

Z-MORH TUNNEL

Contract

Construction, Operation and Maintenance of Z-MORH-Tunnel including Approaches on National Highