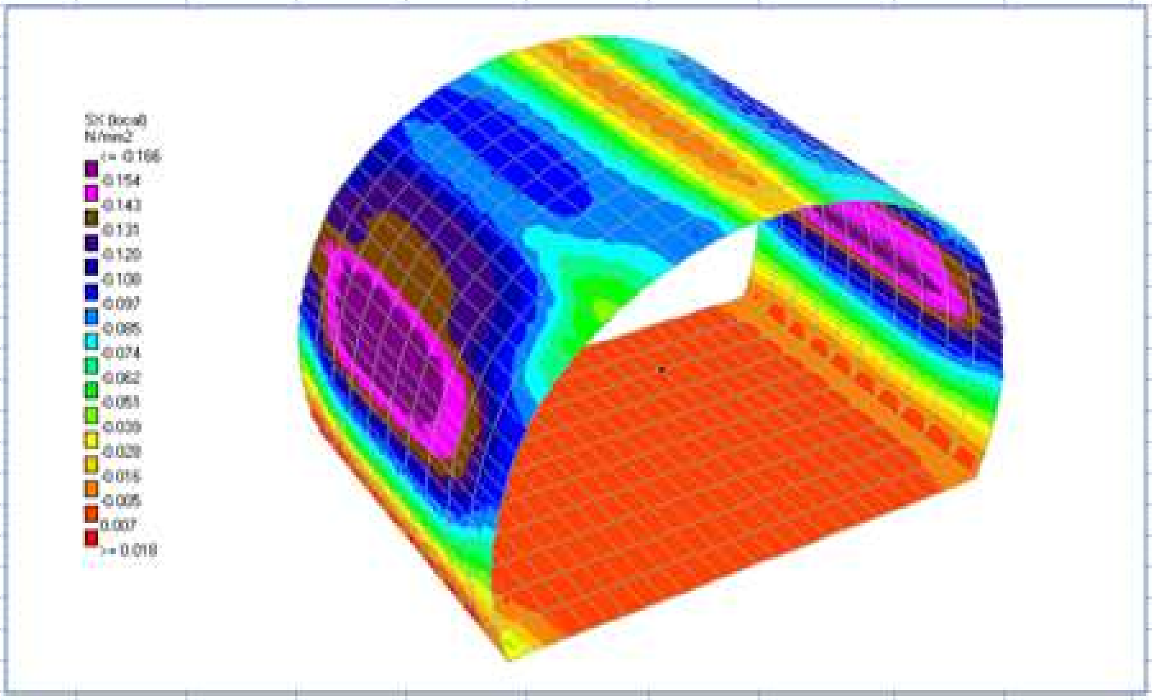


Load case 102: Bending moment (Mx)

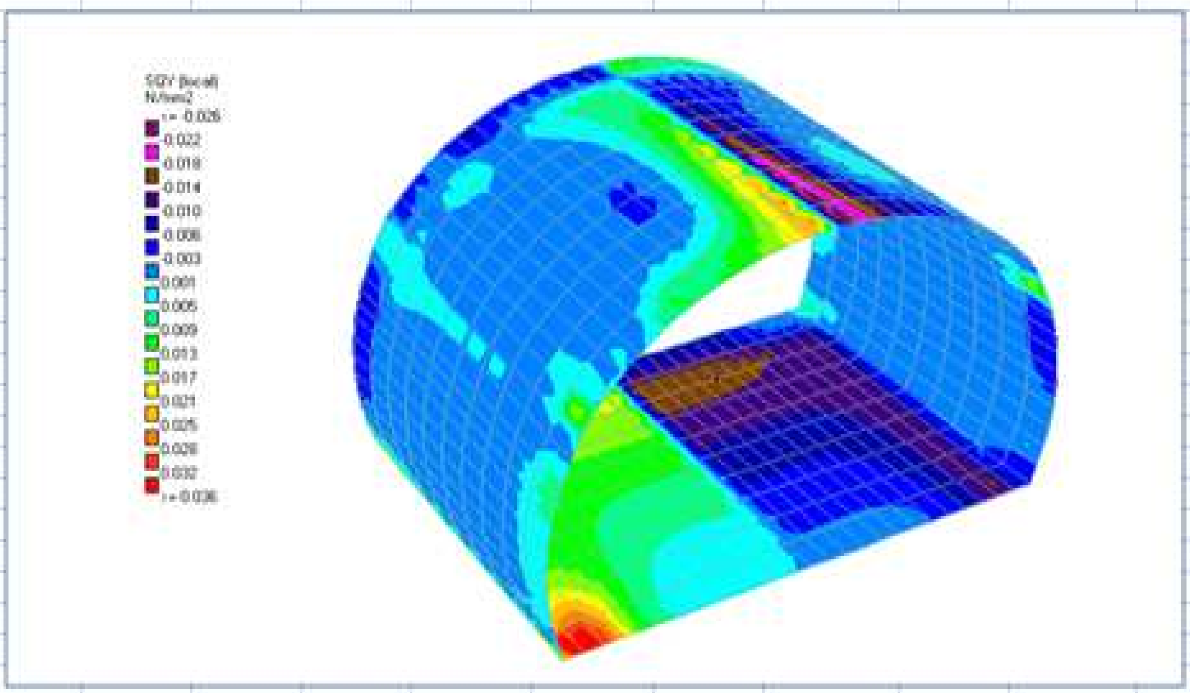


Load case 102: Axial stress (Sx)

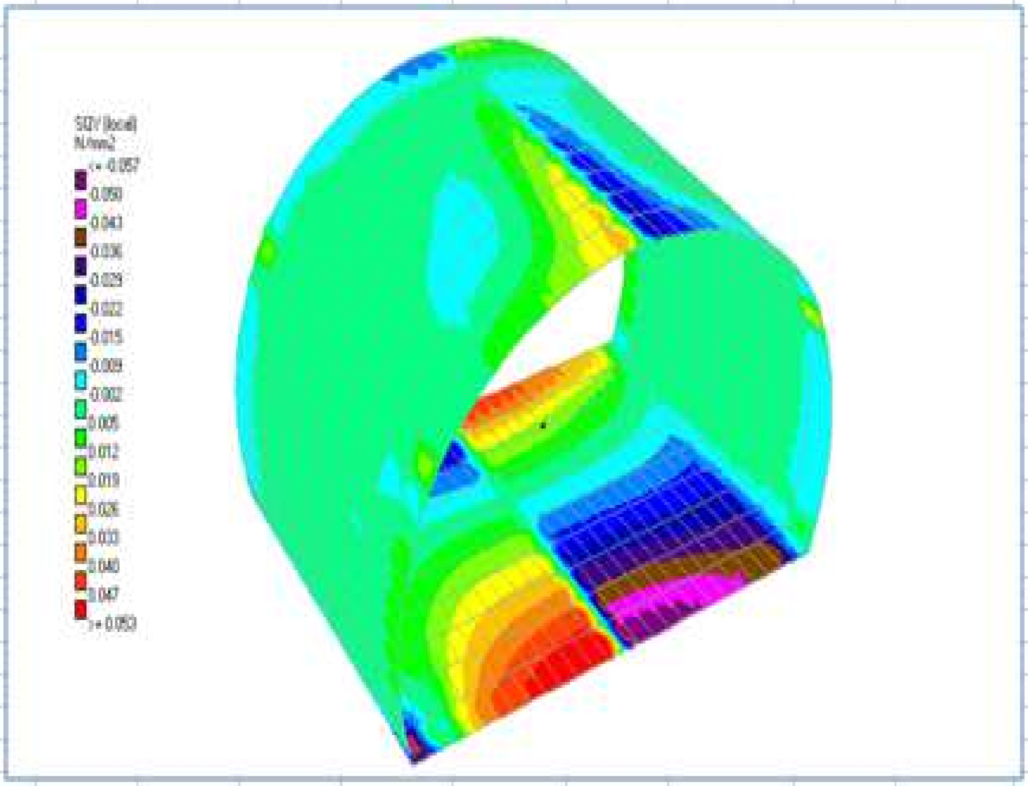
Load case 102: Axial stress (Sx)



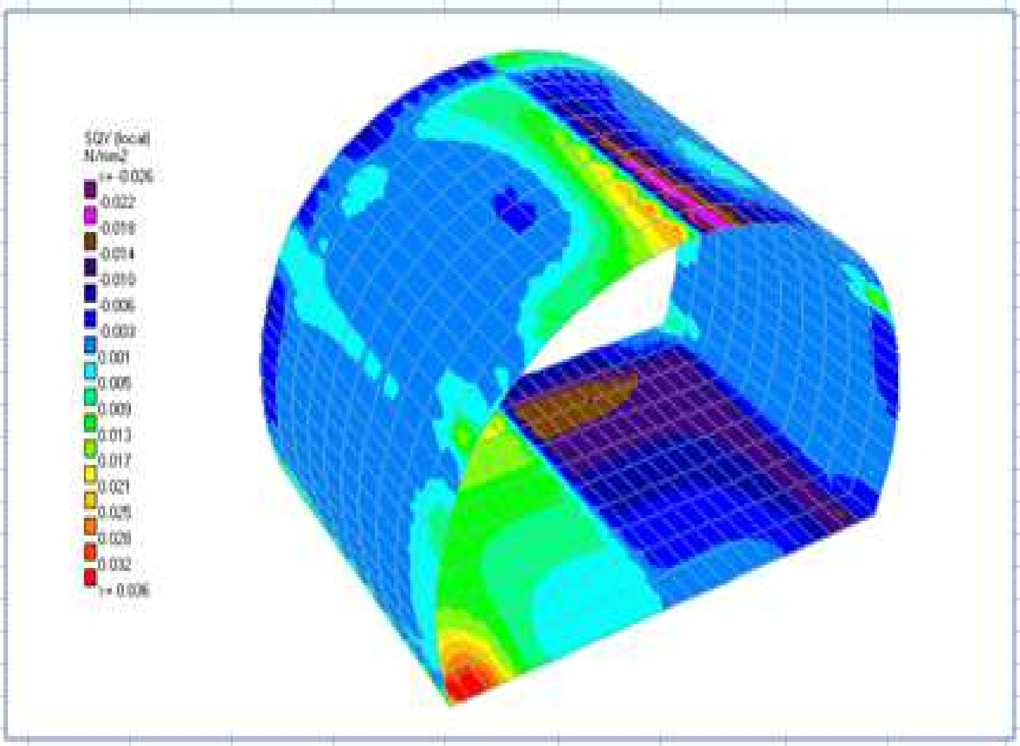
Load case 103: Axial stress (Sx)



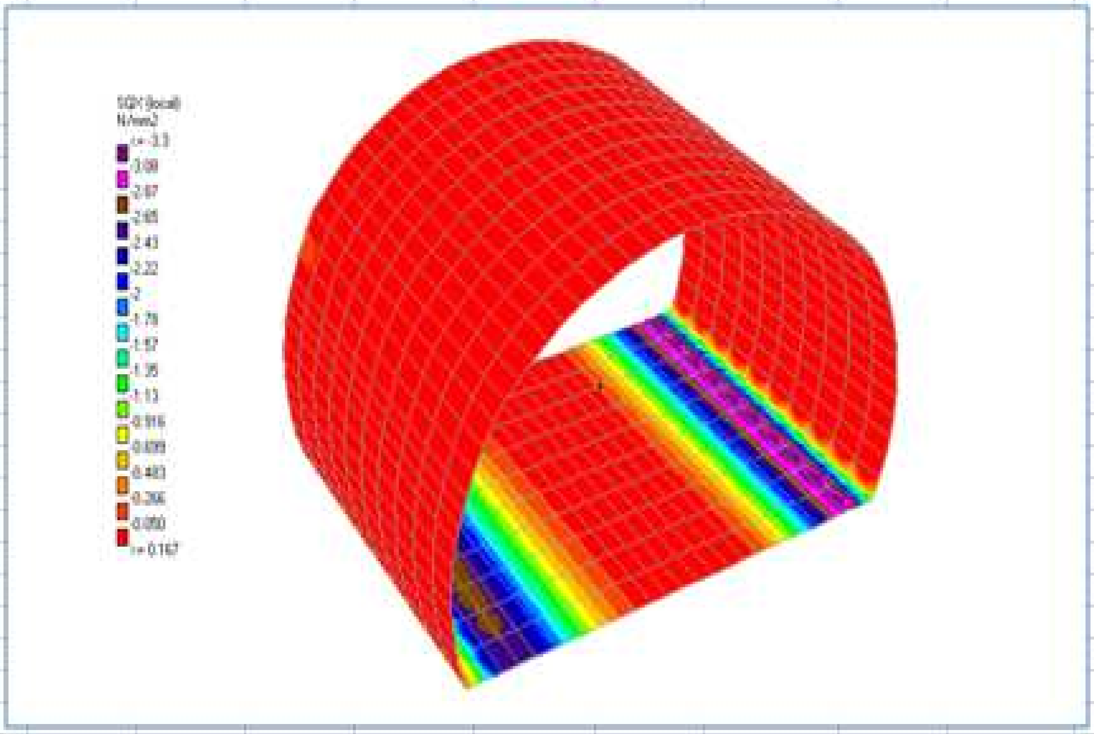
Load case 102: Shear stress (Sqy)



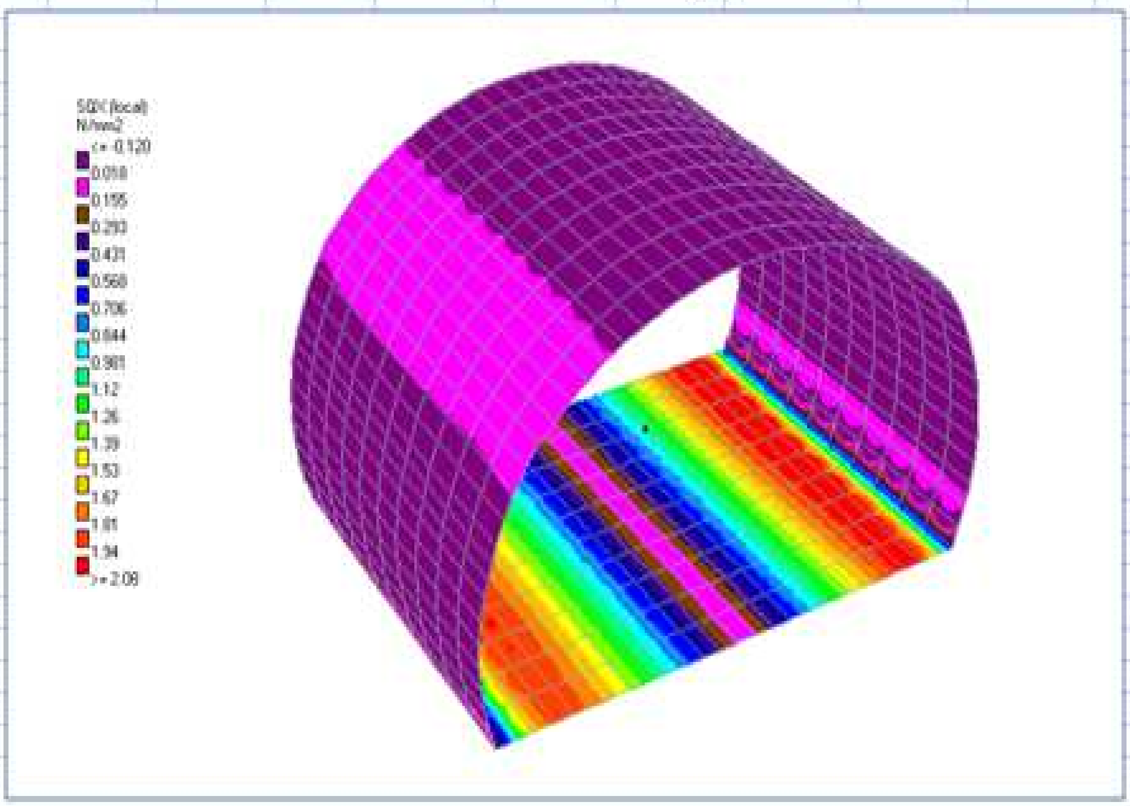
Load case 107: Shear stress (Sqy)



Load case 102: Shear stress (Sqx)



Load case 107: Shear stress (Sqx)



Load case 104: Shear stress (Sqx)

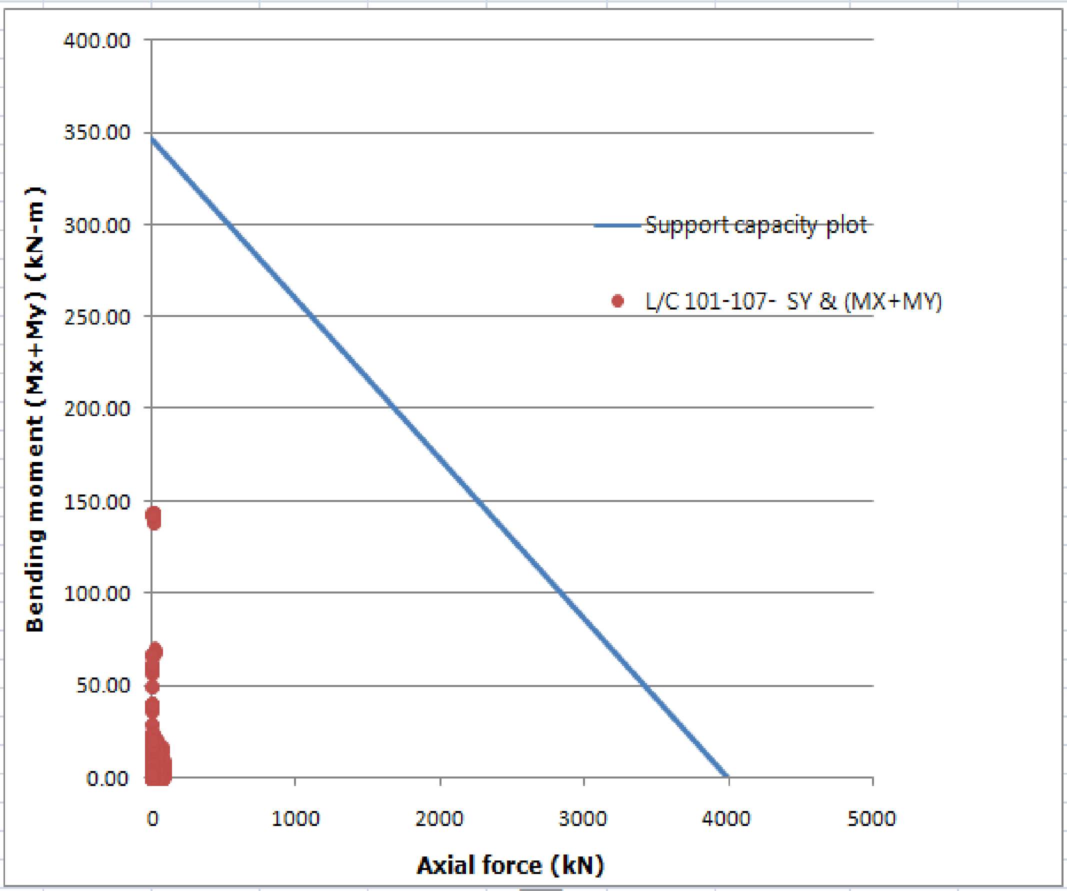
CLASS E TYPE ROCK										
LOAD CASES: LC 101 TO 107										
Description	Plate	L/C	Sqx (N/mm^2)	Sqy (N/mm^2)	Mx (kN-m)	My (kN-m)	Mxy (kN-m)	Sx (N/mm^2)	Sy (N/mm^2)	Sxy (N/mm^2)
Max.My	1796	104	-1.714	-0.007	105	**21.098**	1.424	0.03	0.01	0.568
Max.Sy	1052	107	0.011	0	-17.036	-2.877	0.046	0.079	**0.027**	0.009
Max.Mx	1180	104	-1.718	-0.006	**105**	20.873	0.453	0.028	0.006	0.512
Max.Sx	1609	107	0.037	-0.004	2.28	0.334	-0.177	**0.126**	0.026	-0.025
Max.Sqy	1809	104	0.02	**0.053**	1.183	0.201	-0.004	0	0	-0.01
Max.Sqx	720	105	**2.087**	-0.012	0.082	0.014	-0.001	-0.004	-0.008	-0.006
Max. My+Mx	290	104	-0.004	-0.008	-0.922	-0.566	1.474	-0.066	-0.004	0.009

DESIGN OF CONCRETE LINING

The axial stress is converted to axial force by multiplying the cross-sectional area.

Axial compression+Compression due to bending

Lining thickness	Axial force	Bending moment
(mm)	(kN)	(kN-m)
400	4000	0.00
400	0	346.67



Axial compression+Tension due to bending

Resultant stress ' -' = compression
Resultant stress '+' = tension

L/C	Axial Force kN	Bending moment kN-m	Resultant stress (MPa)	Tension /Compression	Check
104	4.00	**126.10**	4.72	Tension	O.K
107	10.80	**19.91**	0.72	Tension	O.K
104	2.40	**125.87**	4.71	Tension	O.K
107	10.40	**2.61**	0.07	Tension	O.K
104	0.00	**1.38**	0.05	Tension	O.K
105	3.20	**0.10**	0.00	No Tension	O.K
104	1.60	**1.49**	0.05	Tension	O.K

Since all the points corresponding to the maximum axial load (compression) and bending moment are lying within the "Support capacity plot" the section considered for the design is SAFE.

DESIGN -SHEAR CHECK

Percentage of tensile reinforcement provided	=	0	
Permissible shear stress	=	0.20	MPa

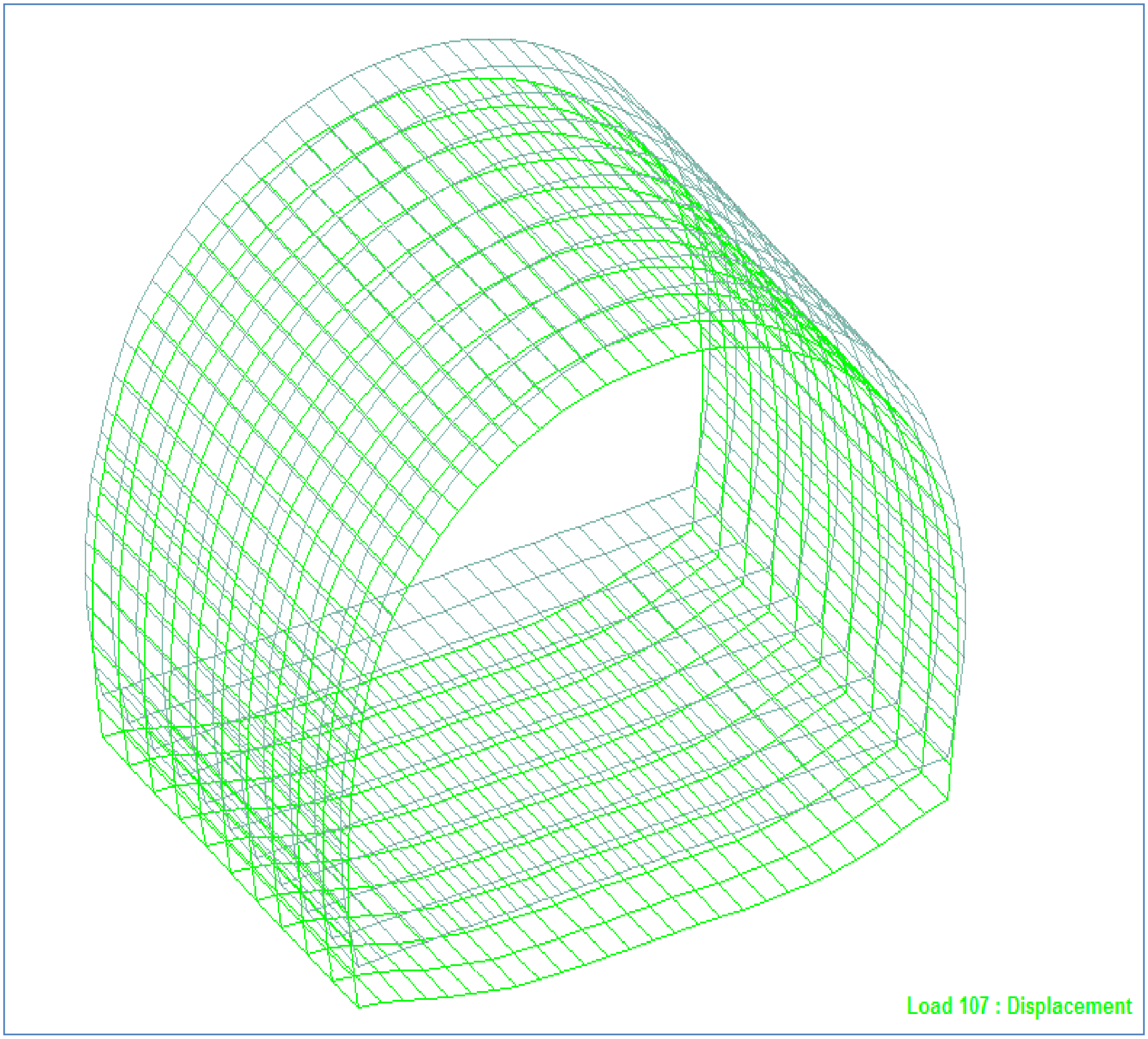
Multiplying factor for shear stress for members subjected to axial compression
(Refer Clause B-5.2.2 , IS 456:2000- Plain and Reinforced Concrete- Code of Practice.)

P = axial compressive force
A_g = gross are of the concrete section

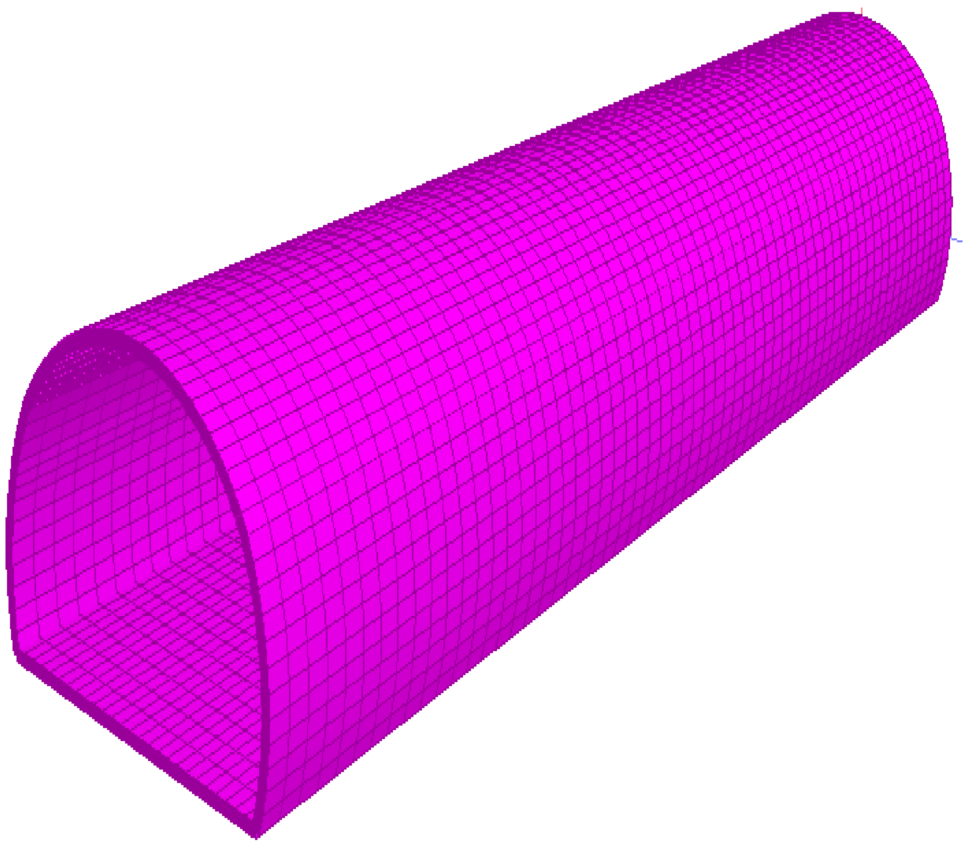
δ	=	1.00	
Hence, permissible shear stress taking the effect of axial compression	=	0.20	MPa
Design shear stress	=	0.05	MPa

For the calculation of increased shear stress the axial force of the element having maximum shear stress is considered.

Hence, the section is safe in shear.



Deflected Shape of Tunnel Lining (Well within allowable Limit)



3D –View of Long Tunnel

Silkyara Bend – Barkot Road Tunnel
Electro Mechanical Report
(A part of Detailed Project Report)

of

2 Lane/ 2 Lane upgradation proposal of Highway between Km 144.00 (Dharasu) and Km 220.00 (Yamunotri) falling along NH - 94 and 123 in the State of Uttarakhand

submitted to

Ministry of Road Transport & Highways
(Government of India)

By

TASPL
(Committed to resource and energy conservation)

M/s TECHNOCRATS ADVISORY SERVICES PVT.LTD.
(Earlier M/s MC Consulting Engineers Pvt. Ltd.)

JV with

G.E.S. & Association with S.I.P.L.

Contents

A. TUNNEL OPERATION SAFETY AND TRAFFIC CONTROL SECTION

1 Project

The tunnel is designed as a bidirectional road tunnel on NH-94 national highway between Dharsu and Barkot of approx. 4.55 km length. With this length the tunnel, when constructed, would reduce the distance between Silkyara-Bend and Barkot by about 20km. As the tunnel lies on starategically important route, therefore state-of-the-art solutions for tunnel operation and control are proposed in this stage of project preparation in order to guarantee adequate safety of the tunnel operation.

General system solutions are proposed and function descriptions provided at this stage, however, it is assumed that development in this field is very fast. Therefore detail specification for individual technical equipments as well as detail design should be provided as close to realization as practical.

1.1 General tunnel data

The tunnel is approx. 4.55 km long, cross sectional area provides 7.5m x 5.5m traffic area clearance. Parallel to the main traffic tunnel there is smaller escape passage part of main tunnel of 3.5m x 4.5m (can be used as carriage way also) clearance serving as emergency escape way as well as for tunnel maintenance and rescue operation purposes.

Cross openings between the main tunnel and escape passage are located at 300 m distances, emergency lay-bays in 1200 m (staggered) distance on both side of the main tunnel carriageway, emergency call niches at 150m distance and fire fighting niches at 150 m. There are 0.75m wide sidewalks on both sides of the tunnel. Tunnel ventilation system is foreseen as a fully transversal one, supplied with fresh air from portal locations only.

2 Integrated Tunnel Control System

2.1 Functional Description

The integrated tunnel control system (SCADA - Supervisory Control and Data Acquisition) serves to status monitoring of all tunnel technical systems, to automatic eventually manual tele control of them. It is realised by one integrated control programme which is implemented in main control PLC (Programmable Logical Control) stations. The system records all the states of monitored elements and all the activities and faults. The system provides all appropriate data for MMI - Machine Man interface, which will be realised by servers and monitors.

There shall be built-up two control centres by both portals of the tunnel. The operator/s workplaces will make possible the operation of the tunnel technical accessories in the same range. Their function shall be identical. One of them shall be appointed for permanent attendance; the second one shall be stand-by operator's workplace, without permanent attendance.

The system shall operate and supervise following subsystems of Tunnel:

- the proper tunnel control system auto-diagnostic of all the control
- equipment, data acquisition and telecommunication elements;
- traffic control system;
- power supply system;
- ventilation system;
- lighting system;
- communication system;
- tunnel safety equipment;
- electrical fire signaling system;
- emergency call system;
- video surveillance system.

Other civil works control systems shall be parts of integrated tunnel control system as e.g. fire water reservoirs, air conditioning systems, etc.

2.2 Basic Specifications

2.2.1 Design

The control system is composed from two main PLC stations with implementation of identical integrated control programmes and several other PLC field substations which are not implemented control programmes. The main PLC stations shall operate in a hot stand-by (automatic back-jump) mode of operation; One main PLC station shall operate above all the systems and shall constantly communicate with the second main PLC station, which is situated in a building by the second tunnel portal. By a failure of the first main PLC station the second one will undertake its activity without any disturbance to control process.

The PLC substations with Input/output modules shall be distributed near controlled elements above mentioned systems. There shall be implemented serial communication interface in execution of metallic field bus.

The main stations shall be connected in return and with the substations by double ring industrial bus in execution of optical cables. Tracing of two lines of one ring industrial bus shall not be the same from the safety reason. The control system shall alone analyse any communication fault and then shall opt for the new optimal transmission path without interruption of control and data acquisition process.

Operator's workplaces shall be equipped with two servers for providing visualisation data to MMI. The two servers shall operate in a hot stand-by mode operation.

Power supply to all the components of the integrated tunnel control system shall be executed by on-line UPS (Uninterruptible Power Supply) systems.

2.2.2 Civil Works

Design documentation for the construction has to regard cable traces and spaces for all the components of the tunnel control system.

2.2.3 Technical Accessories

Control system components: they should be of industrial execution produced by prestigious producers, e.g. GE-Fanuc, Siemens, Belden, etc.

3 Local Control Centres

3.1 Functional Description

There shall be erected two control centres in technology buildings by Silkyara and Barkot tunnel portals. One of them, the main local control centre shall be appointed for a non-stop attendance. The second one shall serve as a reserve one.

The reserve local control centre shall be equipped with only one terminal interactive monitor of the tunnel control system and only one monitor of the video surveillance system. From the reserve operator's workplace shall be possible full–value control and monitoring of tunnel traffic and operation of technical accessories.

The main local control centre shall be equipped with two terminal interactive monitors of the tunnel control system. It consists of two operator's workplaces for two persons of permanent service. The predestination of one of them shall be supervision of traffic, traffic control and operation of emergency services. The second one shall be assigned for technology control and supervision of all the technical equipment. It further includes 6 monitors and two large-screen displays of the video surveillance system.

The local control centres further includes Electrical Fire Signalling Centrals, sound/visual alarm facilities (audible signalling device and warning light) and switchboards for emergency call system and for wireless communication / evacuative broadcasting systems with phone input terminals. The switchboards of video surveillance system are also located in the local control centres.

The tunnel control system makes possible following operator's activities:

- watching of traffic status in overview diagram and detailed schematics;
- follow current traffic load and statistics;
- setting of variable message signs and traffic signals;
- watching of current status of technical systems and subsystems in overview diagrams and detailed schematics;
- watching of current status of select individual technical equipment in detailed schematics;
- observe of values of measured quantities, incl. history of them;
- command of functional aggregates and select individual equipment;

- generation of alarm signals which have arisen from a fire, traffic and technical equipment failures;
- follow of alarm statistics;
- entry to diaries of failures and emergency situations;
- generation of regular reports;
- overview of long-term traffic analysis;
- possibility to execute select systemic functions;
- monitoring of actual failures of technical equipment;
- Monitoring and recording of historical development of failures withdrawing.

3.2 Basic Specifications

3.2.1 Design

The local control centres have to be designed by keeping all the agronomical conditions, esp. as far as furniture, lighting and air conditioning are concerned. A comfortable rear area for the persons of the non-stop attendance is assumed.

3.2.2 Civil Works

The minimum size of the main control centre ground-plan shall be 60 sqm and for the reserve local control room the minimum value is 30 sqm. The sizes constitute also a reserve for other control terminals which could be installed for additional enlargement of the control system, e.g. for near traffic intersections or tunnels. The rear area could include small cooking place, a rest room and a cloak-room. There is supposed an access control to the spaces of the local control centres.

3.2.3 Technical Accessories

Mode of operation: for all the system and subsystems from the interactive terminal monitors by using of electronic laser mouse and keyboard with exception of the terminals of the communication systems.

4 Traffic Control System

4.1 Functional Description

Traffic control is operated by the integrated tunnel control system on basis of tunnel operator's interventions through interactive control system terminals. There shall be used following equipment for traffic control and influencing:

4.2 Traffic Signals

In case of emergency situations like a fire, a failure of power supply system, an accident, etc. the tunnel traffic shall be immediately closed. The traffic lights three coloured (TLTC) shall be used for closing the tunnel traffic and for a diversion of a tunnel traffic to the old route on crossroads before tunnel entrances. The amber light of the TLTC shall serve also as flashing warning signal (AFWL - see below) in exceptional traffic situations. Warning flashing of all the amber lights should be synchronized.

4.3 Variable Message Signs

Dynamic Road Information Panels (DRIP) providing textual messages in front of the tunnel are intended to inform drivers about traffic situation ahead traffic participants. The textual information shall be always executed in local language and in English. Certain information in the two languages will be displayed in rotation with a display time of one-lingual information of about 5 second. The textual information shall be complemented on the DRIP display by various traffic control symbols (VMS's) of directive, warning or information content.

The information about necessity of stopping of vehicle engines by an interrupt of traffic in the tunnel shall be given by the evacuative broadcasting as well.

In case of exceptional traffic situation like a vehicle breakdown, etc. vehicle speed should be limited by using of Speed Limit Variable Message Signs (SL), which shall be complemented by two Amber Flashing Warning Lights (AFWL).

SL Traffic signs combined with symbol of entryway prohibited are situated at the level of circular intersection exit for the tunnel entrance.

Entrance Variable Message Signs (EVS) with "Green Arrow", "Red Cross", "Crossover Yellow Arrow" and "One-way traffic - entryway prohibited" symbols support a tunnel closing, regular traffic operation and make possible automatic redirecting of the tunnel traffic.

Tunnel Variable Lane Signals (TLS) with "Red cross" and "Green Arrow" symbols shall be situated in traffic light signal sections above the middle of opposite direction traffic lane. The TLS will permanently signalling traffic prohibition by "Red Cross" symbol by standard tunnel operation.

Circular intersection information signs with VMS are assigned to inform drivers about tunnel through way prohibition. The embedded VMS represent the symbol of prohibited entryway in case of the tunnel shutdown. By standard traffic conditions there is not represented any symbol on VMS.

4.4 Luminous Traffic Signs

Luminous Traffic Signs (LTS) shall be used for marking of SOS boxes, escape exits to rescue cross passage and escape directions between escape exits inside the tunnel tube. The LTSs for marking of SOS boxes shall be complemented by two AFWL for both traffic directions which will individually operate by opening the door of certain SOS box. All the LTSs shall be permanently illuminated.

4.5 Reflective Traffic Signs

Standing reflective traffic signs ("Overtaking Prohibition", "Switch Vehicle Lights On", "Switch Vehicle Lights Off', "Limits Cancelled", Transmitted Broadcasting Station Frequency and Name and Tunnel Name Plate) shall be located by standard regulations on outside public lighting poles.

Standing reflective traffic signs marking lay-bays ahead shall be installed in the tunnel tube in distance of 100 m in front of appropriate lay-bay. The distance shall be marked on the signs with descriptive number of individual lay-bay.

4.6 Other Traffic Control Equipment

Curbstone Lights (GL) with LED light sources shall be installed in sidewalk curbstone in distance of 25 m to accent carriageway limits to the drivers as traffic leading lighting.

Four Traffic Counting Systems (TCS) shall differentiate personal vehicles, wagon vehicles and trucks and will provide realtime and historical statistics.

There shall be built two Entrance Detection Control Systems (EDCS) comprising Entrance Overheating Vehicle Control System (EOD) based on a thermovision detection principle, Entrance Smoking Vehicle Control System (ESD) based on a video-detection principle and Entrance Height Excessive Vehicle Control System (EHD) based on a light barrier detection principle. The EDCS's shall automatically stop unacceptable vehicles for tunnel traffic and decline them to the old road by using of Traffic Lights Three Coloured, with additional information to drivers which shall provide VMS's.

Besides, there will be installed rigid height barriers to physically prevent entering of oversized vehicles from entering the tunnel.

Mechanical barriers are assigned to support closing of the tunnel for traffic. Crossbar of the mechanical barrier can be executed with horizontal or vertical working. It shall make possible a passage of rescue team vehicles by closing the tunnel.

Traffic safety inside the tunnel shall be significantly supported by recommendation of keeping minimum vehicle spacing by means of textual information provided by Dynamic Road Information Panels and by marking of minimum vehicle spacing strokes on road pavement inside the tunnel tube.

4.7 Basic Specifications

4.7.1 Design

The TLTC's shall be placed in front of the tunnel portals and at signal sections inside the tunnel tube with spacing of about 300 m at height of 2.5 m above emergency sidewalks. The diameter of one head lens of TLTC shall be 300 mm.

The DRIP's shall be placed in front of the tunnel portals (2 pieces) and in front of the places where drives could be declined to the old road aside the Tunnel (next 2 pieces of DRIP's) in vicinity of the frame of Entrance Detection Control System (EDCS).

The SL's shall be placed in front of the tunnel portals and 50 m in front of signal sections for the TLTC inside the tunnel tube with spacing of about 600 m at height of 2.5 m above emergency sidewalks. The SL's shall be equipped with two AFWL whose flashing shall be synchronized with others AFWL in the tunnel tube and in front of the tunnel portals.

The EVS's are proposed to locate on outside entrance road gantries of a bridge type near the tunnel portals above centres of traffic lanes. There shall be located Traffic Counting Systems, Traffic Lights Three Coloured signal devices and rigid height barriers on the gantries.

The LTS's for marking of SOS boxes shall be positioned above or in front of SOS niches.

The LTSIs for marking of escape exits shall be placed above fireproof doors of the exits.

The last mentioned LTS's for SOS boxes and emergency exits marking shall be executed as two-sided lighting (to both traffic directions).

The LTS's for marking of escape direction shall be placed on tunnel sides at height of 2.5 m above emergency sidewalks with spacing of about 50 m between emergency exits. The arrow of the signs will be pointed at the nearest escape exit. On every sign shall be marked a distance to the nearest exit (stated in meters).

The TCS's will be executed on a video-detection principle and they shall be placed near entries to the tunnel tube.

The frame of Entrance Detection Control Systems (EDCS) shall be executed in the way of the bridge road gantry. By findings of an unacceptable vehicle the system shall initialize stopping of the traffic by the red signal light on TLTC located in front of the crossroad with the old road.

Rigid. Height Barriers shall be installed on outside entrance road gantries located in front of tunnel portals, together with TLTC, EVS's and TCS's.

4.7.2 Civil Works

Civil works are assumed for the execution of the outside entrance road gantries (2 pcs.), the frames of the Entrance Detection Control Systems (2 sets), the foundations of intersection control, the foundations of the support structures of DRIP's and for appropriate cable traces. The minimum vehicle spacing strokes shall be implemented transversally across tunnel traffic lanes on pavement with spacing of about 80 m in both directions along entire length of the tunnel tube.

4.7.3 Technical Accessories

Lighting sources for all the traffic signals, signs and lights shall be executed by LED's.

5 Access Control

5.1 Functional Description

The tunnel access control is operated by the integrated tunnel control system. The access control consists in announcement and visualisation of opening of access doors of all the buildings, rooms in operation, technology buildings and underground spaces, opening of selected panel boards, SOS boxes and escape exit doors. It further consists in selected individual entry possibility (e.g. for service attendance personnel) to chosen rooms and to the tunnel tube from the escape adits and to the rescue tunnel from outside.

A removal of firefighting equipment shall be signalized as well.

5.2 Basic Specifications

5.2.1 Design

Sensors are executed in the form of contact switches. An entry permit should be realised by individual chip cards. Sensors shall always be integral parts of appropriate doors and equipment. They are not separately stated in BoQ's.

6 Electrical Fire Signalling System

6.1 Functional Description

The system consists from four Electrical Fire Signalling (EFS) centrals (Master EFS central in the control centre by the southern tunnel portal and Slave EFS centrals in the control centre by the northern tunnel portal and inside the tunnel tube) and fire detectors. Alarm messages of the Master EFS central are brought into the integrated tunnel control system by means of two connections - serial and discrete (contacts) for appropriate processing.

The centrals are connected with addressable line fire detector with fibre laser sensor, discrete automatic smoke and heat detectors and manual button detectors. The EFS line detector serves for fire signalling inside the tunnel tube. The EFS discrete detectors are located in all the operation and technology rooms, e.g. control centres, control rooms, machine-rooms. The EFS manual button detectors are placed in SOS boxes, in operation and technology rooms and by the entries to escape exits in escape adits.

6.2 Basic Specifications

6.2.1 Design

The EFS line detector is divided to four sections. Evaluation units of the EFS line detector are placed in technology and control buildings (Silkyara and Barkot ones) and two of them in the middle control rooms inside the tunnel A cable of fibre laser sensor shall be installed under the tunnel tube roof in accordance with specifications of the sensor producer.

The execution of the system shall match to appropriate regulations. Any fíre alarm shall be announced in the local control centres by using of special alarm facilities - besides of advice of tunnel control system as well as by warning light and warning horn.

7 Emergency Call System

7.1 Functional Description

The emergency call system consists of an emergency switch board on the workplace of operators and SOS boxes situated in front of the tunnel tube at both portals (2 pcs.) and inside the tunnel tube. The main purpose of the system is to assure verbal communication in between operator and a traffic participant for announcement and explanation/clarification of the opportune emergency situation, e.g. stopping vehicle (failure, without fuel), traffic restriction (loss of goods), health troubles, accident, and fire e.t.c. The entry of any person to some SOS box shall activate telephonic communication with using speaker-phone and an amber warning flashing light above the SOS box, which is signalling some traffic problem. Further initialised telephonic communication in the same time has to be mute but signalised to operators.

All the emergency calls have to be recorded and archive for the time of one month (30 days).

It could be also further exploitation for the system - redundant communication possibility by execution of service works between service men and operators.

7.2 Basic Specifications

7.2.1 Design

The SOS boxes are executed as sound tight cabinets, made from stainless steel with degree of protection IP 65. There are placed in the SOS box cabinet a speakerphone, a manual button of fire alarm detector of EFS system, emergency push-buttons (with pictograms for claim of help for drivers with immobile car, health trouble and by an accident), two manual fire extinguisher and tools for fast extrication of persons from a cracked car. Emergency call niches contain also beside SOS box energy socket outlets for service purposes and other technology equipment could be installed there as panel board of low voltage electro-distribution network, components of the tunnel control system, etc.

The SOS box interior is permanently alight with an orientation light. Entry to SOS box is indicated optically and acoustically on operator's workplace. Then also a main interior lighting of a SOS box is automatically activated, above box are activated amber warning flashing lights (for both traffic directions) and at the same time TV picture of appropriate tunnel safety camera bears the shot of the activated SOS box surroundings area on the relevant alarm TV monitor to the tunnel operator.

Emergency functions of SOS boxes, traffic signs with SOS symbols and amber warning flashing lights shall be supplied from uninterruptible power source - UPS.

The SOS boxes will be marked by expressive numeral labelling (readable from a tunnel safety camera shot) and by outstanding inscription with the following text in local and English languages: "This area does not provide protection from fire!!!"

8 Video Surveillance System (Close Circuit TV)

8.1 Video surveillance in front of tunnel portals

8.1.1 Functional Description

A part of the video surveillance system in front of the tunnel portal enables continuous monitoring of the road and its surroundings (e.g. outdoor emergency call box, technology and control building) by two revolving cameras - CR1 (in front of Silyara portal) and CR2 (in front of Barkot portal). Revolving cameras will enable retrieval of visual information about traffic in front of the tunnel and also information of immediate vicinity of the tunnel from range of two hundreds meters in front of tunnel entrance.

8.1.2 Basic Specifications

8.1.2.1 Design

System consists of two revolving cameras which are installed on specific rigid poles, resp. on public lighting poles. The camera revolving range is 360 degree horizontally and 90 degree vertically. Variable ZOOM objective of camera shall enable wide overview of the road traffic as well as detailed vehicle and person identification in relative wide scale of distances. Camera placing shall be in the height of 6 m and 60 m ahead of the portal.

8.1.2.2 Civil Works

Design documentation for the construction has to regard special rigid poles and cable channels.

8.1.2.3 Technical Accessories

Camera housing: Housing degree of protection is IP 66, heated, remote moving with rotation ability 360 degree horizontally and 90 degree vertically, variable ZOOM objective. Housing shall enable camera application in environment with temperature range from -35ºC to +55ºC.

9 Traffic video surveillance system

9.1 Functional Description

Monitoring system of the operation in the tunnel tube is based on traffic monitoring with fixed cameras CT1 – CT32 which will be disposed in the tunnel so as they will guarantee traffic monitoring along the whole length of the tunnel tube.

It is recommended to use a video detection system as above standard solution, which task is relatively accurate evaluation of operation parameters in right and left road traffic lanes. Cameras for the video detection system are constructional coincident with others cameras for the traffic monitoring, but the difference is that camera shot has limited view distance to 75m. Video detection systems make possible to provide alarm signal in the course of e.g. standing vehicle and a rise of a smoke.

9.2 Basic Specifications

9.2.1 Design

Traffic cameras are fixed on tunnel walls at a height of about 4.8 m over the road level by reason of effortless maintenance (regular cleaning). The distance between individual cameras shall be about 150 metres in the line of way. The number of cameras is determined on about 32 pieces. Individual camera visual angle shall be right adjusted and shots shall not be disturbed by obstacles and by curvature of the tunnel tube. A visual routing of the traffic cameras has to be unified to only one direction.

9.2.2 Civil Works

Power supply cables and cables for camera control and video-signal are leaded from distribution point to tunnel tube cross-sections where cameras are placed. Wire bundle cross cable pit, then shelters in reveal to the box next the camera. They are leaded by sealed apertures to the camera. Transverse and lengthwise shelters, boxes and cable pits must be prepared before camera installation.

9.2.3 Technical Accessories

Stationary traffic camera: camera with long focal distance and coloured picture presentation is fixed on a console placed on the tunnel wall.

Camera housing: Housing degree of protection is IP 66, heated. Housing shall enable camera application in environment with temperature range from -35ºC to +55ºC. Housing is surface adapted by anodizing to outside aggressive environment.

Camera adjusting: Moving metal camera fixation joint enables adjustment of a stationary traffic camera. Camera adjusting has to be 30 degree in horizontal direction and 45 degree in vertical direction. The joint is also realised with alteration for aggressive environment.

10 Tunnel safety video surveillance

10.1 Functional Description

The system secures monitoring of SOS boxes and their surroundings (fire fighting niches, lay-bays). This system is based on monitoring by stationary (emergency) cameras with short focal length (with continuous scan shot).

Further two cameras are basic parts of Entrance Smoking Vehicle Control Systems by the frames of the Entrance Detection Control Systems. The cameras shall be firmly positioned and they use a smoke video-detection system which could differentiate trucks too much emitting exhaust smoky gas and initialize diversion of the truck to the direction to the old road beside the tunnel route.

10.2 Basic Specifications

10.2.1 Design

Monitoring system of SOS boxes consists of stationary cameras with short focal length (with continuous scan shot) CE1 – CE31. These emergency cameras are fixed so that it would be possible monitoring of the whole surroundings alongside and in front of individual SOS box. Camera positioning for the monitoring of SOS boxes is fixed. The number of cameras for monitoring SOS is determined on about 31 pieces. The smoke video-detection system (cameras CE60 and CE61) shall be connected to the Entrance Detection Control System of the integrated tunnel control system for automatic truck diversion. A vehicle diversion could be operated also manually after a visual information evaluation by a tunnel operator.

10.2.2 Civil Works

Power supply cables and cables for camera control and video-signal are leaded from distribution point to tunnel tube cross-sections where cameras are placed. Wire bundle cross cable pit, then shelters in reveal to the box next the camera. They are leaded by sealed apertures to the camera. Transverse and lengthwise shelters, boxes and cable pits must be prepared before camera installation.

10.2.3 Technical Accessories

Emergency camera: camera with short (wide-angle) focal distance and coloured picture presentation is fixed on a console placed on the tunnel wall.

Camera housing: Housing degree of protection is IP 66, heated. Housing shall enable camera application in environment with temperature range from -35ºC to +55ºC. Housing is surface adapted by anodizing to outside aggressive environment.

Camera adjusting: Moving metal camera fixation joint enables adjustment of the stationary camera. Camera adjusting has to be 30 degree in horizontal direction and 45 degree in vertical direction. The joint is also realised with alteration for aggressive environment.

11 Picture transmission and processing system

11.1 Functional Description

System of picture transmission and processing supplies signal transmission from individual cameras to control centres in two technical and technological levels:

- signal transmission from cameras to technological nodes via metallic lines,

- signal transmission from technological nodes to the control centres via fibreoptic lines.

11.2 Basic Specifications

11.2.1 Design

System of picture transmission and processing consists of several functional units which are connected this way: cameras are connected by metallic cables (control/video signal/ feed). Considering smoothness in the first and the last control rooms – distributing substations (Distributing substation DS1 and DS5) there are two and two multiplexers – I and 16-channel, in other distributing substations (Distributing substations DS2 and DS4) are only per one 16-channel multiplexer. Together there are 5x16 + 2x8 multiplexers for processing 96 video-signals. The same number of video-amplifier is required for it (at least 92 pieces). Video-signal is transmitted next by fibre-optic cable to video-central in technology and control buildings.

11.2.2 Civil Works

Project documentation for the construction must take into consideration supply cable, control and video-signal cables traces, location of video-amplifiers, multiplexers, video-signal cables and video centrals.

11.2.3 Technical Accessories

Metallic conductors: they are supply conductors to the camera, conductor between camera and video-amplifier and between video-amplifier and multiplexer.

Fibre-optic conductors: they are connecting conductors between individual multiplexers in tunnel and demultiplexer which is located next to video central.

Video-amplifier: they offset cable line slump and concurrently they adjust frequency characteristic of transmitted signal.

Multiplexer: it is used for unit of individual outputs from individual camera video amplifiers to one fibre-optic cable line.

12 Video-central and video recording

12.1 Functional Description

Video-central enables video-signal processing (video-matrix) from all cameras so that operator could monitor the picture from randomly selected camera on video monitors. It mainly enables preset allocation of alarm pictures to alarm monitors automatically.

Picture recording system enables permanent picture recording by using of picture digitalisation and by creation of digital records on some of modern data carrier - e.g. memory fields. There shall be recorded pictures from all the cameras for the duration of 14 days.

12.2 Basic Specifications

12.2.1 Design

Video-central system consists of several functional units which are connected in this way: fibre-optic cables of transmission system are connected to demultiplexer (input). Output is leaded to multiplexers, which enable next multiplexing of video-signal from 16 cameras on one output which is leaded to video-central input. It preserve picture replay on the monitors which are located on operators workplace, processes video-signal for recording system. Control of revolving cameras (positioning and zoom) and over switching of pictures of selected cameras to video monitors is executed by MMI (Machine-Man Interface) - controlling interactive display of integrated tunnel control system.

12.2.2 Civil Works

Project documentation for the construction must take into consideration leading of supply cables lines, signal cables and cables for video-signal, space for video central and video accessories.

12.2.3 Technical Accessories

Demultiplexer: it demultiplexes video-signal from individual fibre-optic feeds to the next processing.

Video-central: it preserves picture processing on monitors which are located on operator's workplace, it processes video-signal for the recording system and it is used as connected place for control of revolving cameras.

Memory field: it enables recording of video sequences from all the video cameras and their spooling out for retroactive analysis of emergency situations.

13 Video monitoring

13.1 Functional Description

The means of the video monitoring system on operator's workplace preserve 3 main tasks:

- automatic monitoring of emergency situations;
- traffic monitoring by standard conditions, automatic and individual overswitching of individual camera pictures on individual video monitors;
- control of outdoor revolving cameras (individual cameras control – slight turning/ZOOM).

13.2 Basic Specifications

13.2.1 Design

Monitors on operator's workplace are segmented into two groups. 6 operational monitors for video-picture monitoring from individual traffic and emergency cameras (pictures from individual cameras will be successively changing on appropriate monitor -e.g. northwards). By standard tunnel operation the monitors are assigned for automatic monitoring as follows : the first - Silkyara (revolving camera), the second – the sector of the length of about 1 km, the third – 1.0 to 2.0km, the fourth – 2.0 to 3.2 km, the fifth – 3.2 to 4.5km and the sixth monitor - Barkot portal (revolving camera). There shall be possible to over switch any camera picture to any monitor from the video surveillance control pad of arbitrary interactive control display.

The next group are two large-screen monitors. One of them is assigned for monitoring of alarm pictures and the second for projection of chosen interactive control display (traffic control, ventilation control, access control, lighting control, power supply control, water treatment control) by standard tunnel operation. There shall be possible to overswitch any camera picture to any large-screen monitor from the video surveillance control part of arbitrary interactive control display.

13.2.2 Civil Works

Project documentation for the construction must take into consideration traces of supply cables, signal cables and cables for video-signal and also the way of installation of individual monitors.

13.2.3 Technical Accessories

Monitors: LCD (lower power input) or plasmatic monitors (higher power input) are intended for 6 operational monitors (size of 21"), backward projection or direct projection systems for large-screen monitors (40").

B. ELECTRO - MECHANICAL EQUIPMENT SECTION

14 Power Supply System

14.1 Functional Description

The system includes high voltage and low voltage distribution networks in the range of control rooms, transformers, technology LV network for power supply of all the technical systems, earthing and provision against erratic current. HV power transmission lines to both portals are not in the content of the tunnel power supply system.

14.2 Basic Specifications

14.2.1 Design

Voltage systems:

- HV - 3 AC 50 Hz 22kV/ IT (arc suppression coil/resistance node earthing)
- LV - 3 PEN AC 50 Hz 400 V/ TN-C-S

Short circuit relations have to be complemented on basis of electro distributor's data.

Protection against casualty:

HV - 3 AC 50 Hz 22 kV/ IT:

- Living parts - by insulation, constraints, locality;
- Non Living parts - by earthing in network where the source node is not grounded, potential consolidation.

Complementary protection in HV control rooms: dielectric carpet.

LV - 3 PEN AC 50 Hz 400V/ TN-C-S:

- Living parts - by insulation, covers;
- Non Living parts - self-acting disconnection from a source, complementary potential consolidation.

The power supply shall be provided from two independent power sources – two independent HV transmission lines brought to both tunnel portals from two VHV networks HV/LV transformer stations shall be executed by both tunnel portals in technology buildings and further 3 transformer stations inside the tunnel. The distance between transformer stations inside the tunnel shall not overlap 1 km. All the HV/LV transformers shall be loop connected from the transmission lines for the possibility of self-acting overswitching by a failure of one of them.

In the HV/LV transformer stations in the technology buildings by the tunnel portals shall be installed always 4 transformers (in total 8 x 1000 kVA). In the transformer stations inside the tunnel tube shall be installed always 2 transformers (in total 4 x 250 kVA).

The control rooms inside the tunnel shall be located in detached fire segregate spaces.

If two independent transmission lines will be beyond possibility, it shall be necessary to use emergency power sources to ensure required level of power supply.

LV system shall be designed in the way that LV control rooms shall be located in all tunnel detached fire segregate spaces. They shall be connected with HV/LV transformers with two detached cable power lines. One of them shall be located in the tunnel tube under tunnel sidewalks and the second shall be located in the parallel escape tunnel. Individual equipment in the tunnel shall be connected with LV control rooms with only one power supply cable.

To ensure uninterruptible power supply of individual equipment (elements of control system, traffic control system, emergency call system, emergency lighting there shall be installed on-line UPS in LV control rooms.

Energy balance:

Powered systems	Max. simultaneous power (kw)
Ventilation system	3262
Lighting system	135
Other technical accessories	50

Total	3447

14.2.2 Civil works

The control rooms of power supply networks shall be executed as separate fire segregated spaces. Cable passages through walls (borders) of fire segregated spaces shall be tightened by appropriate fireproof packing.

A corrosion investigation has to be executed before elaboration of a civil works design. Required level of protection provision shall be then elaborate on its results. An earthing is preferentially designed as underlaying ground electrodes imbedded in concrete layers of tunnel foundation. The value of tunnel earthing resistance shall be less than 1 Ohm. All the electrical equipment of the tunnel is connected to the tunnel earthing system.

14.2.3 Technical Accessories

All components: they have to respond to using intention, transferred power or load and to conditions of objective environs of places of installation. Into the bargain there have to be determined fire resistance and resistance against corrosive effects of environs. The components which are installed in the tunnel tube have to agree with special operation conditions as humidity, salt, exhaust emissions, pollution, power water, e.t.c. Degree of protection of electrical equipment in the tunnel tube is required IP 65 and support structures, e.g. cable trays, have to be made from stainless steel of the type AISI316TI.

All cables which are placed in the tunnel tube environment have to be characterized by enhanced fire resistance, by low invasiveness of fire products and by low flame propagation.

For the civil works design should be calculated ground areas for the equipment of the power supply network as follows:

- HV transformer room in technology buildings by the tunnel portals - 4 m x 3 m for one HV/LV oil transformer with height of about 3.5 m;
- HV transformer room in. technology spaces inside the tunnel adits (rescue stole connecting the tunnel tube with the escape tunnel) - 3 m x 2,5 m for one HV/LV oil transformer with height of about 3 m;
- HV control room in technology buildings by the tunnel portals - 10 m x 3 m for 6 HV/LV transformers situated next to it;
- HV control room in technology spaces inside the tunnel drifts - 4 m x 3 m for two HV/LV transformers situated next to it;
- LV control room intended also for panel boards of other technical systems of the tunnel complex situated in technology buildings by the tunnel portals 2x5mx7 m for the one building;
- LV control room intended also for panel boards of other technical systems of the tunnel complex situated in technology spaces - 4 m x 6 m for the one adit.

15 Ventilation System

15.1 Main Tunnel with Escape Passage ventilation

15.1.1 Functional Description

A fully transversal ventilation system for the main tunnel tube is proposed. There are two air channels above the roof of the tunnel tube. Traffic profile cross section of the main tunnel tube is 65 sqm. Ventilation channel cross-section for inlet of fresh air is the same as for exhausted air – 6.9 sqm. The inlet and the outlet of the air are executed from ventilation machine-rooms which are located at the tunnel portals (southern and northern portals).

The air flow in the tunnel tube shall be adapted, esp. in the case of the fire near the tunnel portals, by means of jet fans which shall be located at upper area of the tunnel tube by tunnel walls.

The spaces of the escape tunnel and tunnel cross passage shall be over pressured by means of two jet fans situated at roof niches by the escape tunnel portals. The escape tunnel having an overpressure of about 30 Pa - 50 Pa to prevent any infiltration of smoke to protected rescue ways by openings of emergency exit doors in case of fire in main tunnel. The fans shall serve to periodic operational ventilation of the spaces as well.

15.1.2 Basic Specifications

15.1.2.1 Design

Silkyara portal ventilation machine-room - ensures the ventilation of the half of the tunnel tube - length of 2500 m, amount of ventilation air - 400 c.m per second. There are proposed two ventilators for fresh air with capacity of - 2 x 200 c.m per second, pressure 2000 Pa, electric ventilator engines 2 x 650 kW. Outlet of the fresh air from fresh air ventilation channel is made by slots distanced 8 m along whole length of the tunnel tube.

For exhaust air outlet are foreseen similar ventilators of capacity - 2 x 200 c.m per second, pressure 2000 Pa, electric engines 2 x 650 kW. Inlets of the exhaust polluted air is made through ventilation flaps of the size of 2.5 m x 2.5 m with spacing of 80 m - 100 m. Ventilation flaps are installed in exhaust channel ceiling and are remote adjustable by means of servo-motors controlled through tunnel control system

Northern portal ventilation machine-room and ventilation system is identical with the southern ventilation part of the tunnel

Silencers are installed to inputs and outputs of the vent air from and to outer environment.

For fire ventilation, exhaust air inlets shall be used and should provide capacity of 210 m3 per second, through 3 flaps in exhaust air channel closest to a fire location.

15.1.2.2 The informative evaluation of the transversal ventilation system

The basic input data for the ventilation calculation are:

- Tunnel dimensions;
- Maximum longitudinal pavement inclination – 4.8%;
- Projection of traffic data trends to the year 2024 (10 years after the supposed tunnel opening) : - hour peak value M = 280 (number of vehicles in the tunnel in both directions), from that
  - Mp = 224 (number of passenger cars)
  - Mt = 56 (number of trucks)
- Required operational fresh air amount $Q_{FA} = \max(Q_{CO};Q_{OP})[m^3.s^{-1}]$, where

Q_{CO} - required fresh air amount for carbon-monoxide exhaust gas dilution;
Q_{OP} - required fresh air amount for elimination of inadmissible opacity.

$E_{co} = \left(\frac{M_p.e_p}{v_p} + \frac{M_t.e_t}{v_t}\right).\frac{L}{3600}$;($m^3.s^{-1}$) - amount of CO emission, where

- e_p - average passenger car CO emission in determined date, 0.06 $m^3.s^{-1}$;
- e_t - average truck CO emission in determined date, 0.1 $m^3.s^{-1}$;
- v_p - average passenger car speed in the tunnel in determined date, 50 $km.h^{-1}$;
- v_t- average truck speed in the tunnel in determined date, 50 $km.h^{-1}$;
- L - tunnel length, 4.55km.

$E_{CO} = 0.000495$

$Q_{CO} = E_{CO}x10^6 \, x1/c = 0.000495 \times 10^6 \times 1/200 = 2.48 \, [m^3.s^{-1}]$, where

- c - limit concentration of carbon-monoxide (ppm) in the tunnel.

$E_{OP} = \left(\frac{M_p.O_p}{v_p} + \frac{M_t.O_t}{v_t}\right).\frac{L}{3600}$;($m^2.s^{-1}$) - amount of smoke emission, where

- O_P - average passenger car smoke emission in determined date, 24 $m^2.h^{-1}$;
- O_t - average truck smoke emission in determined date, 90 $m^2.h^{-1}$;
- V_p - average passenger car speed in the tunnel in determined date, 50 $km.h^{-1}$;
- V_t - average truck speed in the tunnel in determined date, 50 $km.h^{-1}$;
- L - tunnel legth, 4.55 km.

$E_{OP} = 0.271$

$Q_{OP} = E_{OP}. 1/K= 0.271 \times 1/12= 0.023 \, [m^3.s^{-1}]$, where

- K - limit value of opacity (m^{-1}) in the tunnel.

Additional axial jet fans shall be installed in the main tunnel tube to control longitudinal direction of the air flow on the both sides of the main tunnel above sidewalks. There shall be installed 4 axial jet fans by the Silkyara tunnel portal and 4 axial jet fans by the Barkot tunnel portal. Each of them shall have air pressure power of about 612 Pa. Fan drives - electric motors of the power 8 x22kW.

Escape Passage ventílation: In escape passage, there has to be provided super-atmospheric air pressure by axial fans located by both escape passage portals. Two fans with capacity of 2 x $35m^3.s^{-1}$ assure velocity of air in the escape passage of 3 m per second. Outlet of the vent air into the tunnel tube is executed through overpressure fire flaps. Fan drives - electric motors of the power 2x30kW

15.1.3 Civil Works

The ventilation machine-rooms of the tunnel tube ventilators shall be executed as separate fire segregated spaces. Cable passages through walls (borders) of fire segregated spaces shall be tightened by appropriate fireproof packing.

Smooth surfaces of vent air channels are presupposed.

For the design of civil works following space requirements for the equipment of main ventilation system are considered:

- machine-rooms in technology buildings by the tunnel portals - 25 m x 40 m for one building and four ventilators, with height of 6 m; the machine-room shall be equipped by an appropriate electric gantry crane:

15.1.4 Technical Accessories

Exhaust ventilators: heat resistivity of the vents has to be 250 degree of Celsius for the time of min. 90 minutes.

Control of ventilators: by the tunnel control system in accordance with the acquired data from the measuring facilities for CO and opacity values. For operation of fire ventilation are critical fire case scenarios and measurement of air convention, direction and velocity in the tunnel tube.

Emission limits in the tunnel tube	CO limit (ppm)	K limit (l/m)
Vehicle speed (km/h)		
10-100	100	0.007
0-10	150	0.009
Tunnel has to be Closed	200	0.012

15.2 Physical Values Measurement

15.2.1 Functional Description

The operational ventilation of the tunnel tube shall be managed particularly in accordance with data acquired by continuous measurement of tunnel air quality conditions.

Measurements of amount of carbon-monoxide (CO) in tunnel air and opacity (transparency of tunnel air) are assured by integrated detectors for permanent acquisition of CO and opacity data. On the basis of the data, the operation of ventilation system by standard traffic conditions is automatically controlled by the integrated tunnel control system. The programme also advantageously makes use of special prediction routines based on acquired data by traffic counters (Traffic Counting Systems).

The control ventilation programme uses data of an air circulation measurement as well. These data are especially important for main tunnel tube ventilation in case of a fire. They include measurement of the air flow direction and velocity inside the tunnel tube and the barometric pressure by the tunnel portals.

The measurements of appropriate physical and electrical values of various tunnel devices, equipment and networks (e.g. bearing temperature, electrical power supply, current, etc.) are the parts of individual tunnel systems.

15.2.2 Basic Specifications

15.2.2.1 Design

Carbon-monoxide and opacity detector system consists from optical sender and receiver which are positioned in the distance of 10 m along a tunnel side. The systems shall be located in 14 locations equally situated along the tunnel tube in lay-bays to make easy their regular cleaning. They shall be installed in the height of 3.5 m above road pavement level. Evaluation units of the systems will be situated in close LV control rooms.

Air circulation detector systems (5 sets) shall be situated on the tunnel sides near the tunnel portals and inside the tunnel tube in the height of 4 m. They will operate on the ultra-sonic detection principle using evaluation of transversal ultra-sonic beam. Two meteorological detectors by tunnel exit roads shall acquire data of air humidity, air temperature, wind velocity and direction, barometric pressure, intensity and type of precipitation.

16 Tunnel Lighting

16.1 Main Tunnel Lighting

16.1.1 Functional Description

Main tunnel lighting represents significant constituent of tunnel traffic safety. It consists of the night road lighting of tunnel access roads in front of the tunnel portals, the controlled lighting of accommodation sections at both ends of the bidirectional tunnel tube and of the trough (transit) lighting of the whole tunnel tube. The accommodation section lighting regulation is imptemented by a program of the integrated control system of the tunnel on basis of data from two luminance meters which are located in front of tunnel portals. Photometric sensors (CCD cameras) shall continuously evaluate outdoor luminance. The regulation is operational by day light in steps. It is assumed night degree of lightening (by CIE 88/90) with the through lighting.

16.1.2 Basic Specifications

16.1.2.1 Design

Access Road Sections: it is considered standard public road lighting with lighting posts along one side of the road (an access side). Lighting fixtures will be set for high pressure natrium discharge lamps (HPNL) with nominal power of 150 W, posts shall be of height of 12 m and with span of 20 m. Installation of the road lighting shall be executed up to 200 m from portals.

Accommodation Sections: threshold and transition zone lighting fixtures of the tunnel accommodation sections are situated on the roof of the tunnel tube in a line passing over the middle of an access traffic lane. They are in execution of Counter Beam Lighting (CBL) with nominal power of 400 W, resp. 250 W and 150 W. Lighting sources are HPNL.

Required luminance of road pavement is given by tunnel light calculation. Accomplishment of luminance values is given by:

- lighting fixture specifications;
- nominal power of light sources,
- execution of the tunnel tube;
- elevation and lateral location of lighting fixtures inside the tunnel tube;
- spacing of lighting fixtures;
- overswitching regulation of lighting fixtures.

An example of lighting fixture type and spacing can be identified as it is noted in the table below:

ZONE	LENGTH of the ZONE (m)	LAMP SPACING (m)	LAMP NOMINAL POWER (W)	TYPE OF LIGHTING FIXTURE
Threshold zone 1 (TH-1)	50	1	400	CBL
Threshold zone 1 (TH-2)	50	1.6	400	CBL
Transition zone 1 (TR-1)	55	2.6	250	CBL
Threshold zone 1 (TR-2)	60	10	150	CBL

Through (Transit) Lighting: lighting fixtures are situated in the centre-line of the tunnel tube on the roof. They shall be hanged on cable tray. They lighting characteristic is symmetric and are set for nominal power of lighting source of 150 W. A span of the lighting fixtures is 15 m. Lighting source is HPNL.

Main Tunnel Lighting Calculation: A system of main tunnel lighting shall be calculated on basis of supplier's data with a respect to Guide for Lighting of Road Tunnels and Underpasses CIE 88/1990 (with exception concerning interior lighting). Control program algorithm: on basis of lighting fixtures supplier's indications. Two CCD cameras of photometric detectors shall be located on poles in front of the tunnel tube portals in distance of 100 m and height of 6 m.

Energy budget: max. power requirement of 167 kW.

Lighting operation: in standard status of the tunnel operation the main tunnel lighting shall be controlled automatically. In the emergency status of the tunnel operation there shall exist possibility to control main tunnel lighting from work place of operators (local control and supervision centre of the tunnel). There is not supposed a local sectional manual control of main tunnel lighting segments.

Power supply: the main tunnel lighting is supplied from the standard main power distribution network of the tunnel complex. There shall not be used a substitutive power supply system (emergency power supply - a diesel generator set, UPS – uninterruptible power source) for the main tunnel lighting. It means that the tunnel entrance shall be closed for the traffic in case of a main tunnel lighting power supply drop-out for a minimum time period of 20 minutes. The time period has to be observed with respect to technical specifications of HPNL light sources.

16.1.3 Civil Works

Civil works design documentation has to consider requirements of spaces for distributors and switch-boards of the main tunnel lighting and to protective cable conduits transversally leading from a backbone electric energy line (longitudinal) to the roof of the tunneltube.

16.1.4 Technical Accessories

Lighting fixtures: Casings and hanging structures are made from non-corrosive material. Conditions for elimination of electro-galvanic corrosion in mechanical connections have to be accomplished. Fixture reflector is supposed to be made from polished and anodic oxidized aluminium alloy.

Liqhtinq Sources: the high pressure natrium discharge lamps with operating life of min. 16 000 hours.

Cable Trays under a roof of a tunnel tube: galvanised steel (zinc dipping).

Cables situated under a roof of a tunnel tube: they shall correspond with specifications of European standard EN 50 266 and similar actual ruling - in case of a fire accident they may not propagate flame.

Handing of cable trays and lighting fixtures: stainless steel (pro-chrome) bolts, nuts, washers and anchors. Anchors with chemical fixation.

16.2 Emergency Tunnel Lighting

16.2.1 Functional Description

The emergency lighting is important part of road tunnel technical accessories. It consists of an emergency lighting of unprotected escape ways (for lay-bays, emergency exits, SOS boxes, FF niches and tunnel sidewalks) and an emergency lighting of escape ways in the tunnel complex (for cross passage and escape tunnel, escape ways in technology buildings and rooms).

Power supply of all the emergency lighting fixtures has to be executed by on-line uninterruptible power sources (UPS). By power supply drop-out has to be assured feeding of the fixtures for a minimum time period of 60 minutes.

16.2.2 Basic Specifications

16.2.2.1 Design

Lay-bay HPNL lighting: roof lighting, lighting fixtures for HPNL 70 W, each LB equipped with 2 lighting fixtures.

Sidewalk lighting: lighting units for LED lighting sources located on both tunnel walls in the elevation of 1 m above sidewalk pavement. Spacing of the lighting fixtures shall be 15 m. They shall assure maintained illuminance of the sidewalk pavement with minimum value of 2 lx and with maximum longitudinal evenness of 40: 1 ratio. The lighting fixtures shall not light to the upper half-plane.

Accentuating lighting (for escape exits and SOS/fire fighting niches) : for the lighting are used lighting units for LED lighting sources with the view of contour accentuation of these objects, with expectant value of maintained illuminance 5 lx for escape side-walk near the objects. Colour nuance of the lighting is recommended such as light green.

Escape way lighting: lighting fixtures shall execute for LED lighting sources. Maintained illuminance shall be 15 lx on a floor with min. evenness of the 1: 10 ratio.

Emergency Tunnel Lighting Calculation: A system of the emergency tunnel lighting shall be calculated on basis of supplier's data.

Energy budget: max. power requirement of 53 kW

Lighting operation: in standard traffic status of the tunnel operation the emergency tunnel lighting for LB, emergency exits and SOS and FF niches shall be permanently switched-on and the one for escape ways shall be switched-off. The emergency lighting for escape ways shall be controlled automatically. In the emergency status of the tunnel operation shall be immediately switched-on. The possibility to control emergency tunnel lighting for escape ways has to exist from work place of operators (local control and supervision centre of the tunnel) in a case of service works. There is supposed a local sectional manual control of emergency tunnel lighting for escape ways.

Power supply: the emergency tunnel lighting is normally supplied from the standard main power distribution network of the tunnel complex through UPS. There shall be used a substitutive power supply system (emergency power supply on-line UPS uninterruptible power source).

16.2.3 Civil Works

Civil works design documentation has consider requirements of spaces for distributors and switch-boards of the emergency tunnel lighting located inside escape ways of the tunnel.

16.2.4 Technical Accessories

Lighting fixtures: Casings and hanging structures are made from non-corrosive material. Conditions for elimination of electro-galvanic corrosion in mechanical connections have to be accomplished.

Lightings sources: high intensity Light Emitting Diodes (LED) with white colour for the escape ways and with light green colour for the unprotected escape ways (with exception of HPNL for LB).

Fixing Structures and Cable Trays: galvanised steel (zinc dipping).

Hanging of Cable Trays and Lighting Fixtures: stainless steel (pro-chrome) bolts, nuts, washers and anchors. Anchors with chemical fixation.

17 Communication Systems

17.1 Wireless Communication System

17.1.1 Functional Description

The wireless communication system serves for communication of emergency intervention teams and service attendance personnel. It should be also equipped by mobile phone operator/operators accessories. It consists of an aerial tower with antennas placed outdoor beside the tunnel, processing unit panel boards and line slot radiating tunnel antenna.

17.1.2 Basic Specifications

17.1.2.1 Design

Antennas of the aerial tower which location has to be selected attentively in accordance with reception conditions for they should assure reception of all the required frequencies (FM communication bands, broadcasting and TV stations) and casting of emergency, tunnel service and mobile phone operator's frequencies. It is supposed to install two towers at both tunnel portals.

The processing units should make possible synthesize and split up all the communication signals. A slot broadband radiation cable antenna inside the tunnel tube shall be situated under the roof of the traffic profile of the tunnel tube along all the length of the tunnel tube with exception of about 200 m long sections by the tunnel portals inside the tunnel. It will be divided to four sections, each of them fed from separate amplifiers, located in correspondent control rooms at the technology portal buildings (2 pcs.) and in the control rooms located in the middle of the tunnel tube (2 pcs.).

A switch board of the wireless communication system is placed on the operator's workplace. It should make possible verbally enter in transmission of broadcasting station by emergency situations. Thereto the system for the transmission of prepared phonetic messages shall be designed. The similar system has to be in disposal for the evacuative broadcasting system.

The fixed traffic signs with introduction of transmitted frequency of broadcasting station shall be placed in front of the tunnel entries.

17.2 Evacuative Broadcasting

17.2.1 Functional Description

The evacuative broadcasting system contributes significantly to the tunnel operation safety, esp. in case of emergency situations, e.g. a fire of a vehicle. In case of a fire, drivers have promptly to know that they must immediately leave their cars and leave off the tunnel tube with using of the escape exits. The evacuative broadcasting serves to the effect. Moreover it is used for provision of traffic information, e.g. in case of traffic stopping by traffic lights three coloured with red signal active.

17.2.2 Basic Specifications

17.2.2.1 Design

The sound distribution inside the tunnel tube shall be established by regularly dislocated horn loudspeakers with spacing of about 50 m. The sound signal feed from the end section amplifiers shall be divided to 29 sections. The sound amplifiers will be installed in every second emergency call niches in reserved spaces of power supply panel boards. The operator's workplace has to be equipped by microphone entry to make possible verbally enter in transmission of evacuative broadcasting by emergency situations. The system for the transmission of pre-prepared phonetic messages shall be designed as well. In case of a confirmed fire inside the tunnel tube, an appropriate message shall be automatically transmitted. A version could be for example following: "The fire in the tunnel, leave the tunnel immediately!" The message will be repeatedly transmitted in local and English languages.

C. TECHNICAL ACCESSORIES COORDINATION

18 Implementation Design Coordination

18.1 Functional Description

Within this technological complex there are needs to describe all collective integrated elements of technological systems but mainly those, that don't belong to any system. It is necessary to create logical tunnel division, unambiguous marking and numeration of constituent elements of technological systems, to determine cable run and cable coordination along the tunnel.

In the tunnel complex shall be determined commitment marking and numeration system of tunnel technological parts and elements. It also assumes visible number tunnel section marking with setting out of direction to the nearest escape.

It is necessary to differentiate and also space separate power cables and data cables. The main reason is to eliminate metallic cable paralleling by reason of disturbance. There is no disturbance in optical cables.

The main part of the coordination will be complete cable coordination with unambiguous fixing in protection tubes and all the cable designation in the tunnel complex.

18.2 Basic Specifications

18.2.1 Design

Cable run for power cables will be lead under western tunnel footpath all the way to distribution point in control and technology buildings. Cable run for data cables will be lead under eastern footpath. Runs in the tunnel will be solved with enough number of protection tubes. Cables will be lead in block channels.

There will be cable shafts situated on cable lines so that it will be possible to retract needed cables to protection tubes.

In lay-bays, concreted protection tubes shall be located under road pavement so that it is possible cables deviate to secondary distribution point as to escape passages.

2 Lane/ 2 Lane upgradation proposal of Highway between Km 144.00 (Dharasu) and Km 220.00 (Yamunotri) falling along NH - 94 and 123 in the State of Uttarakhand

submitted to

Ministry of Road Transport & Highways
(Government of India)

By

TASPL
(Committed to resource and energy conservation)

M/s TECHNOCRATES ADVISORY SERVICES PVT.LTD.
(Earlier M/s MC Consulting Engineers Pvt. Ltd.)

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1 INTRODUCTION

The construction of 77 Km long (designed) Dharasu-Barkot-Yamunotri Highway, a 2 Lane/2 Lane expansion/ upgradation including bypass/realignment of NH-94 and 123, in the State of Uttarakhand pass through a hilly section of Lesser and Higher Himalayan zone between CH-144.00 (Dharasu) and CH-220.00 (Yamunotri) as shown in Figure-1. The total existing length of highway at present is 97.900 Kms that comprises a major proportion of cut and fills with a tunnel of about 4.500km between CH-25.400 (Silkyara bend) and CH-51.000 (Pall Gaon-Barkot) in Dharasu - Barkot Section **(Figure-1)**. Under National Highway Authority of India (NHAI, Ministry of Road Transport and Highways, Govt. of India) the DPR investigations related to the project vide Package-V are being executed by M/S MC Consulting Engineers Pvt. Ltd., JV with G.E.S. & Association with S.I.P.L. As the extended highway construction passes through undulating mountain topography, it would require a considerable depth of further formation cutting where natural geo-structural controls may largely influence stability along cut-slopes. Similarly in the areas of fill or debris and soil slopes, excavation/ cutting may induce instability in the slope and therefore the present report tries to evaluate geological/ geotechnical conditions of the proposed expansion/ upgradation of highway to assure feasibility.

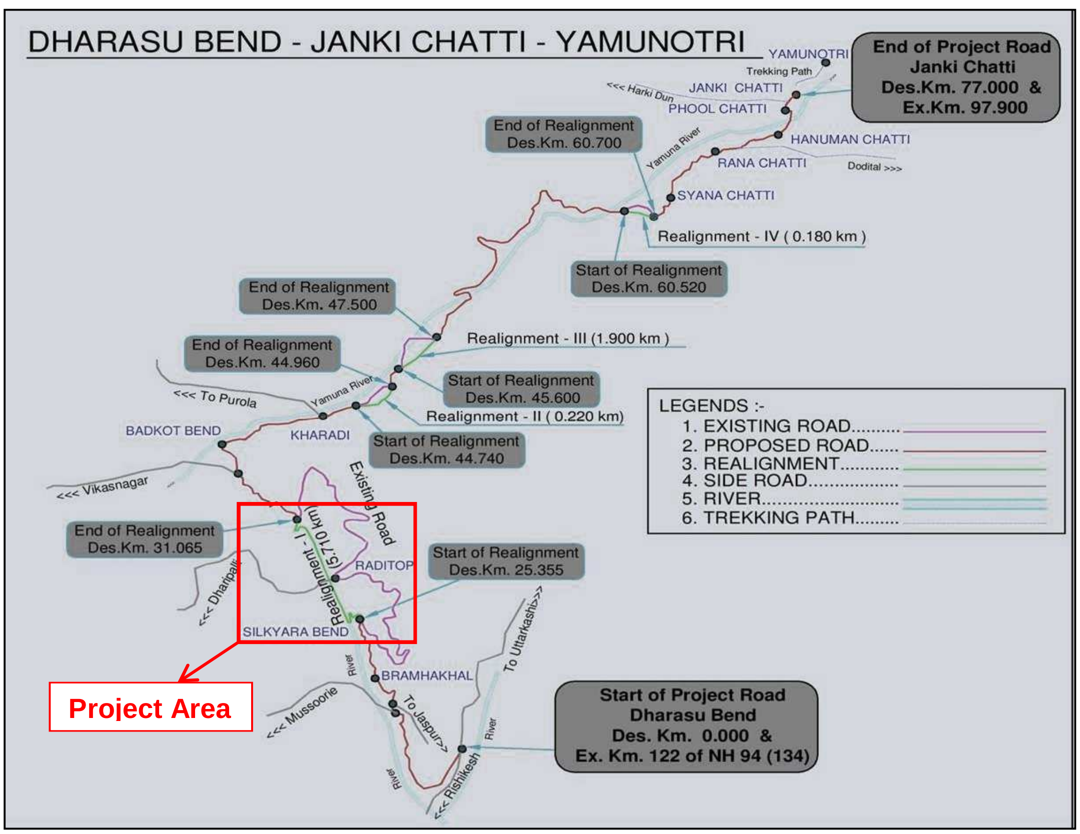


Figure-1: Map showing location of Highway in the project area

2 GEOMORPHOLOGY

The proposed highway tunnel of about 4.500km long between CH-25.400 (Silkyara bend) and CH-51.000 (Pall Gaon-Barkot) in Dharasu - Barkot Section. is located in Uttrakhand or Uttranchal Himalaya. The Himalaya has been divided into four east-west trending physiographic zones, viz Outer or Sub- Himalaya, Lesser Himalaya, Great Himalaya and Tethys or Tibetan Himalaya. The Tibetan Plateau is generally referred to as the Trans-Himalaya.

Sub-Himalaya, the southern most geomorphic zone of Himalaya rises abruptly from Indo - Gangetic Plains along the Foot Hill Fault/ Thrust (FHF/FHT) and attains altitudes upto 1200m. It exposes mainly Cenozoic sediments belonging to Siwalik Super group. The Main Boundary Fault/ Thrust (MBF/MBT) defines its northern limit against Lesser Himalaya. It is also referred to as Siwalik and hosts synclinal intermontane basins – the Duns for deposition of Quaternary sediments (Auden, 1937).

The Lesser Himalaya is a broad physiographic zone that lies between Sub-Himalaya in the south and Great Himalaya in north. This zone is also referred to as Lower Himalaya or Himachal Himalaya and attains altitudes between 1200m and 3000m. The Main Boundary Fault/ Thrust and Main Central Thrust (MCT) define its southern and northern limits against Sub-Himalaya and Great Himalaya respectively. It is also sometimes informally divided into Inner Lesser Himalaya and Outer Lesser Himalaya. This zone has a mild and mature topography with gentle slopes but deeply dissected valleys of major rivers.

Great Himalaya is a narrow physiographic zone that lies between Lesser Himalaya in the south and Tethys Himalaya in the north. This physiographic region is also referred to as Himadri (Singh, 1971). The southern limit of this physiographic zone is defined by the MCT while in the north, generally it imperceptibly passes into Tethys Himalaya except a few places where a tectonic plane, Dar-Martoli (Himadri) Fault defines its northern limit. The mean altitude in this zone varies between 4800m and 6000m. This zone is characterised by highly rugged topography with snow covered high peaks. Some of the high peaks in this zone include Chaukhamba (7138m), Kamet (7756m), Banderpunch (6315m), Gangotri (6614m), Kedarnath (6940m), Nanda Devi (7817m), Dunagiri (7066m), Trishul (7120m), Nandakot (6861m), Pachchuli (6510m) etc. Some of prominent Himalayan glaciers located in this zone include Gangotri, Milam, and Shunkalpa etc. It remains snow bound for major part of the year and is characterised by glacial land forms such as morains, cirques, arêtes and horn peaks. The valleys are glacial U-shaped with hanging glaciers and valleys subsequently are in the form of steep gorges. The proposed project is located in this physiographic zone of Himalaya **(Figure-2).**

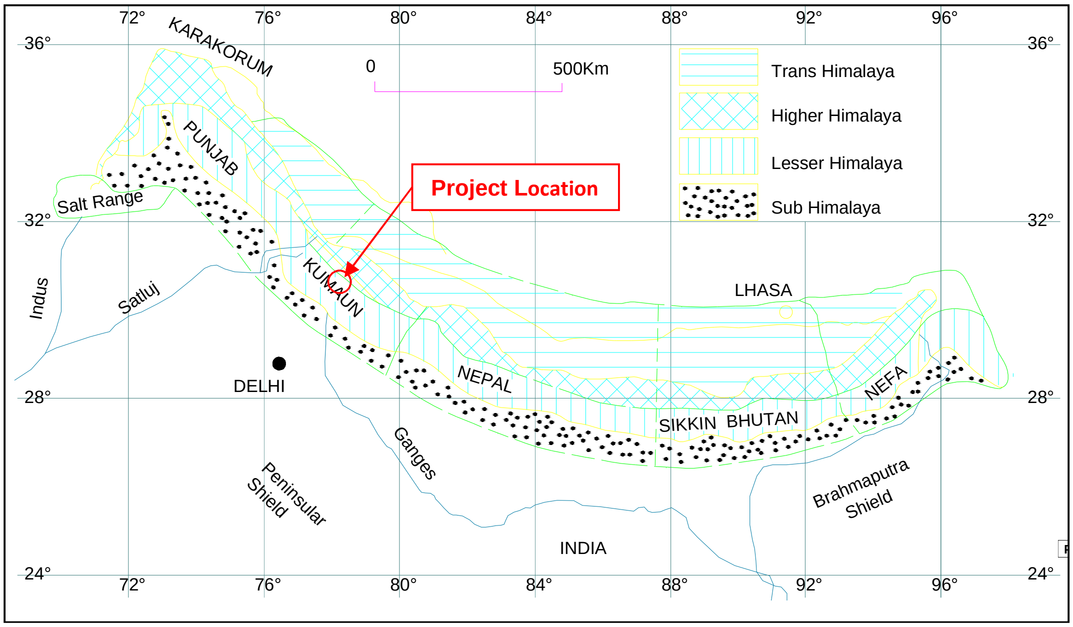


Figure-2: Linear Geomorphic Divisions of Himalaya (After Burrard and Haydon, 1933)

Tethys Himalaya is considered northern most physiographic sub- division of the Himalaya that imperceptibly passes from Great Himalaya that lies to its south. The Indus – Tsangpo Suture separates it from Trans Himalayan Zone in the north. General altitude in this zone varies from 3500m to 4800m. It is generally made up of Phanerozoic rocks and is characterised by anticlinal ridges and synclinal valleys. The general elevation in this physiographic zone varies between 3500m and 4800m.

3 Regional Geology

Uttaranchal or Uttarakhand Himalaya occurring in the central part of the Himalayan folded belt exposes rock types varying in age from Proterozoic to Late tertiary period, disposed in four major tectonic belts designated as the Foothill Siwalik belt, Lesser Himalayan belt, Central Crystalline and Tethyan belt.

The Main Frontal Thrust (MFT) which is considered neotectonically active is the southernmost thrust that brings the rocks belonging to Siwalik Super Group over the recent alluvium. It has been termed as MBF III by Ravi Shanker et al (1989) (Figure-2). The Sub-Himalaya constitutes of Siwalik Hills, with altitude ranging from 250 m to 800 m and width between 25-100 km and one characterized by flat floored structural valleys called Duns. The foothills consist entirely of a narrow belt of Lower Siwalik sediments consisting of sandstone, siltstone, shale and conglomerates. Middle and Upper Siwaliks are subordinate with contact often marked by strike faults. The individual Siwalik sections are mostly normal and are demarcated on the north by an important geotectonic feature named as the Main Boundary Fault/Thrust. In Garhwal Himalaya only Middle and Upper Siwaliks are represented to the south of Dehradun and north of Kotdwara in a linear belt from Kalsi to Kalagarh.

The Lesser Himalayan belt in Uttrakhand consists of unfossiliferous rocks covering a vast stretch in Garhwal and Kumaoun regions. It is bounded by the Main Boundary Fault/Thrust (MBF/MBT) in the south and the Main Central Thrust (MCT) in the north. On the basis of lithostratigraphy and structure it has been included in Main Himalayan Belt (MHB) by Kumar (2000). This belt is geologically very intricate. The rocks belonging to Super Sequences IIa to XI of Ravi Shanker et al (1989) are exposed in this zone. This is characterised by several important tectonic units bounded by faults and thrusts. This belt includes argillaceous, calcareous, arenaceous meta sedimentary rocks ranging in age from Precambrian to Tertiary. Doubly plunging synforms named Mussorie Synform, Garhwal Synform and Nainital Synform form a part of this belt. This belt includes rocks belonging to Mandhalis, Chandpurs, Nagthat overlain by Blaini, Infra Krol, Krol, Tal and Paleogene Nummulitics in ascending order. The other important belt in Lesser Himalaya is Almora-Dudatoli Crystalline Belt which includes pelitic, psemitic and semipelitic schists and quartzites intercalated with bands of migmatites, granitic gneisses and non- foliated granite rocks occurring in asymmetric synform. The other significant belts in Lesser Himalayas include the Ramgarh, Eastern Kumaon and smaller crystalline belts in Kumaon area. Garhwal Group of rocks comprising volcano-sedimentary sequences is another important rock group in the northern sedimentary belt. It comprises unfossilferous sediments. This belt extends from Uttarkashi in the north-west to Kali River in the south east where it further extends into Nepal and is represented by ortho-quartzite-carbonate sequence with minor argillaceous component.

The Central Crystalline Belt consist of a complex of mylonite gneisses, phyllite, garnetiferous schist and kyanite bearing schist, calc silicate rock and quartzite with associated migmatites, syntectonic granite gneisses and late to post tectonic tourmaline bearing granite that includes the famous Badrinath and Gangotri granites. Gansser (1964) indicated that a normal sequence of decreasing metamorphism is noticeable in the upper part of the Central crystalline belt where it grades into Martoli Garbyang formation. This belt is subjected to poly-phase deformation and poly-metamorphism with isoclinal and reclined folds plunging towards NNE. Kata-zonal assemblages, poly-metamorphism three or four fold symmetries characterize this belt. The rocks belonging to Super Sequence I of Ravi Shanker et.al (1989) exposed in this belt **(Figure-3)**. The Central Crystalline belt at places is characterised by mica schist and gneisses with sills of amphibolites and those of gabbroid to dioritic composition. Lower most gneisses show upward increase of the content of plagioclase feldspar. Overlying rocks are the psammitic gneisses with the preponderance of garnet, staurolite, kyanite etc. within the overall biotite gneisses or migmatitic zone. In Garhwal Himalaya enormous thickness of quartzite is developed with short strike extension. Linear intrusion of tourmaline granite is seen towards the upper most part of Central Himalaya.

The Tethys Himalaya occupies approximately a 40 km wide zone north of Higher Himalaya. This zone is characterized by about 10 km (maximum) thick sedimentary sequences ranging in age from the Late Precambrian to the Lower Eocene. The Tethyan zones extend all along the southern margins of the Tibetan Plateau in the east to the Zanskar Mountains in the west. Earlier workers described a gradational passage between the Tethys Himalayan rocks and the underlying crystalline basement of the Higher Himalayan Zone. Of late, several workers have recorded a tectonic break (Shear Zone, South Tibetan Detachment, Normal Fault and Trans Himadari Thrust) between the crystalline basement and the rocks belonging to Tethyan Zone. The Tethyan belt includes a thick succession of marine fossiliferous sediments belonging to Martoli and Garbayng Formations separated at places from rocks belonging to underlying Central Crystalline Group by Dar-Martoli fault which is of discontinuous nature. The northern limit of Tethyan belt is marked by a major thrust near Kailash region where a feebly metamorphosed and south dipping flysch zone with intercalated ophiolites and some exotic blocks is thrusted along south dipping tectonic plane over the thick and horizontally bedded Kailash conglomerate (Gansser, 1964). This thrust, Indus-Tsangpo Thrust or Suture Zone probably divides the Himalaya from the Trans-Himalaya and marks the northern limit of the Tethyan Himalaya.

The trans-Himalayan zone, beyond Tethys Himalayan Zone includes the Kohistan sequence, the Indus and Shyok sutures of Ladakh and the Karakoram Zone of western Himalaya. The ophiolites, the flysch and molasses sedimentaris of the Kailash range, the Yarlung-Tsangpo belt and the Lhasa block of southern Tibet represent the eastern continuation of the Trans Himalayan zone. The evidence for subduction is provided by the occurrence of the ophiolitic mélange and high pressure (blue schist) metamorphic rocks.

The Uttrakhand Himalaya, on the basis of lithostratigraphy and structure has been sub-divided into two WNW-ESE trending linear belts. These are Main Himalayan Belt (MHB) and Frontal Fold Belt (FFB). These are separated from each other by Main Boundary Fault or thrust (MBF/ MBT-1). The main Himalayan Belt includes formations ranging in age from Paleo-Proterozoic to early Middle Paleogene (Super Sequences I to XI of Ravi Shanker et. al. (1989) and has a complex geotectonic history as compared to Frontal fold Belt that includes Late Middle

Paleogene to Early Pleistocene successions (Figure-3). According to Kumar (2005), the entire MHB did not behave uniformly during different orogenic movements as some sectors were repeatedly transgressed while others remained positive and were under active erosion between two orogenic movements. The MHB, that includes all the sequences except Murree and Siwalik Groups, has been subjected to different orogenic movements as a result of which has complicated structures. It abuts against Ladakh and Karakoram ranges along Indus – Tsangpo Suture in the north and along Tidding Suture in Arunachal Pradesh in the east. The MHB on its south abuts against FFB along MBF/MBT. The Tethyan and higher Himalayan Zone located in the north are separated from southern Lesser Himalayan Zone by Main Central thrust (MCT). Further the Higher Himalayan Zone is divided into two zones in eastern part by Dar Martoli Fault where as North Almora Thrust divides lesser Himalayan zone into two sub-zones.

Some of the significant tectonic plates **(Figure-4)** present from north to south in both MHB and FFB in Uttrakhand Himalaya are described below.

Dar-Martoli Fault is a major plane of dislocation mapped in Kali valley. At Dar, it separates Dar Formation from Central Crystallines. It has been traced to south of Martoli. It is traceable to the Dhauliganga valley upto Matoli where it is off-set by Matoli Fault.

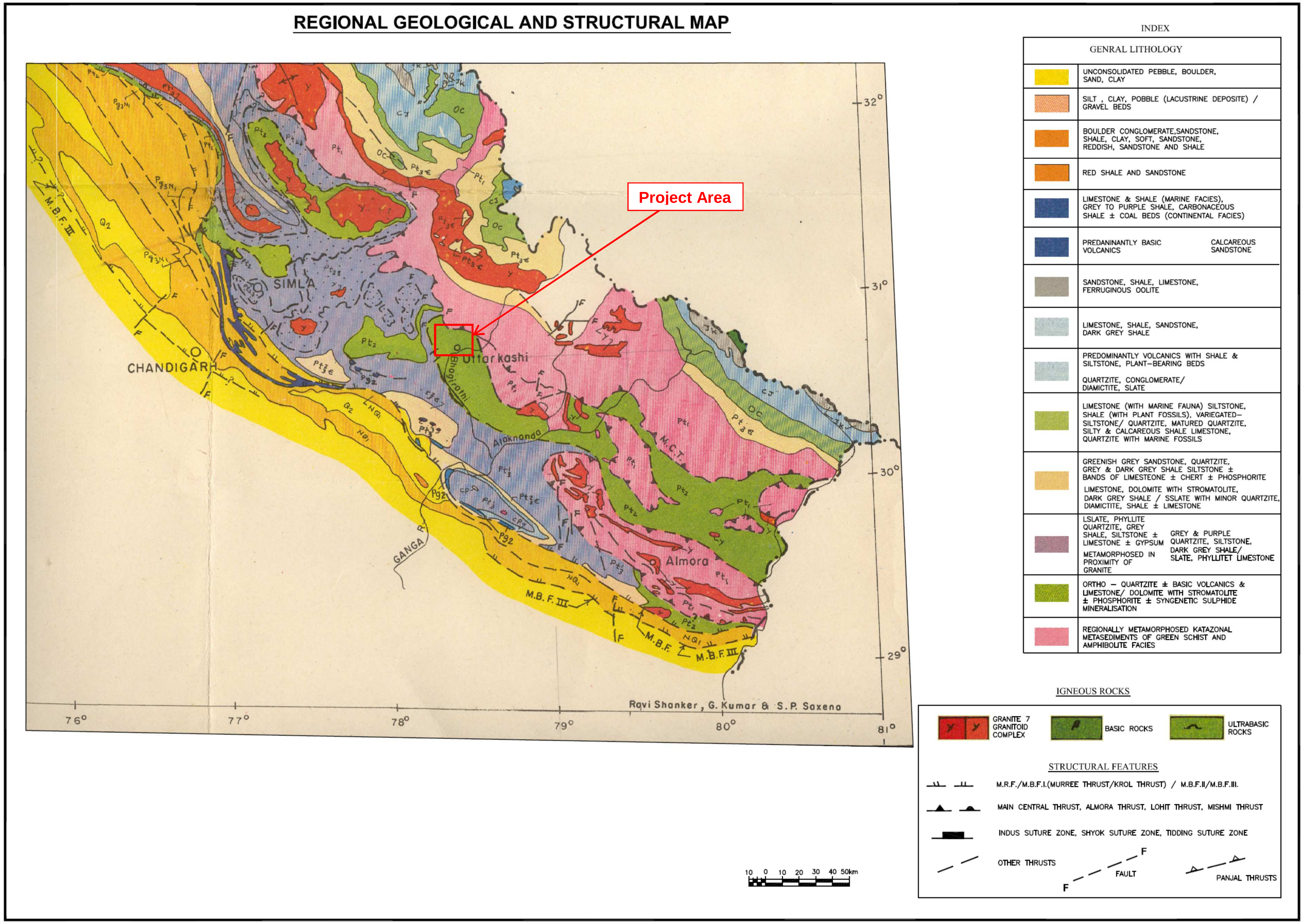


Figure-3: Regional geological map of Uttaranchal by Ravi Shankar et al (1989)

Main Central Thrust (MCT) is a steep northward dipping major tectonic plane that defines the northern tectonic limit of sedimentation of Garhwal Group (Super Sequence II of Ravi Shanker et al, 1989) with Central Crystallines belonging to Super sequence I. In Uttrakhand Himalaya its position has been mapped from north of Dharchula in Kaliganga valley in the east, north of Munsiari in Goriganga valley, north of Loharkhet in Sarju valley, around Helang in Alaknanda valley and traced to Bhatwari in Bhagirathi valley. Beyond Uttrakhand, it has been traced to abut against Tidding Suture Zone in Arunachal Pradesh in the east. In north-western part of Himalaya it is concealed under the Super sequence III in the area west of Yamuna. However, it has been mapped in isolated areas forming the southern tectonic boundary of Central Crystallines in Satluj valley in Himachal Pradesh and Chenab Valley in Jammu and Kashmir.

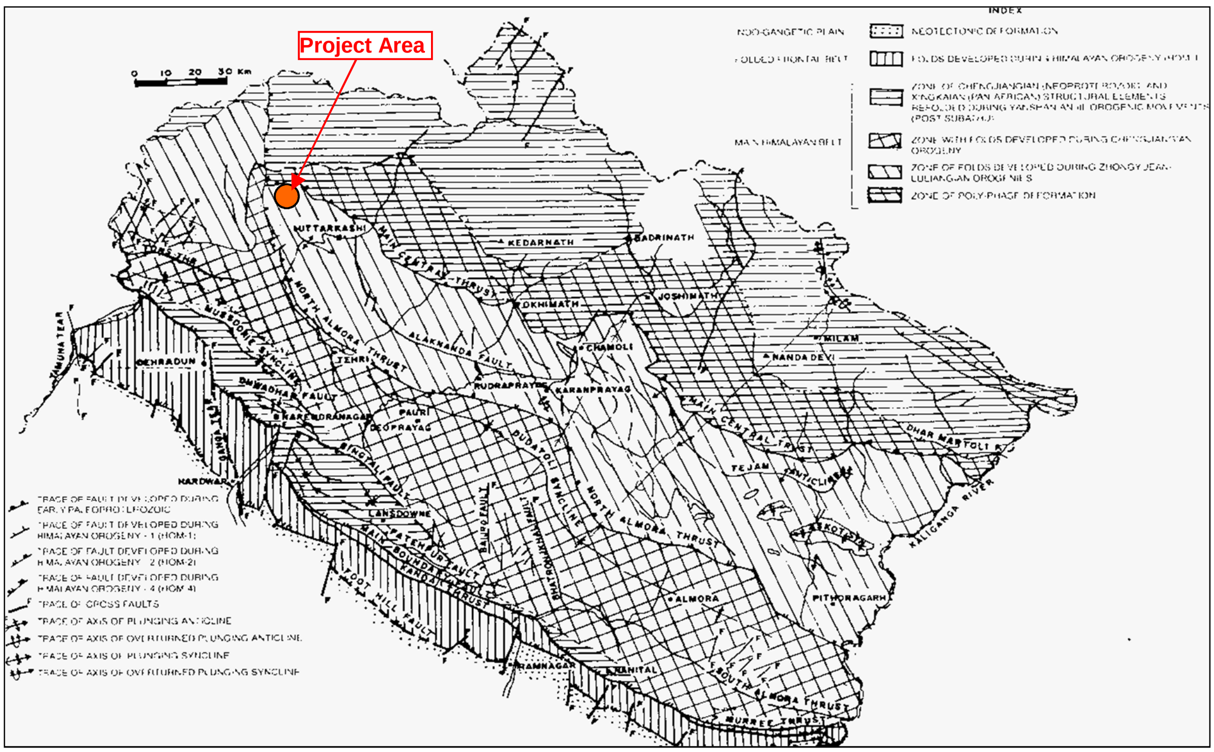


Figure-4: Tectonic map of Uttarakhand (after Kumar, 2000)

Alaknanda Fault is a major fault mapped in the Alaknanda valley extending from south of Nandprayag in the east to beyond Chirpatiyakhal in the west. It continues northwestward almost parallel to NAT and appears to offset MCT in Bhagirathi valley.

North Almora Thrust (NAT) is a high angle WNW-ESE to NW-SE trending tectonic plane that separates the Garhwal Group of inner Lesser Himalaya in the north from Jaunsar and Dudatoli Groups of the outer Lesser Himalaya in the south. In general it dips towards south in the eastern part and at places it is vertically to sub-vertically disposed with steep dips on either side. It is traceable from Kali valley in the east to the Tons valley in the west. Locally, it is also referred to as Srinagar Thrust in Alaknanda valley and Dharasu Thrust in Bhagirathi valley. Further east, it continues into western Nepal and appears to merge with MBF.

South Almora Thrust (SAT) Heim and Gansser (1939) identified a tectonic plane separating 'Crystalline Zone of Almora' from unfossilferous 'Calcareous Series' (now grouped with Mandhali Formation) exposed in Bhowali- Ramgarh - Mukteshwar section, south of Almora and named it South Almora Thrust (SAT). Although there is general acceptance of existence of this tectonic plane in eastern part, but its existence in western part of Uttrakhand is disputed by many workers. It is defined as a tectonic plane, as defined by Heim and Gansser (1939), that separates Nagthat and/or Kalsi Limestone (Mandhali) from overlying Manila Formation. It is a high angle fault along which the rock lying to its south constituting the Mandhali/ Bhimtal formations are either cut off or are juxtaposed with younger Manila Formation. In the west it abuts against a cross fault at Bhatronjkhal and in the east it has been traced to Tarkuli in the western Nepal in Kali valley.

Tons Thrust is a fault plane that separates Mandhali and Jaunsar Formations from 'Morar Chakrata beds' in the Tons valley in Kulsi-Chakrata area. It dips towards southwest and south, passes through Korwa along Kalsi- Chakrata road and extends further into Yamuna valley.

In addition, a large number of thrust faults have been mapped in the region of Tethys Himalaya resulting in repetition of beds (Kumar, 2005).

Murree Thrust (MBF-1) is a steep north dipping tectonic plane which defines the southern boundary of MHB and northern boundary of FFB. It is traceable from north of Uri in Jhelum valley, Jammu & Kashmir in the NW to the south of Nahan near Himachal- Uttrakhand border. Further east, in western Uttrakhand, it separates the pre-Tertiary rocks from Tertiary rocks at Kalsi. Further east, it appears to merge with MBF-2 that brings Super Sequence XIII in direct contact with MHB. It again reappears in Ladhiya valley and continues into western Nepal.

Main Boundary Fault (MBF-2) is a steep north dipping fault forming tectonic contact between rocks belonging to Murree and Siwalik Groups in the west of Yamuna valley in west and in the area north of Chalthi in Ladhiya valley in the eastern part. It however, marks southern tectonic contact between MHB and FFB in the area between Yamuna and Ladhiya valleys. It runs almost parallel to general trend of Himalayas from Kalsi on the Tons valley in the west to the Kali valley in the east and beyond in Nepal.

Foot Hill Fault/ Thrust (FHF or FHT) has also been referred to as Main Boundary Fault -3. It defines the southern limit of Himalaya with Indo-Gangetic and Brahmaputra Plains as well as tectonic boundary between Varanasi Alluvium of plains with the Siwalik Group. It is also a north dipping steep fault and has been traced from one end of Himalaya to the other except the places where it has been concealed by Newer Alluvium.

Cross Faults: In addition to above faults/ thrusts that follow the Himalayan trends, a number of cross faults have been mapped within the MBH that off-set the major structural elements. These faults in general trend either N-S or NNE-SSW. Of these, a major N-S trending Matoli Fault near Niti Pass is significant. In the north, it continues into Tibet and in the south it has been mapped near Barmatiya in the Girthi valley. Further south, It is traceable in Rishiganga valley and beyond in Central Crystalline Group.

Many cross faults that have caused considerable amount of horizontal shift and have been interpreted as dextral or sinistral wrench faults have been mapped in FFB. Some of the significant cross faults mapped in FFB Juma (presently Yamuna) Fault, Ganges Fault and Bhimgoda fault.

Folds: According to Kumar (2005), the folds developed during different orogenic movements in different parts of Uttrakhand Himalaya are of six geometries. According to Kumar (2005), in case of MHB, although adequate data is not available from Central Crystalline, these appear to be poly-phase deformed and metamorphosed. Folds F_1, F_2 and F_3 are restricted to Central Crystalline, Garhwal and Jaunsar/ Vaikrita Groups and are not observed in overlying younger successions. In case of Frontal Fold Belt (FFB), the structure is generally simple as compared to MHB and has been subjected to the last phase of tectonic deformation related to Himalayan Orogeny (HOM-4). Three major zones of deformation recognized in this include zone of open folding, fault zone displaying a number of reverse faults that dip steeply towards north and zone of closely spaced strike faults and severely compressed folds terminating at Main Boundary Fault (MBF). The rocks in FFB are folded in a series of broad anticlines and synclines and are referred to as F_6 related to last phase of Himalayan Orogenic Movement (HOM-4).

4 SEISMOTECTONIC AND SEISMICITY

The Indian Standard (ISI) has recognized five seismic zones based on the intensity of earthquakes, viz., (i) Zone 1 of intensity V or below, (ii) Zone 2 of intensity VI, (iii) Zone 3 of intensity VII, (iv) Zone 4 of intensity VIII and (v) Zone 5 of intensity IX and above. The zones of intensity in Uttar Pradesh and Uttarakhand are shown in **Figure-5.**

Based on the tectonic set up, seismic patterns, contemporary style and with the manifestation of neotectonic activities, direction if shortening in Quartarnery sediments and source mechanism of discrete seismic events, the Northwest Himalaya has been divided into five longitudinal seismic zones **(Figure-6),** viz., (i) Foothill Seismic Zone, (ii) Main Himalayan Seismic Zone, (iii) High Himalayan Seismic Zone, (iv) High Plateau Seismic Zone and (v) Kashmir Syntaxial Seismic Zone. Of these, the first three have well defined transverse boundaries marked by interpretative fundamental faults (Narula et al., 2000). These transverse features play a significant role in generation and modification of source parameters.

The Himalays, being a product of collision of the Indian and the Eurasian Plates, is one of the most seismically active regions of the world where numerous large magnitude earthquakes occurred in the past/ The Garhwal Himalaya has well known seismic history and had received large magnitude earthquake (greater than 5 on Richter scale) between the Long 78^0 – 81^0 and Lat. 29.5^0 – 31^0. The majority of the events has been interpreted to be the thrust type of deformation and is clustered around the surface trace of the Main Crystalline Thrust. The Garhwal group of rock have been brought in juxtaposition with the Dudatoli Group of rocks along a major tectonic surface, the Srinagar thrust (North Almora Thrust of Aggarwal and Kumar 1973) which is a steep angle fault (Dip: 45^0 – 80^0) dipping in the northeast in Bhilangana valley and in the southwest direction.

The tectonic flux map prepared by Narula, 1991 indicates that there are three prominent tectonic flux faults one west of Uttarkashi, one along the Alakananda Valley and the third one in the vicinity of the Indo Nepal boarder in Garhwal Kumaon Himalaya. These NE and NNE trending faults are interpreted as the fundamental fractures. Narula, 1991 further contended that the Main Seismotectonic Belt displaying the thrust type of deformation could be divided into sub-domains because of the presence of transverse features across which contrasting geophysical attributes are interpreted to have brought crustal block of different properties in juxtaposition. It is also argued that the strain build-up at different locales depends on the surface trace of the tectonic features. In Garhwaland Kumaon area the strain build-up is taking place in the vicinity of the MCT. Seeber *et. Al.*(1981) and Ni and Barazangi (1984) suggested that the MCT, MBT and other thrusts further south area all imbrications along a decollement and merge in depth with a low angle northly dipping detachment surface. So any of these surfaces could be the domain of strain build-up or stress relief.

It is understood that the MCt is dipping towards the northly direction. Narula (1991) and Khatri *et. Al.* (1989) mentioned that the epicenters of the past earthquake events are clustered around the

MCT in Garhwal and Kumaon Himalaya. As well the microseismic events studied by Department of Earthquake Engineering during June 1974 to May 2977 and later by Khatri *et.al.* (1989) lie predominantly south of the surface trace of MCT. So, it can be possibly assumed that the basement thrust front is located south of the surface trace of the MCT in the Garhwal block.

Seismically, the project area traverses through highly active Himalayan seismic belt and falls in Zone-IV but very close to Zone-V of seismic zoning map of India [IS: 1893 (Part-1) – 2002]. The sesmic history of the area reveals occurrence of many major earthquakes of high intensities on Richter scale. One of the most devastating earthquake occurred in 1803 (Geol. Surv. Ind. Spl. Pub. No. 30, 1992). An earthquake of magnitude 6.6 in Richter scale occurred in October 1991 in Uttakashi affected a vast area of the district **(Figure-7).** It had some affets in Jhala – Harsil area in the form of developing cracks in the wall and a few wall collapses of Katcha houses at Sukhi village. The officials information indicates that 723 persons perished, and thousands were injures by this earthquake (Geol. Surv. Ind. Spl. Pub. No. 30, 1992). It is reported that the source mechanism of this shock has both thrust and strike slip components and this is located south of the surface of the northerly dipping MCT, a major tectonic thrust. The most recent earthquake occurred in December 2005 which had its epicenter at Uttarkashi and was of magnitude 4.6 on Richer scale, but it had no impact on the site. The list of major earthquakes in Kumaon Himalaya is given in **Table-1.**

The geoseismological studied and isoseismal patterns of the Himalayan earthquakes indicate seismic sources in the tectonic features paralleling the Himalayan ternd with occasional modifications by transverse features. The earthquakes in Gangetic plains and Shield region are caused by the release of part of the strains away from the plate boundaries through intricate fabric of faults, many of which extend into the Himalaya (Geol. Surv. Ind. Misc. Pub. No.30 XIII).

Table-1: Chronological list of earthquakes of magnitude 5 and above, Kumaon Himalaya, Uttarakhand (Source: Narula et. Al. 2000; Khatri, 2000, ASC-India, 2006)

Ref. No.	Year	Month	Date	Hr.	Min.	Sec.	Lat. (°N)	Long. (°E)	Mm_b/M_3	Depth	Source
1	1803	09	01	-	-	-	30.30	78.80	8.0	-	-
2	1816	05	26	22			30.90	79.00	6.5	-	IMD
3	1842	03	05	21	10		30.70	78.00	5.5	-	IMD
4	1902	06	16	-	-	-	31.00	79.00	6.0	-	IMD
5	1906	06	13	-	-	-	31.00	79.00	6.0	-	IMD
6	1911	10	14	23	24	00.0	31.00	80.50	6.7	-	GR
7	1916	08	28	-	-	-	30.008	81.00	7.7	-	-
8	1926	07	27	-	-	-	30.50	50.05	6.0		IMD
9	1927	10	08	07	23	36.0	30.50	80.50	6.0	-	IMD
10	1935	03	05	10	34	28.0	29.75	80.25	5.8	-	GR
11	1945	06	04	22	12	53.0	30.30	80.00	6.5	60	IMD
12	1947	08	19	12	08	55.0	31.20	79.09	5.9	-	IMD
13	1949	02	05	20	07	06	31.20	79.05	5.5	-	IMD
14	1958	12	28	08	55	20.0	29.50	80.00	6.0	-	CGS
15	1958	12	31	-	-	-	30.10	80.70	6.0	-	-
16	1961	12	24	05	34	36.0	29.43	80.83	5.6	59	ISS
17	1962	07	13	07	13	30.0	30.50	79.60	5.5	25	IMD
18	1962	07	14	05	01	08.6	30.40	79.50	5.5	40	IMD
19	1963	01	30	15	58	53.7	29.50	80.90	5.5	-	IMD
20	1964	09	26	10	33	50.0	29.56	80.46	5.8	50	ISC
21	1966	03	06	00	46	02.6	31.50	80.50	6.0	50	ISC
22	1966	06	27	02	15	57.2	29.62	80.83	6.0	06	ISC
23	1966	06	27	10	41	08.1	29.71	80.89	6.0	36	ISC
24	1966	12	16	10	59	18.1	29.62	80.79	5.7	19	ISC
25	1979	05	20	20	52	16.3	29.93	80.27	5.7	16	ISC
26	1991	10	19	22	59	11.6	30.77	78.79	6.4	15	ISC
27	1997	01	05	21	23	15.0	29.80	80.50	5.5	16	IMD/ISC
28	1999	03	28	19	05	13	30.41	79.41	6.4	21	ASC
29	2003	05	27	04	23	28	30.55	79.33	5.0	28.9	ASC
30	2005	12	14	07	09	54	30.42	79.24	5.0	51	ASC

Although seismicity will have little or no Impact on underground structures and surface structure would be designed using site specific seismic parameters.

It is zone IV and seismic coefficient as 0.24 and 0.16 has been taken as horizontal and vertical seismic coefficient .

Figure-5: Seismic map of Uttarpradesh and Uttarakhand (after Anon, 1983)

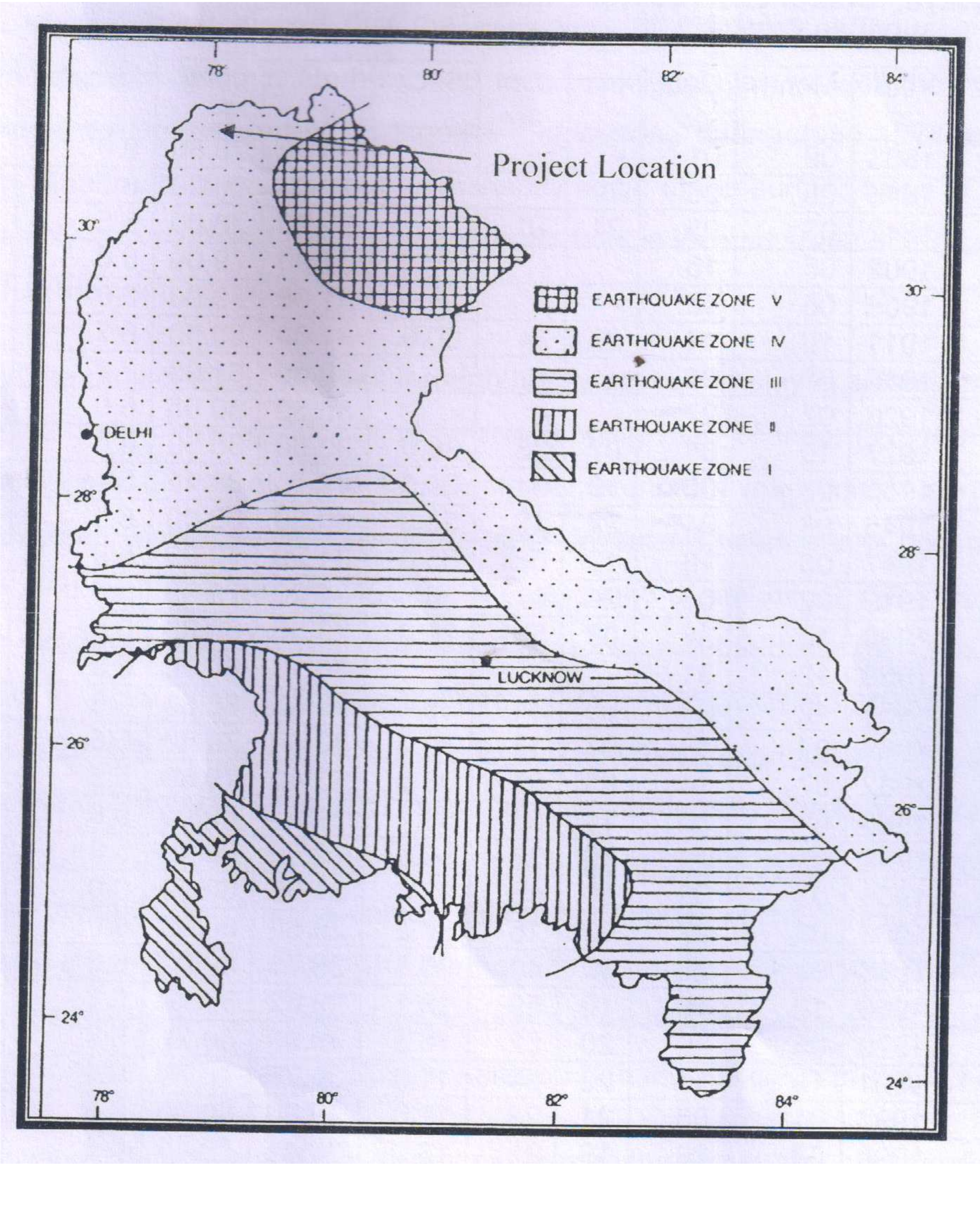
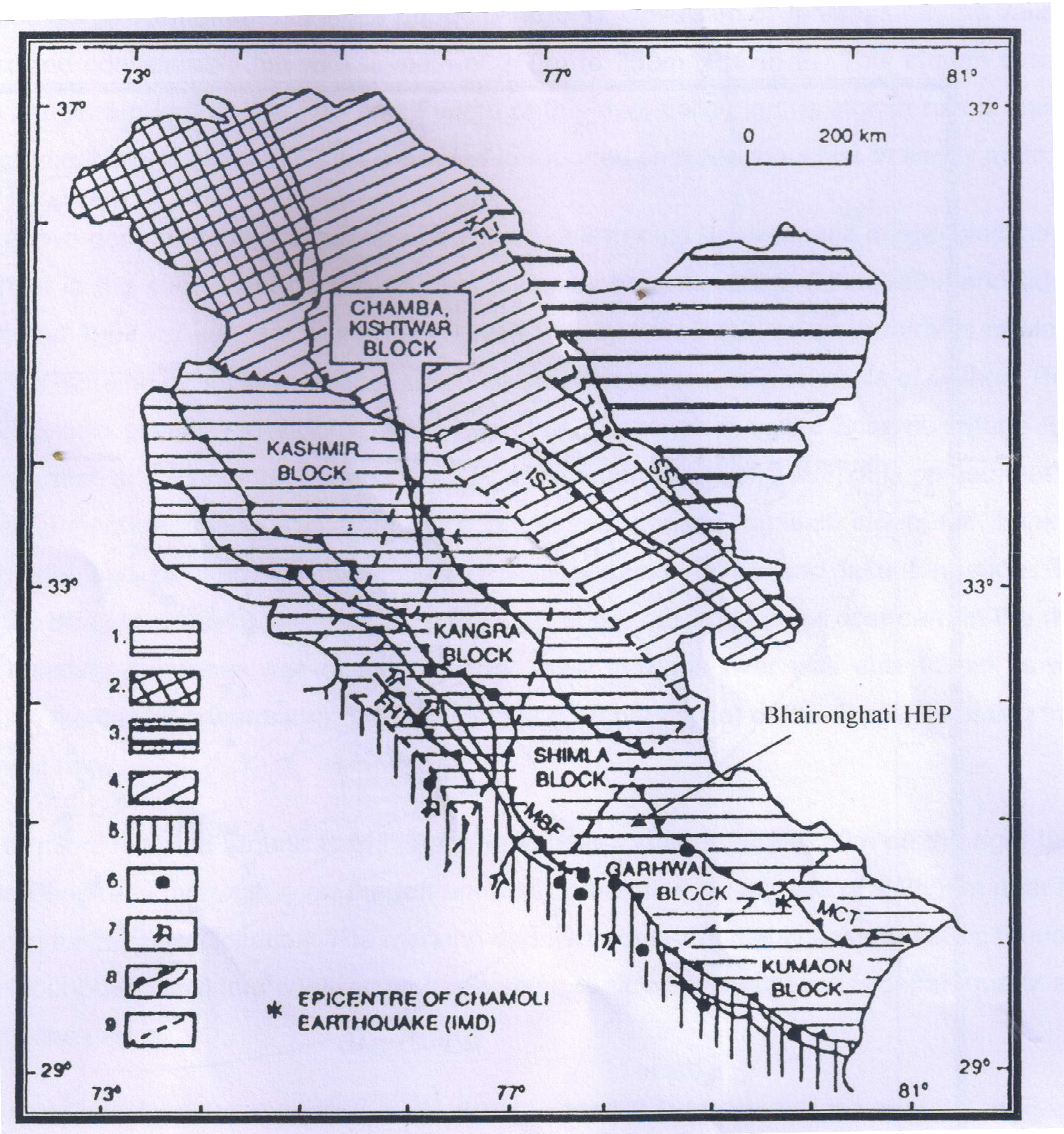
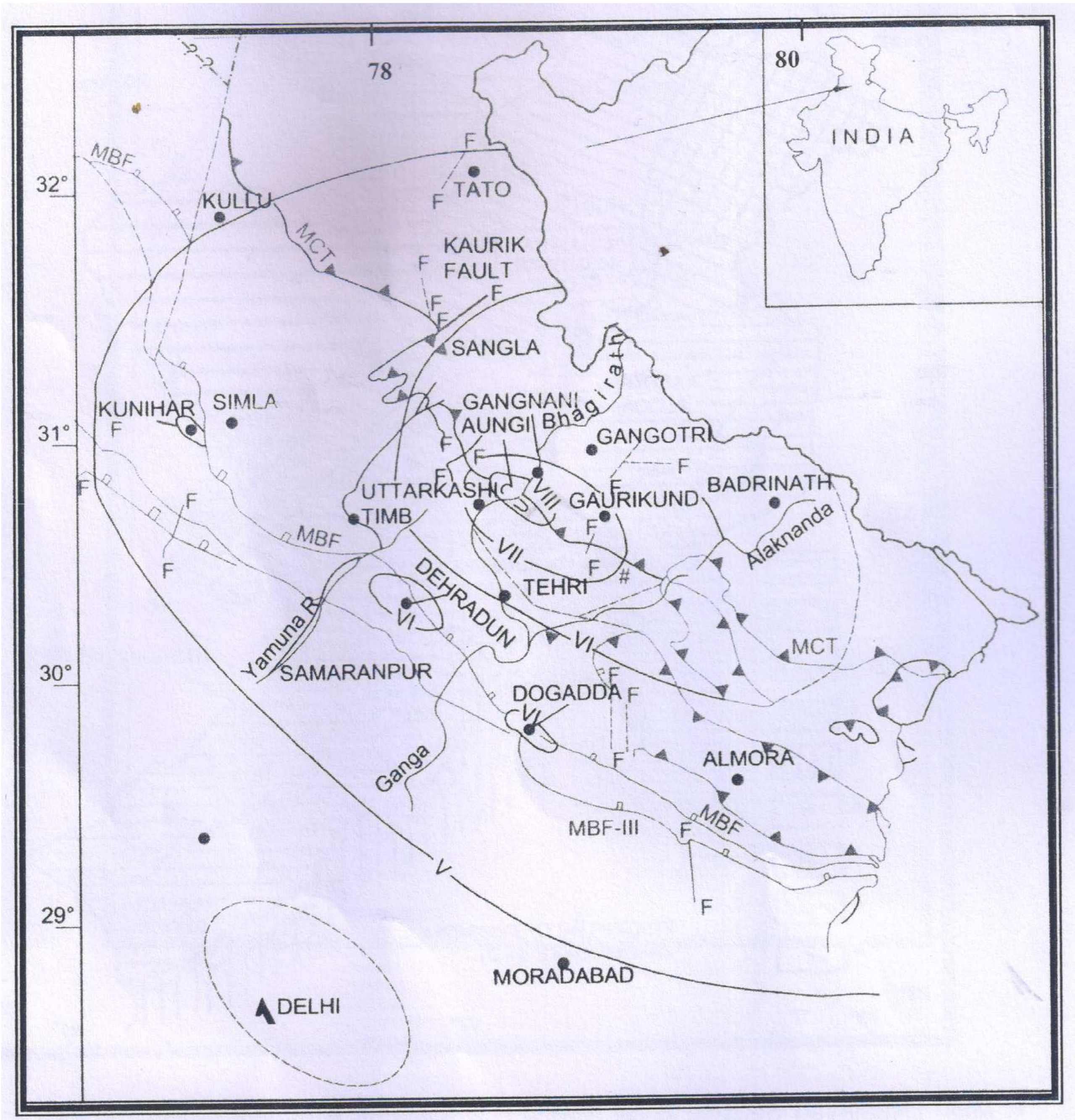


Figure-6: Seismotectonic domain of NW Himalayan seismic belt



1. Main Himalayan Seismic Zone (MHSZ); **2**. Kashmir syntaxial Seismic Zone (KSSZ); **3**. High plateau Seismic Zone (HPSZ); **4**. High Himalaya Seismic Zone (HHSZ); **5**. Foot Hill Seismic Zone (FHSZ); **6**. Specific locations where neotectonic activity has been recorded; **7**. Direction of crustal shortening during Quarternary**;** **8**. Suture Zone; **9**. Block Boundary based on geological/geophysical/tectonic flux attributes. **SSZ**-Shyok Suture Zone; **ISZ**-Indus Suture Zone Fault; **KF**-Karakoram Fault; **MCT**-Main Central Thrust; **MBT**-Main Boundary Fault; **FHT**-Foot Hill Thrust (after Narula et. Al.)

Figure-7: Isoseismal Map of Uttarkashi earthquake of October 1991 (after Narula, 1995)



5 GEOLOGY OF THE PROJECT AREA

The geology of project area is represented by both metasedimentary rocks of Lesser Himalaya and the crystallines metamorphics of Higher Himalaya. The metamorphics/ Higher Himalayan Crystallines (HCC) thrust over the Lesser Himalayan rocks along a major tectonic plane known as the Main Central Thrust (MCT). MCT forms a thick shear zone bounded between MCT Roof

Thrust (corresponding to Vaikrita Thrust) on the north and MCT Sole/ Floor Thrust (corresponding to Chail/ Munsiari Thrust) in the south and therefore the bedrock sequence found within the zone has been classified under Munsiari Formation. The rocks of window zone are grouped under Garhwal Group represented by low-grade quartzitic sandstone, dolomitic limestone and slates with metabasic sills and dykes. Table 1 summarises the lithological and tectonic setting of the project.

Table-2: Tectono-stratigraphic sequence

Higher/ Central Himalaya	**Higher Himalayan Crystallines**	**Vaikrita Group**	Kyanite-sillimanite gneiss, quartz-granulites, banded granitic gneisses and migmatites, garnetiferous-biotite-schist, calc silicate gneisses and amphibolites
		MCT Roof Thrust/ Vaikrita Thrust	
		Munsiari Formation	Sequence of Quartz mylonites, garnetiferous quartz-mica-schist, calc-silicate schists and gneisses, granitic gneisses and migmatites with metabasics/amphibolite gneisses. The above sequence gets repeated three to four times with quartz mylonites at the base.
		MCT Floor Thrust	
Lesser Himalaya	***Window zone (Garhwal Group)***	**Kuthnor Formation**	Alternating thick succession of mildly metamorphosed sandstones/ quartzite, variegated shales/ slates and dolomitic limestone with contemporaneous lava flows (in the form of altered basic volcanics/ amphibolites in the form of both sills and dykes)
	Garhwal Thrust		
	Dudatoli-Almora Nappe	**Damta Group**	Huge successions of fine grained sandstone-siltstone-slates-shales (which sometimes appear to be phyllitic) constitute the typical bedrocks, profusely intruded by amphibolite/ epidiorite dykes

Higher Himalayan Crystallines: Within the MCT zone (thereby considered to be Outer Crystallines) a thick sequence of Quartz mylonites, low grade metamorphics such as garnetiferous quartz-mica-schist, calc-silicate schists and gneisses, and medium to high grade metamorphics as granitic gneisses and migmatites with altered metabasics/amphibolite gneisses. The above sequence gets repeated three to four times with quartz mylonites at the base.

Damta Group: Huge successions of fine grained sandstone-siltstone-slates-shales (which sometimes appear to be phyllitic) constitute the typical bedrocks. This, largely a turbidite sequence, has been referred in published literature as Simla slates, Chakrata Formation, Chandpur Formation etc. The sequence is profusely intruded by amphibolite/ epidiorite dykes and thicks sills almost form more than 40% part of the Group. The sequence along the highway transect is prepared as shown below.

Kuthnor Formation: The rocks exposed within the tectonic window, limited on the north by MCT and south by Garhwal Thrust, are classified under Garhwal Group represented by low-grade quartzitic sandstone/ quartzite, dolomitic limestone and variegated shales/ slates. This sedimentary sequence has penecontemporaneous lava flows in the form of sills and dykes.

6 Field Investigations

The field investigation carried out at different sites of different appurtenants of about 4.50km long highway tunnel {between CH-25.400 (Silkyara bend) and CH-51.000 (Pall Gaon-Barkot) in Dharasu - Barkot Section}. This include detailed surface geological mapping on 1:1000 scale and subsurface investigation including exploratory drilling **(Plate-1)** at different project locations.

6.1 Surface Explorations – Geological Mapping

The project area has a very rugged topography characterized by sharp crested ridges and narrow valleys. The altitude varies between 1300m to about 2200m and most of the area is covered by vegetation. The detailed geological mapping of the highway tunnel was carried out on 1:1000 scale. However, the drawings have been reproduced on 1:5000.

The detailed geological mapping along the tunnel (Scale 1:1000) has been carried out including both portals (Scale 1:100) and data presented on the topographical map. Attempts were made to pick up all the accessible bedrock outcrops and their details during the course of detailed surface geological mapping. Detailed geological map of the area is appended as **Plate-1**.

The length of tunnel is about 4.5m (portal to portal). The Silkyara bend portal of the tunnel is located just downstream of Silkyara village **(Plate-1)**. In-situ exposed bedrock **(Photo-1)** is observed during the detailed surface geological mapping in and around the tunnel portal (Silkyara bend). The slope on this portal is, in general, steep in initial reach after that the slope is gentle and slightly to moderately strong, slightly to moderately weathered, slate with occasionally thin bands of siltstone rock exposures are seen around the portal upto an elevation of EL 2200.m and above this superficial overburden is observed. The tunnel is initially aligned for a length of about 1980m in the direction of 150^0 - 330^0 (Sector 1) to obtain adequate rock cover over the tunnel. Finally the tunnel is aligned 145^0 - 335^0 direction for the rest of their length (Sector 2) till their exit portal located before Barkot Bend. The area of the Barkot end portal, exposed in-situ bedrock is observed during detail surface geological mapping. From EL 1500m, superficial overburden is also observed.

One intermediate bend have been provided in the tunnel alignment with a view to optimize their length and ensure adequate cover all through their length. Thus, the tunnels have been sub-divided into two sectors based on their orientation.

<u>Analysis of Discontinuity Data</u>

The discontinuity data collected during the course of detailed geological mapping from rock outcrops on both the portals and along the road between both portals has been analyzed with the help of "DIPS" software. The stereographic projection and major plane projections of surface rock data have been prepared and given in **Figures-8 and 9.**

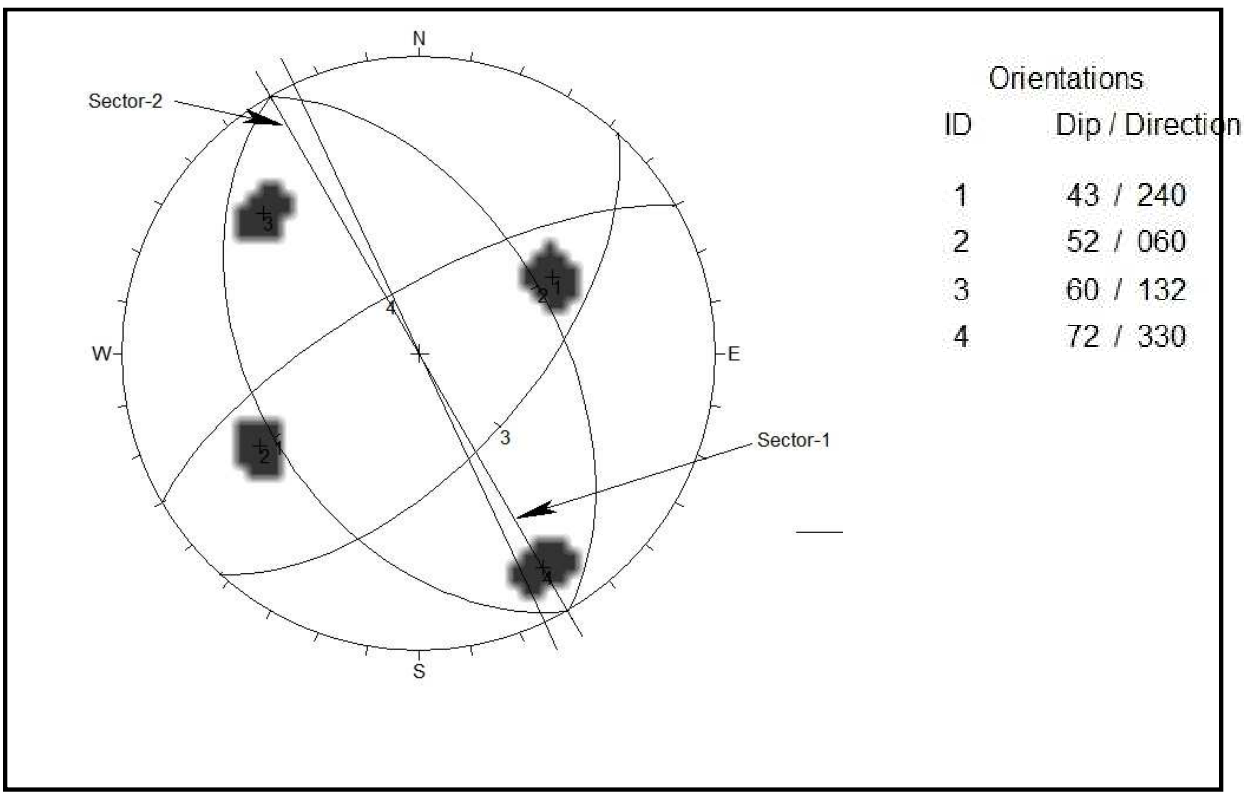


Figure-8: Stereographic plot of major planes of discontinuities of Slate/siltstone rock along tunnel

The analysis of data on discontinuities traversing the rock mass collected during the course of detailed geological mapping (**Figures 4 & 5)** at the dam site and is summarized in **Table-3, 4, 5 and 6.**

Table-3: Range of Discontinuity Data in Slate and siltstone

Set	Strike		Dip Direction		Dip Amount	
	Range	Average	Range	Average	Range	Average
J1*	140° - 160°	150°	230° - 250°	240°	20° - 65°	43°
J2	130° - 170°	150°	040° - 80°	060°	40° - 65°	52°
J3	025° - 060°	042°	115° - 150°	132°	40° - 80°	60°
J4	230° - 250°	240°	320° - 340°	330°	60° - 85°	72°

J1* *oriented along foliation*

Table-4: Details of Discontinuities in Slate and siltstone

Set	Strike	Dip Amount	Dip Direction	Continuity (m)	Spacing (cm)	Aperture (mm)	Roughness	Alteration	Filling
J1*	150^{0}- 330^{0}	43^{0}	240^{0}	>10	5 to widely spaced	Tight-5	RP*	Nil	NIL
J2	330^{0}- 150^{0}	52^{0}	060^{0}	05-10	10-100	Tight to 1.0	RU*/RP*	NIL	NIL
J3	042^{0-} 222^{0}	60^{0}	132^{0}	05-10	100 to 200	Tight to 0.5	RU*/ RP*	NIL	NIL
J4	060^{0-} 240^{0}	72^{0}	330^{0}	02-05	Widely spaced	Tight	RU*/SP*	NIL	NIL

J1* *oriented along beddind* ***RU*** *Rough Undulatory,* ***RP*** *Rough Planar,* ***SP*** *Smooth Planar*

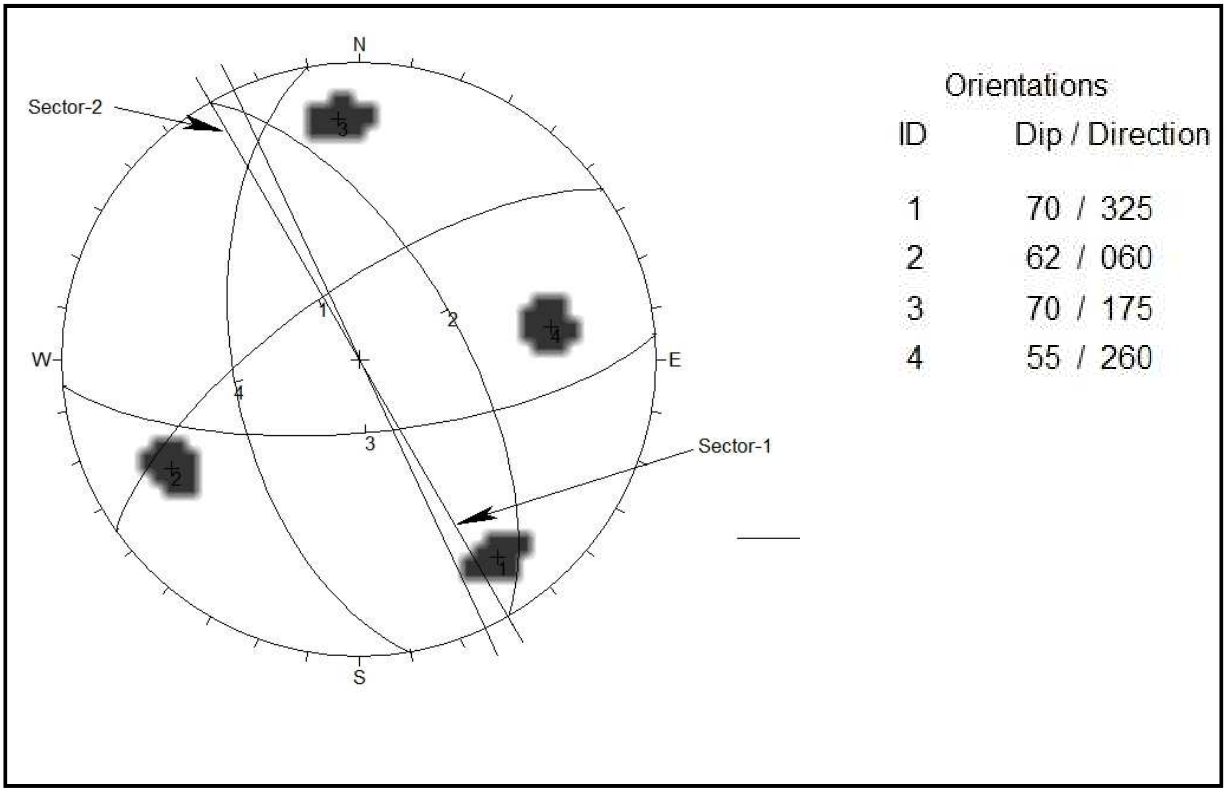


Figure-9: Stereographic plot of major planes of discontinuities Amphibolite rock along tunnel

Table-5: Range of Discontinuity Data in Amphibolite

Set	Strike		Dip Direction		Dip Amount	
	Range	Average	Range	Average	Range	Average
J1	120° - 170°	145°	300° - 350°	325°	60° - 80°	70°
J2	220° - 260°	240°	040° - 80°	060°	50° - 75°	62°
J3	085°	085°	175°	175°	70°	70°
J4	170°	170°	260°	260°	55°	55°

Table-6: Details of Discontinuities in Amphibolite

Set	Strike	Dip Amount	Dip Direction	Continuity (m)	Spacing (cm)	Aperture (mm)	Roughness	Alteration	Filling
J1	145^0-325^0	70^0	325^0	04-10	Widely spaced	Tight-5	RU*	Nil	NIL
J2	330^0-150^0	52^0	060^0	02-05	Widely spaced	Tight	RU*/RP*	NIL	NIL
J3	042^{0-} 222^0	60^0	132^0	05-10	Widely spaced	Tight to 0.5	RU*/ RP*	NIL	NIL
J4	060^{0-} 240^0	72^0	330^0	02-05	Widely spaced	Tight	RU*	NIL	NIL

RU *Rough Undulatory,* ***RP*** *Rough Planar*

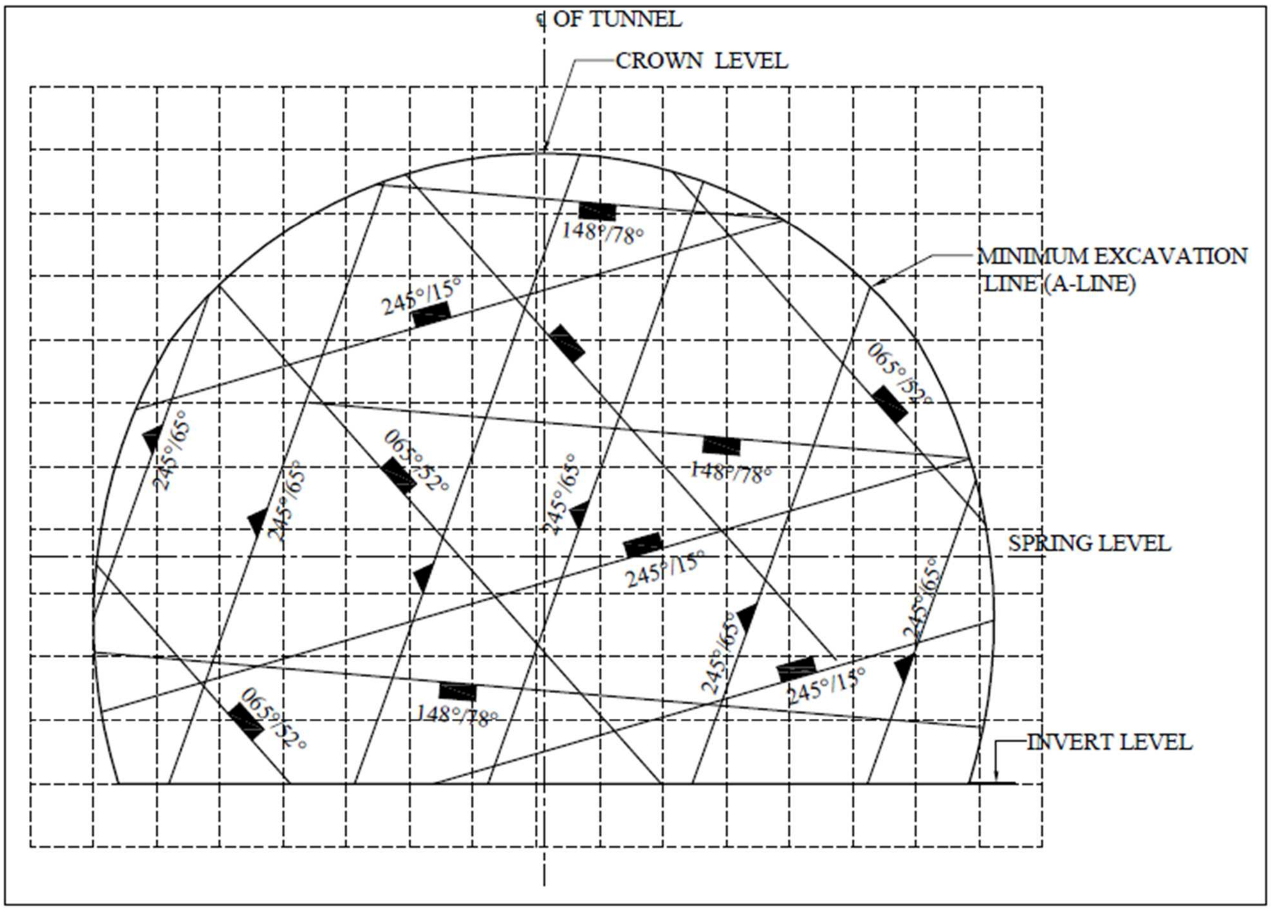
Detailed geological mapping carried out along the tunnel and portals **(Plate-2)** indicates that the bedrock on the portals and along the tunnel are traversed by four sets of discontinuities of which those aligned parallel to foliation are most prominent. The foliation of Slate, siltstone & shale, in general, on an average strikes in 150^{0} – 330^{0} direction and dips by 43^{0} towards 240^{0}. The bedrock is traversed by three sets of joints in addition to foliation joint. The joints dip 72^{0} towards 060^{0}, 60^{0} towards 132^{0} and 72^{0} towards 330^{0} respectively.

Geotechnical Assessment of Tunnel

Geological section along the proposed alignment of tunnel **(Plate-2)** indicates that rock cover over the overt of this 13.7 diameter tunnel varies between 30m and 585m, in general, which can be considered adequate. The tunnel at its initial reach i.e. Sector-1 from portal to 1980.06m is aligned in 150^{0} – 330^{0}. It is observed that the tunnel in this sector, Slate (occasionally siltstone & shale) is aligned askew to the strike of foliation joints (S1) by 0^{0}, with strike of joints belonging to set S2 by 0^{0}, S3 by 72^{0} and by 90^{0} with the strike of joints belonging to set S4. Amphibolite bedrock in this sector is aligned askew to the strike of joint belonging to S1 set by 05^{0}, S2 by 90^{0}, S3 by 65^{0} and by 20^{0} with the strike of joint belonging to set S4. In last i.e. Sector-2 from 1980.06m to end of the tunnel is aligned in 145^{0} – 335^{0}. It is observed that the tunnel in this sector, Slate (occasionally siltstone & shale) is aligned askew to the strike of foliation joints (S1) by 5^{0}, with strike of joints belonging to set S2 by 5^{0}, S3 by 77^{0} and by 85^{0} with the strike of joints belonging to set S4. Amphibolite bedrock in this sector is aligned askew to the strike of joint belonging to S1 set by 0^{0}, S2 by 85^{0}, S3 by 60^{0} and by 25^{0} with the strike of joint belonging to set S4. It is seen that all sector the alignment is very favourable with respect to S3 and S4 but is very unfavourable with respect to joints belonging to set S1 and S2. So the possibility of forming wedges in the crown and side wall cannot be ruled out in those sectors and has to be taken care of during construction planning. From the surface geology it may be anticipated that the rock type to be encountered along the diversion tunnels would be 20% good (Class II), 50% fair (Class III), 15% poor (Class IV), and 15% very poor (Class V) quality.

Face logging and Kinematic analysis of Portals:

Face logging of Portal near Silkyara bend

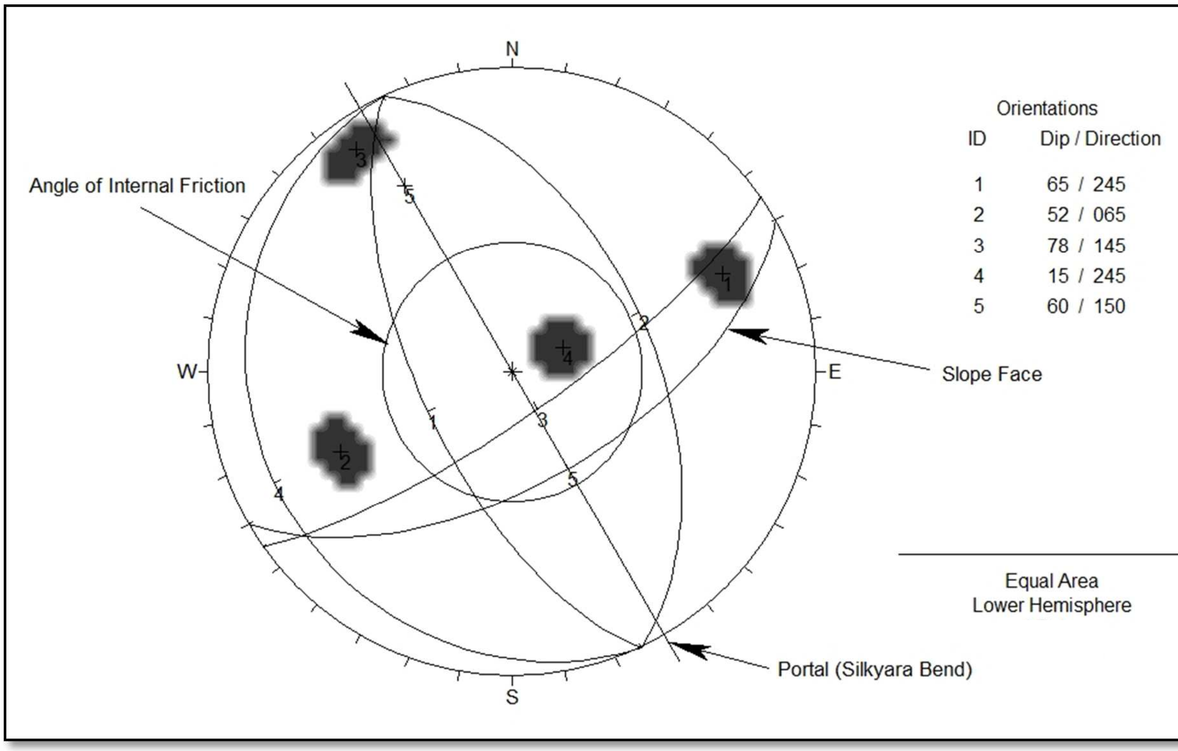


PORTAL (SILKYARA BEND) (SCALE 1:100)

Around Portal near Silkyara bend, slate with intrusion of Quartz vein is observed. Occasionally, bands of siltstone are also observed during surface geological mapping. Rocks around this portal are moderately strong to strong, fresh, surface staining along joints, dry etc are observed. On the basis of different geotechnical parameters, rock around portal comes in rock class III. The RMR value is 45.

Kinematic analyses of Portal near Silkyara bend

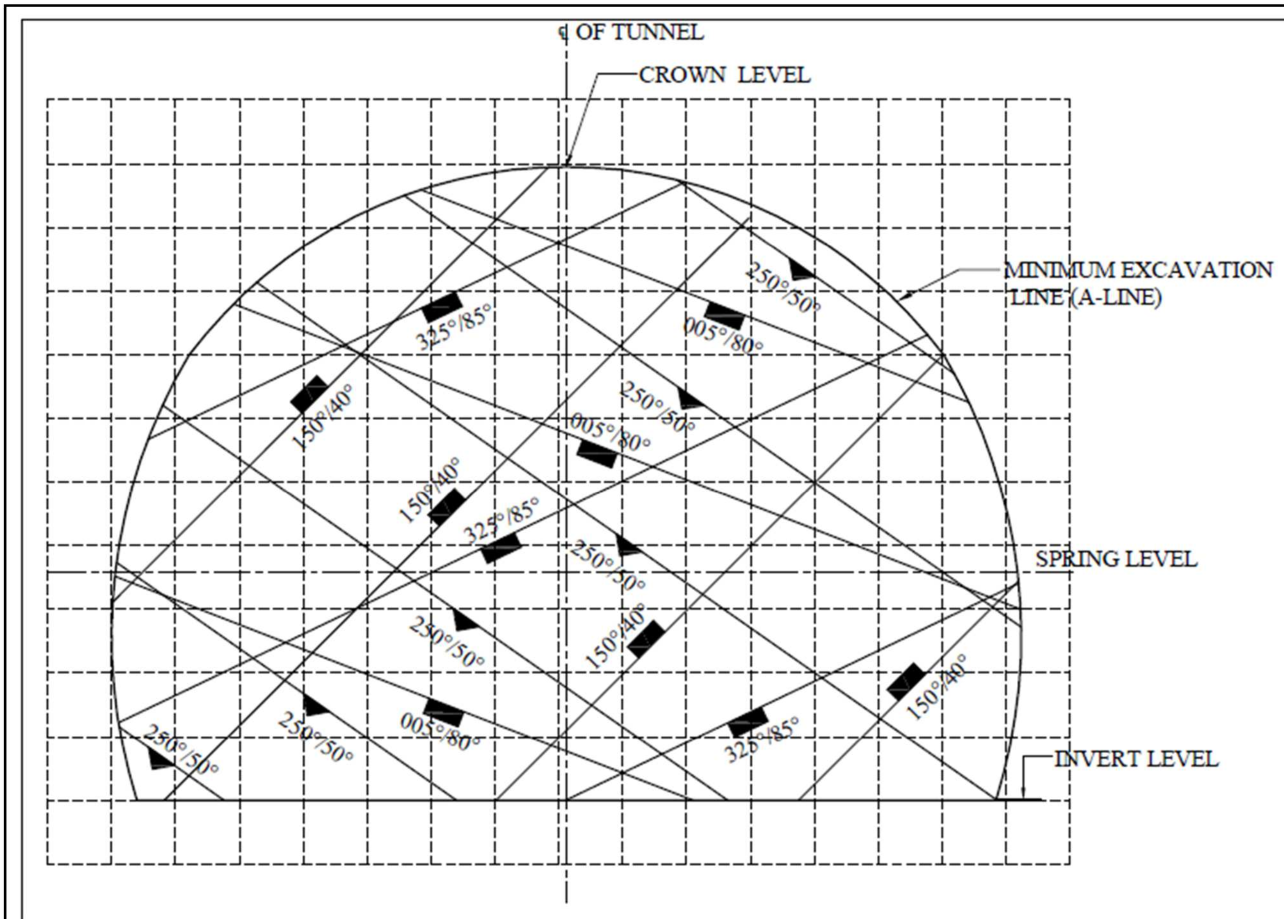
Tunnel is oriented in the direction of 150^0 – 330^0 with its portal facing towards 150^0. The co-efficient of internal friction for the rock mass has been considered as 35^0.



In case of portal the wedges formed by intersection of joints 1 and 3 will possibly slide along the line of intersection of these joints towards SW sector.

There is a chance of slip circle failure along slope face. Based on these analyses, support has to be evolved.

Face logging of Portal near Barkot bend

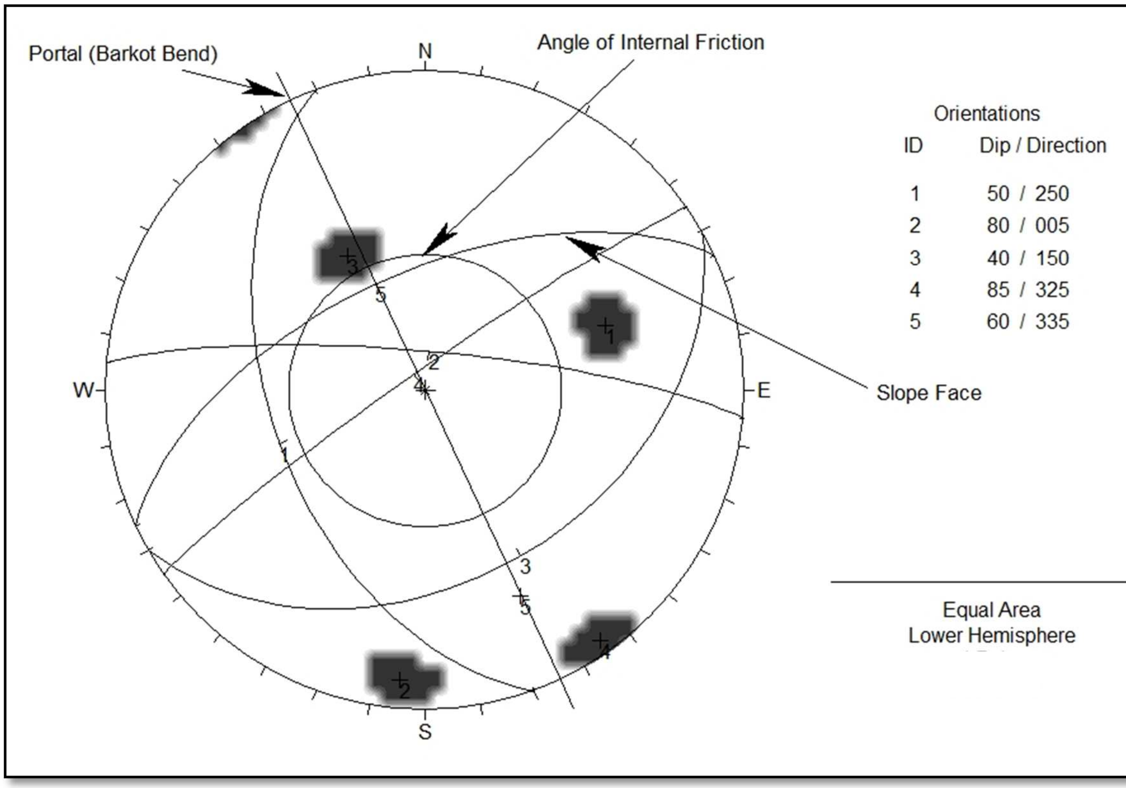


PORTAL (BARKOT) (SCALE 1:100)

Around Portal near Barkot bend, thinly foliated slate with intrusion of Quartz vein is observed. Occasionally, bands of siltstone are also observed during surface geological mapping. Rocks around this portal are weak to moderately strong, slightly weathered to moderately weathered etc are observed. On the basis of different geotechnical parameters, rock around portal comes in rock class IV. The RMR value is 24.

Kinematic analyses of Portal near Barkot bend

Tunnel is oriented in the direction of 155^0 – 335^0 with its portal facing towards 335^0. The co-efficient of internal friction for the rock mass has been considered as 35^0.



In case of portal there is a chance of slip circle failure along slope face. Based on these analyses, support has to be evolved.

Considering the tunnel trend of $155^0 – 335^0$ with face excavation towards 155^0, the wedges formed on the NE wall side may slide along the joint planes 2 and 4. Based on these analyses, support has to be evolved.

6.2 Sub-surface Exploration – Exploratory Drilling

A total of 3 numbers of drill holes aggregating to 180.0m cumulative depth were drilled at both portals and around centre of the tunnel. Locations of these drill holes are shown in **Plate-1** and summarized in **Table-7** . Geological logs of drill holes have been given in **appendix**

Table-7: Details of Exploratory Drilling

S.No.	Drill Hole No.	Location/Feature	Co-ordinates	Collar Elevation (m)	Depth (m) Elevation (m)	Depth of Overburden Elevation(m)
1	***BH-1**	Barkot Portal	N 3405964.364 , E 238047.973	1530	50 m (El. 1550)	0.5 (El. 1539.5)
2	**BH-2**	Silkara Portal	N 3409964.479 , E 235992.281	1725	50 m(EL 1740)	0.5(1739.5)
3	**BH-3**	Radi Top	N 3407375.837 , E 237240.436	2200	50 (EL 2260)	2.5 (2257.50)

6.3 Laboratory Studies

Photographs

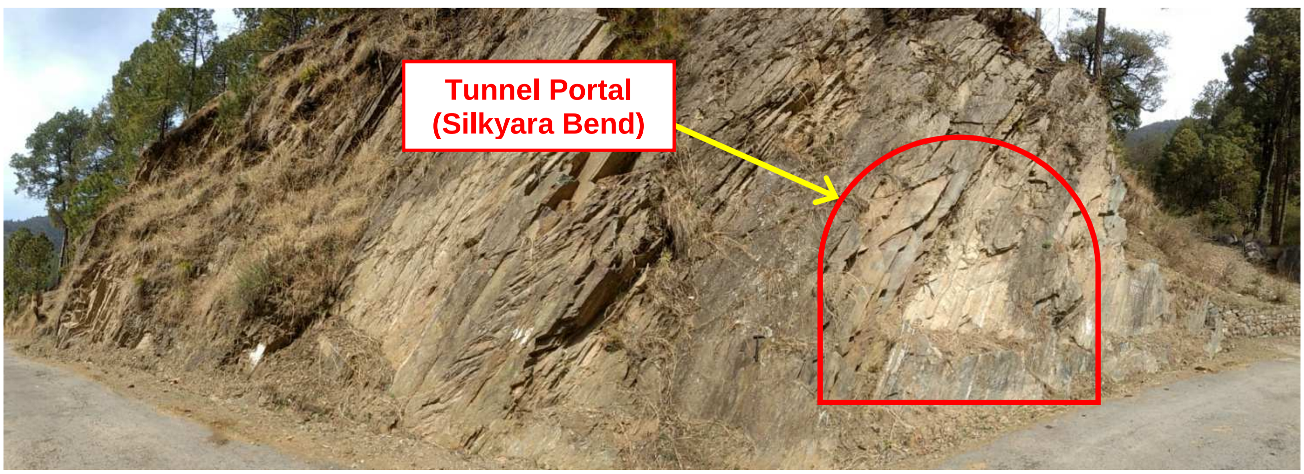


Photo-1: Outcrop at Silkyara bend Portal

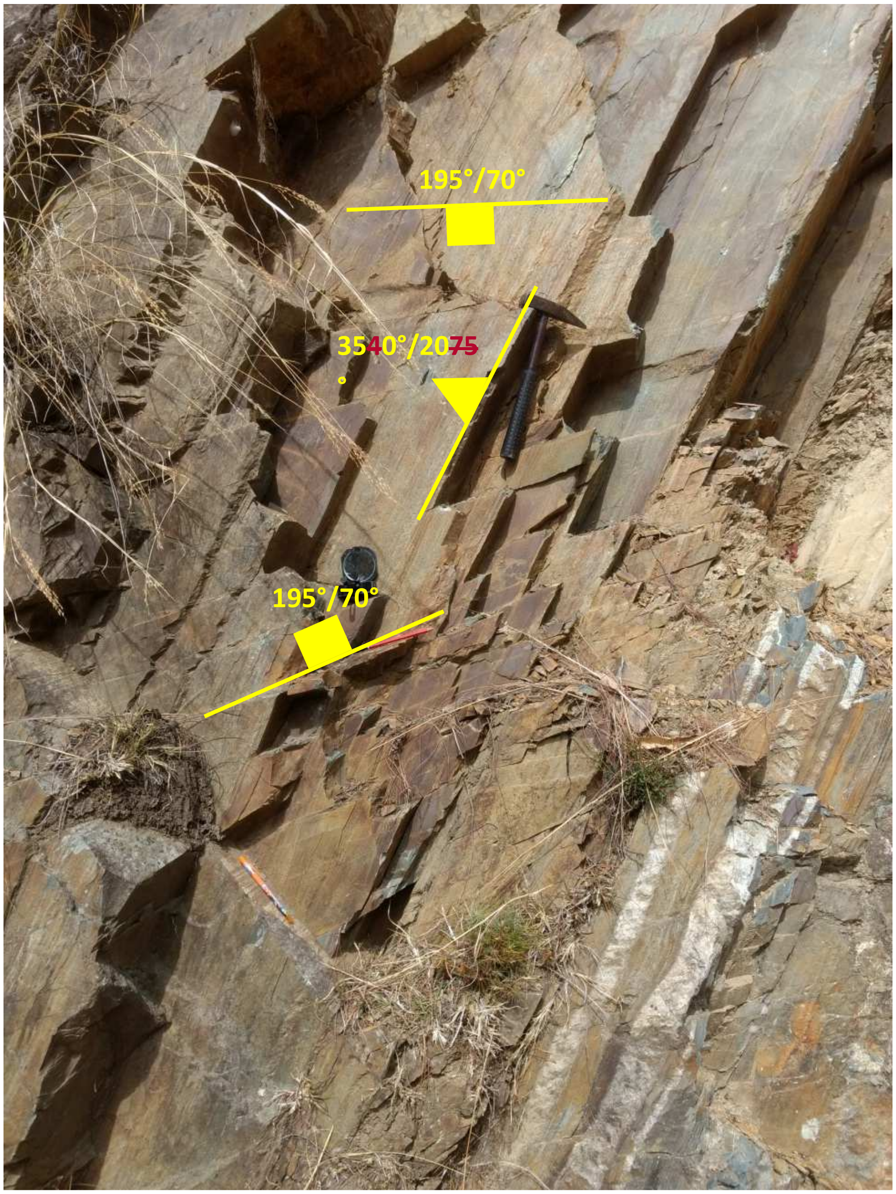
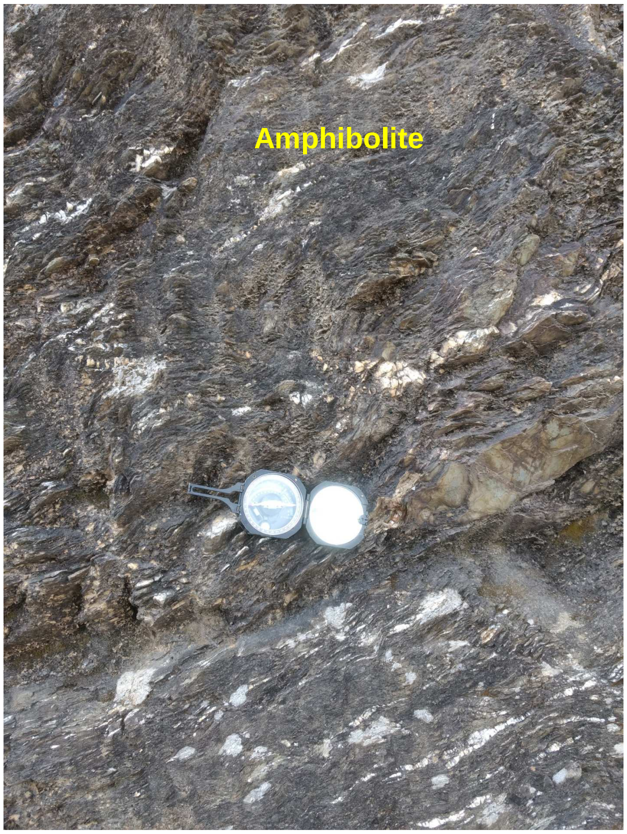


Photo-2: Outcrop at Silkyara bend portal



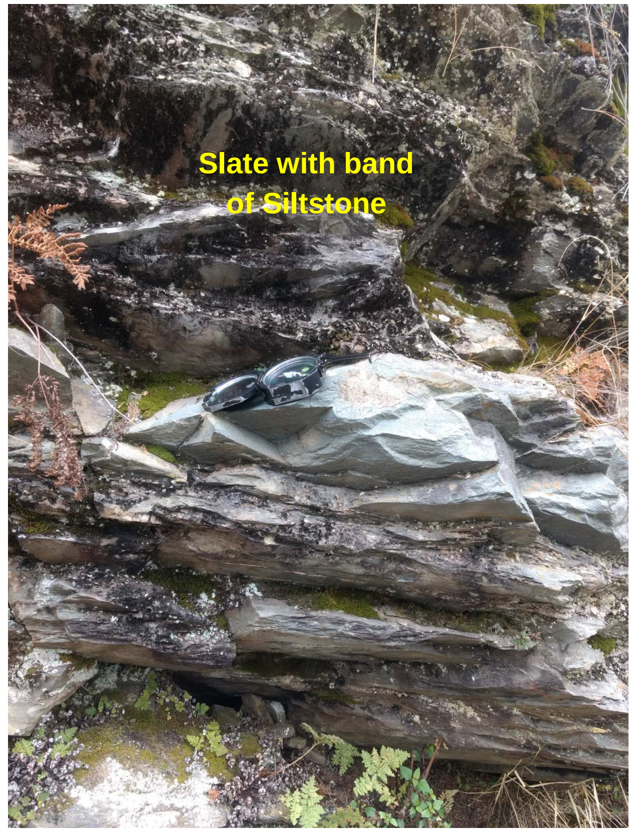


Photo-3: Thinly foliated Slate

Photo-4: Siltstone

Photo-5: Amphibolite **Photo-6: Slate with band of Siltstone**

Photo-7: Siltstone **Photo-8: Amphibolite**

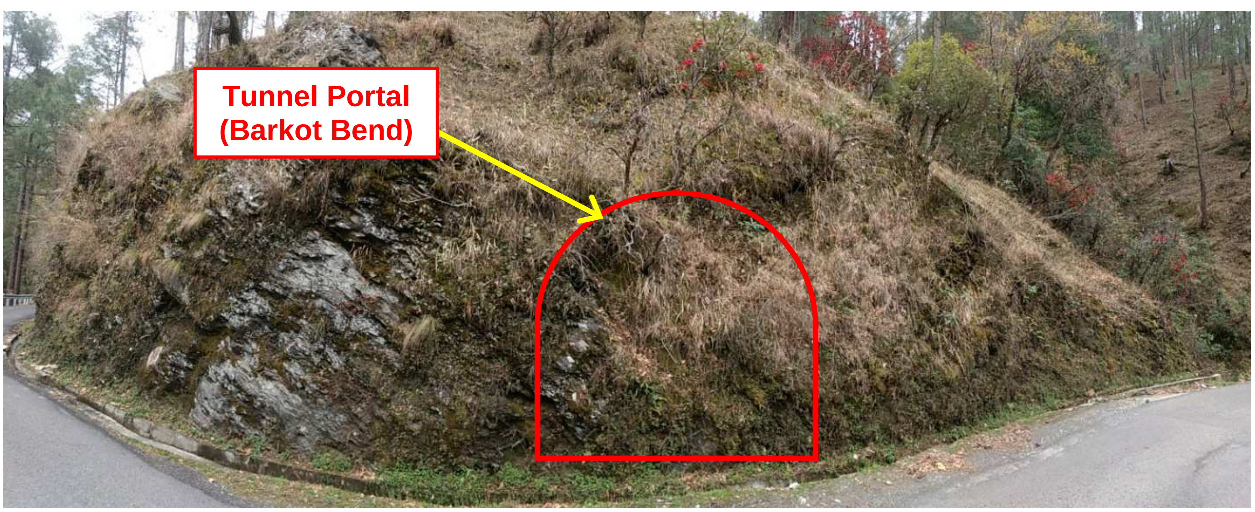


Photo-9: Thinly foliated exposed Slate around portal (Barkot bend)

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GEOLOGICAL LOG OF DRILL HOLE

Sheet 1 of 2

Project:	Rehabilitation and Up-graduation to 2 lane/ 2lane with Paved Shoulders Configuration & Strengthening of National Highways No.-94 from Km 144.00(Dharasu) to 220.00 (Yamunotri) in State of Uttarakhand (Package No. 5)	Coordinates	N 3405964.364 E 238047.973		Drill Hole No.	BH-1	
Location :	Portal (Silkyara Bend)	Angle with horizontal	Vertical		Total depth	50.0 M	
Feature	Highway Tunnel	Collar Elevation	1740m		Types of Core barrel	Tripple tube	
Started	22-Jan-2015	Ground Elevation	1739.80m		Drilling Agency	IGS	
Completed	6-Feb-2015						

Depth (m)	Elevation (m)	Lithology: Description	Log	Size of Core Pieces (mm): <10	10--25	25-75	75-150	>150	Structural Condition	Percent Core Recovery: 0-20	20-40	40-60	60-80	80-100	RQD (%)	Fracture Frequency /m	Type of Bit	Size of Hole	Casing	Depth of Water Table (m)	Drill Water Loss: Nil	Partial	Total	Permeability: Test Section	10^{-3}cm/sec or lugeon	Rate of Penetration (cm/min)	Special observation
0	1740																										
0.50	1739.50	Slopewash															Hx casing bit	Hx	Hx	Water Table Not Encountered						2	Overburden
1.50	1738.50	Slightly to moderately weathered, weak to moderately strong Slate													Nil											2	Bed rock encounter at El 1739.5m
3.00	1737.00														Nil		Nx casing bit	Nx	Nx							2.5	
4.50	1735.50	Slightly weathered, moderately strong Slate													Nil											2.1	
6.00	1734.00								F 65^0 RP JT 75^0 R						Nil		Nx Core bit		No casing							1.9	
7.50	1732.50	Fresh, moderately strong Slate							F 60^0 SP JT 50^0 RP						Nil											1.7	Surface staining along joints.
9.00	1731.00								F 65^0 SP JT 15^0 R						Nil											2.3	
10.50	1729.50	Fresh, moderately strong to srtong Slate							F 65^0 RU JT 75^0 RP JT 15^0 R						Nil		NMLC Core bit									3	
12.00	1728.00								F 65^0 RU JT 50^0 R						Nil											3.3	
13.50	1726.50	Fresh, moderately strong to srtong Slate							F 65^0 RP						Nil											3.1	
15.00	1725.00								F 65^0 RP JT 55^0 R						Nil											2.9	
16.50	1723.50	Fresh, moderately strong to srtong Slate							F 65^0 RP JT 50^0 R						Nil											2.8	
18.00	1722.00								F 60^0 RP JT 80^0 R						Nil											2.5	
19.50	1720.50	Fresh, moderately strong to srtong Slate							F 60^0 RP						Nil											2.5	
21.00	1719.00								F 60^0 RP						Nil											3	
22.50	1717.50	Fresh, moderately strong to srtong Slate							F 65^0 RP JT 50^0 R						Nil											2.8	
24.00	1716.00								F 60^0 RP JT 75^0 R						Nil											2.8	
25.50	1714.50	Fresh, moderately strong to srtong Slate							F 65^0 RP JT 70^0 R						Nil											2.7	
27.00	1713.00								F 65^0 RP JT 75^0 R JT 15^0 R						Nil											2.7	

GEOLOGICAL LOG OF DRILL HOLE

Project:	Rehabilitation and Up-graduation to 2 lane/ 2lane with Paved Shoulders Configuration & Strengthening of National Highways No.-94 from Km 144.00(Dharasu) to 220.00 (Yamunotri) in State of Uttarakhand (Package No. 5)	Coordinates	N 3405964.364 E 238047.973	Drill Hole No.	BH-1
Location :	Portal (Silkyara Bend)	Angle with horizontal	Vertical	Total depth	50.0 M
Feature	Highway Tunnel	Collar Elevation	1740m	Types of Core barrel	Tripple tube
Started	22-Jan-2015	Ground Elevation	1739.80m	Drilling Agency	IGS
Completed	6-Feb-2015				

Depth (m)	Elevation (m)	Lithology: Description	Log	Size of Core Pieces (mm): <10 / 10--25 / 25-75 / 75-150 / >150	Structural Condition	Percent Core Recovery: 0-20 / 20-40 / 40-60 / 60-80 / 80-100	RQD (%)	Fracture Frequency /m	Type of Bit	Size of Hole	Casing	Depth of Water Table (m)	Drill Water Loss: Nil / Partial / Total	Permeability: Test Section / 10^{-3}cm/sec or lugeon	Rate of Penetration (cm/min)	Special observation
0	1740															
28.50	1711.50	Fresh, moderately strong to srtong Slate			F 65^{0} RP, JT 20^{0} R, JT 80^{0} R		Nil		NMLC Core bit	Nx	No casing	Water Table Not Encountered			2.9	
30.00	1710.00				F 60^{0} RP		Nil								2.6	
31.50	1708.50	Fresh, moderately strong to srtong Slate			F 65^{0} RP		Nil								2.9	
33.0	1707.00				F 60^{0} RP, JT 20^{0} R, JT 50^{0} R		Nil								2.7	
34.5	1705.50	Fresh, moderately strong to srtong Slate			F 65^{0} RP, JT 15^{0} R		Nil								2.8	
36.0	1704.00				F 65^{0} RP, JT 50^{0} R		11								2.7	
37.5	1702.50	Fresh, moderately strong to srtong Slate			F 60^{0} RP, JT 20^{0} R		Nil								2.6	
39.0	1701.00				F 60^{0} RP, JT 75^{0} R, JT 50^{0} R		Nil								2.7	
40.5	1699.50	Fresh, moderately strong to srtong Slate			F 65^{0} RP, JT 75^{0} R, JT 40^{0} R		Nil								2.8	
42.0	1698.00				F 65^{0} RP, JT 75^{0} R, JT 45^{0} R		Nil								2.7	
43.5	1696.50	Fresh, moderately strong to srtong Slate			F 65^{0} RP		Nil								2.8	
45.0	1695.00				F 60^{0} RP		13								2.9	
46.5	1693.50	Fresh, moderately strong to srtong Slate			F 60^{0} RP		26								2.8	
48.0	1692.00				F 60^{0} RP		28								2.7	
49.5	1690.50				F 60^{0} RP		45								2.7	
50.0	1690.00						Nil								3	

INDEX: Slopewash Material; Slate with band of Siltstone; F = Foliation; JT = Joint; RU = Rough Undulating; RP = Rough Planar; R = Rough

Observations:

1. The depth of overburden is 0.5m (i.e. El.1739.5m), which is mainly composed of top soil and pieces of slate and siltstone.
2. Bed rock, in general fresh, moderately strong to very strong slate with band of siltstone and intrusion of Quartz vein. Due to thinly foliated slates are break-up into small pieces.
3. In general core recovery in bed rock varies between 30 to 80%.
4. RQD, in general, varies between 0 to 45%.

GEOLOGICAL LOG OF DRILL HOLE

Project:	Rehabilitation and Up-graduation to 2 lane/ 2lane with Paved Shoulders Configuration & Strengthening of National Highways No.-94 from Km 144.00(Dharasu) to 220.00 (Yamunotri) in State of Uttarakhand (Package No. 5)	Coordinates	N 3409964.479 E 235992.281	Drill Hole No.	**BH-2** (Sheet 1 of 2)
Location :	Portal (Barkot Bend)	Angle with horizontal	Vertical	Total depth	50.0 M
Feature	Highway Tunnel	Collar Elevation	1550.00m	Types of Core barrel	Tripple tube
Started	22-Jan-2015	Ground Elevation	1549.780m	Drilling Agency	IGS
Completed	6-Feb-2015				

Depth (m)	Elevation (m)	Lithology Description	Log	Size of Core Pieces (mm): <10 / 10--25 / 25-75 / 75-150 / >150	Structural Condition	Percent Core Recovery: 0-20 / 20-40 / 40-60 / 60-80 / 80-100	RQD (%)	Fracture Frequency /m	Type of Bit	Size of Hole	Casing	Depth of Water Table (m)	Drill Water Loss: Nil / Partial / Total	Permeability: Test Section / 10^{-3}cm/sec or lugeon	Rate of Penetration (cm/min)	Special observation
0	1550															
0.50	1549.50	Slopewash													2	Overburden
1.50	1548.50	Moderately to highly weathered, weak to slightly strong, thinly foliated Slate					Nil		Hx casing bit	Hx	Hx	Water Table Not Encountered			3.33	Bed rock encounter at El 1549.50m
3.00	1547.00						Nil								2.72	
4.50	1545.50	Moderately weathered, weak to moderately strong, thinly foliated Slate			F 50^{0} RP		Nil		Nx casing bit	Nx	Nx				2.14	
6.00	1544.00				F 45^{0} RP		Nil								4.28	Surface staining along joints.
7.50	1542.50	Moderately weathered, weak to moderately strong, thinly foliatedSlate			F 45^{0} SP		Nil		Nx Core bit		No casing				3.75	
9.00	1541.00				F 50^{0} SP		Nil								3.33	
10.50	1539.50	Moderately weathered, weak to moderately strong, thinly foliated Slate			F 50^{0} RU		Nil								2.88	
12.00	1538.00				F 45^{0} RU		Nil		NMLC Core bit						3.75	
13.50	1536.50	Moderately weathered, weak to moderately strong, thinly foliated Slate			F 45^{0} RP		Nil								2	
15.00	1535.00				F 50^{0} RP		Nil								1.87	
16.50	1533.50	Slightly weathered, slightly to moderately strong, thinly foliated Slate			F 50^{0} RP		Nil								2.14	
18.00	1532.00				F 50^{0} RP		Nil								2	
19.50	1530.50	Fresh to Slightly weathered, slightly to moderately strong, thinly foliated Slate			F 50^{0} RP		Nil								1.87	
21.00	1529.00				F 45^{0} RP		Nil								2	
22.50	1527.50				F 50^{0} RP		Nil								2.14	
24.00	1526.00				F 45^{0} RP		Nil								1.76	
25.50	1524.50				F 50^{0} RP		Nil								1.87	
27.00	1523.00				F 40^{0} RP		Nil								2.01	

GEOLOGICAL LOG OF DRILL HOLE

Project:	**Rehabilitation and Up-graduation to 2 lane/ 2lane with Paved Shoulders Configuration & Strengthening of National Highways No.-94 from Km 144.00(Dharasu) to 220.00 (Yamunotri) in State of Uttarakhand (Package No. 5)**	Coordinates	**N 3409964.479 E 235992.281**	Drill Hole No.	**BH-2** (Sheet 2 of 2)
Location :	**Portal (Barkot Bend)**	Angle with horizontal	**Vertical**	Total depth	**50.0 M**
Feature	**Highway Tunnel**	Collar Elevation	**1550.00m**	Types of Core barrel	**Tripple tube**
Started	**22-Jan-2015**	Ground Elevation	**1549.780m**	Drilling Agency	**IGS**
Completed	**6-Feb-2015**				

Depth (m)	Elevation (m)	Lithology: Description	Structural Condition	RQD (%)	Type of Bit	Size of Hole	Casing	Depth of Water Table (m)	Rate of Penetration (cm/min)	Special observation
0	1550									
28.50	1521.50	Fresh, slightly to moderately strong, thinly foliated Slate	F 40^0 RP	Nil	NMLC Core bit	Nx	No casing	Water Table Not Encountered	2.16	
30.00	1520.00		F 45^0 RP	Nil					1.76	
31.50	1518.50		F 45^0 RP	Nil					1.66	
33.0	1517.00		F 50^0 RP	Nil					1.57	
34.5	1515.50		F 45^0 RP	Nil					1.76	
36.0	1514.00		F 45^0 RP	Nil					1.66	
37.5	1512.50	Fresh, moderately strong to srtong Slate	F 50^0 RP JT 40^0 R	Nil					1.2	
39.0	1511.00		F 50^0 RP	Nil					1.07	
40.5	1509.50	Fresh, moderately strong to srtong Slate	F 50^0 RP JT 75^0 R	Nil					1.25	
42.0	1508.00		F 50^0 RP JT 45^0 R	Nil					2	
43.5	1506.50	Fresh, moderately strong to srtong Slate	F 45^0 RP JT 80^0 R	Nil					2.3	
45.0	1505.00		F 40^0 RP JT 45^0 R	Nil					1.87	
46.5	1503.50	Fresh, moderately strong to srtong Slate	F 40^0 RP JT 55^0 R	Nil					2.8	
48.0	1502.00		F 45^0 RP JT 75^0 R	Nil					2.7	
49.5	1500.50		F 40^0 RP	Nil					2.3	
50.0	1500.00		F 40^0 RP	Nil					1	

Other columns (Log; Size of Core Pieces (mm): <10, 10–25, 25–75, 75-150, >150; Percent Core Recovery: 0-20, 20-40, 40-60, 60-80, 80-100; Fracture Frequency /m; Drill Water Loss: Nil, Partial, Total; Permeability: Test Section, 10^{-3}cm/sec or lugeon) are shown graphically or left blank.

INDEX: Slopewash Material; Slate with band of Siltstone; F = Foliation; JT = Joint; RU = Rough Undulating; RP = Rough Planar; R = Rough

Observations:

1. The depth of overburden is 0.5m (i.e. El.1549.5m), which is mainly composed of top soil and pieces of slate and siltstone.
2. Bed rock, in general Slightly weathered to fresh, slightly strong to strong slate with band of siltstone and intrusion of Quartz vein. Due to thinly foliated slates are break-up into small pieces.
3. In general core recovery in bed rock varies between 20 to 70%.
4. RQD, in general, nil. This is due to thinly foliated bedrock.

GEOLOGICAL LOG OF DRILL HOLE

Project:	**Rehabilitation and Up-graduation to 2 lane/ 2lane with Paved Shoulders Configuration & Strengthening of National Highways No.-94 from Km 144.00(Dharasu) to 220.00 (Yamunotri) in State of Uttarakhand (Package No. 5)**	Coordinates	**N 3407375.837 E 237240.436**	Drill Hole No.	**BH-3**
Location :	**Radi Top**	Angle with horizontal	**Vertical**	Total depth	**50.0 M**
Feature	**Highway Tunnel**	Collar Elevation	**2260.00m**	Types of Core barrel	**Tripple tube**
Started	**22-Jan-2015**	Ground Elevation	**22659.88m**	Drilling Agency	**IGS**
Completed	**6-Feb-2015**				

Depth (m)	Elevation (m)	Lithology: Description	Lithology: Log	Size of Core Pieces (mm): <10	10--25	25-75	75-150	>150	Structural Condition	Percent Core Recovery: 0-20	20-40	40-60	60-80	80-100	RQD (%)	Fracture Frequency /m	Type of Bit	Size of Hole	Casing	Depth of Water Table (m)	Drill Water Loss: Nil	Partial	Total	Test Section	Permeability 10^{-3}cm/sec or lugeon	Rate of Penetration (cm/min)	Special observation
0	1550																										
2.50	1547.50	Slopewash																								1.5	Overburden
3.50	1546.50	Moderately to highly weathered, weak to slightly strong, thinly foliated Slate													Nil		Hx casing bit	Hx	Hx	Water Table Not Encountered						3.33	Bed rock encounter at El 2257.50m
4.50	1545.50														Nil											2.72	
5.00	1545.00	Moderately weathered, weak to moderately strong, thinly foliated Slate							F 30^0 RP						Nil		Nx casing bit	Nx	Nx							2.14	
6.00	1544.00								F 55^0 RP						Nil											4.28	
7.50	1542.50	Moderately weathered, weak to moderately strong, thinly foliatedSlate							F 55^0 SP						Nil		Nx Core bit		No casing							3.75	Surface staining along joints.
9.00	1541.00								F 55^0 SP						Nil											3.33	
10.50	1539.50	Moderately weathered, weak to moderately strong, thinly foliated Slate							F 50^0 RU						Nil											2.88	
12.00	1538.00								F 35^0 RU						Nil		NMLC Core bit									3.75	
13.50	1536.50	Moderately weathered, weak to moderately strong, thinly foliated Slate							F 35^0 RP						Nil											2	
15.00	1535.00								F 50^0 RP						Nil											1.87	
16.50	1533.50	Slightly weathered, slightly to moderately strong, thinly foliated Slate							F 55^0 RP						Nil											2.14	
18.00	1532.00								F 55^0 RP						Nil											2	
19.50	1530.50	Fresh to Slightly weathered, slightly to moderately strong, thinly foliated Slate							F 55^0 RP						Nil											1.87	
21.00	1529.00								F 55^0 RP						Nil											2	
22.50	1527.50								F 55^0 RP						Nil											2.14	
24.00	1526.00								F 55^0 RP						Nil											1.76	
25.50	1524.50								F 50^0 RP						Nil											1.87	
27.00	1523.00								F 50^0 RP						Nil											2.01	

GEOLOGICAL LOG OF DRILL HOLE

Project:	Rehabilitation and Up-graduation to 2 lane/ 2lane with Paved Shoulders Configuration & Strengthening of National Highways No.-94 from Km 144.00(Dharasu) to 220.00 (Yamunotri) in State of Uttarakhand (Package No. 5)	Coordinates	N 3407375.837 E 237240.436	Drill Hole No.	**BH-3** Sheet 2 of 2
Location :	Radi Top	Angle with horizontal	Vertical	Total depth	50.0 M
Feature	Highway Tunnel	Collar Elevation	2260.00m	Types of Core barrel	Tripple tube
Started	22-Jan-2015	Ground Elevation	22659.88m	Drilling Agency	IGS
Completed	6-Feb-2015				

Depth (m)	Elevation (m)	Lithology		Size of Core Pieces (mm)					Structural Condition	Percent Core Recovery					RQD	Fracture Frequency /m	Type of Bit	Size of Hole	Casing	Depth of Water Table	Drill Water Loss			Permeability		Rate of Penetration (cm/min)	Special observation
0	1550	Description	Log	<10	10-25	25-75	75-150	>150		0-20	20-40	40-60	60-80	80-100	(%)					(m)	Nil	Partial	Total	Test Section	10^{-3}cm/sec or lugeon		
28.50	1521.50								F 50⁰ RP						Nil											2.16	
30.00	1520.00								F 55⁰ RP						Nil											1.76	
31.50	1518.50	Fresh, slightly to moderately strong, thinly foliated Slate							F 55⁰ RP						Nil											1.66	
33.0	1517.00								F 50⁰ RP						Nil											1.57	
34.5	1515.50								F 45⁰ RP						Nil											1.76	
36.0	1514.00								F 45⁰ RP						Nil											1.66	
37.5	1512.50	Fresh, moderately strong to srtong Slate							F 50⁰ RP JT 40⁰ R						Nil											1.2	
39.0	1511.00								F 50⁰ RP						Nil		NMLC Core bit	Nx	No casing	Water Table Not Encountered						1.07	
40.5	1509.50	Fresh, moderately strong to srtong Slate							F 50⁰ RP JT 75⁰ R						Nil											1.25	
42.0	1508.00								F 50⁰ RP JT 45⁰ R						Nil											2	
43.5	1506.50	Fresh, moderately strong to srtong Slate							F 45⁰ RP JT 80⁰ R						Nil											2.3	
45.0	1505.00								F 40⁰ RP JT 45⁰ R						Nil											1.87	
46.5	1503.50								F 40⁰ RP JT 55⁰ R						Nil											2.8	
48.0	1502.00	Fresh, moderately strong to srtong Slate							F 45⁰ RP JT 75⁰ R						Nil											2.7	
49.5	1500.50								F 40⁰ RP						Nil											2.3	
50.0	1500.00								F 40⁰ RP						Nil											1	

INDEX: Slopewash Material; Slate with band of Siltstone; F = Foliation; JT = Joint; RU = Rough Undulating; RP = Rough Planar; R = Rough

Observations:

1. The depth of overburden is 0.5m (i.e. El.2247.50m), which is mainly composed of top soil and pieces of slate and siltstone.
2. Bed rock, in general Slightly weathered to fresh, slightly strong to strong slate with band of siltstone and intrusion of Quartz vein. Due to thinly foliated slates are break-up into small pieces.
3. In general core recovery in bed rock varies between 40 to 80%.
4. RQD, in general, nil. This is due to thinly foliated bedrock.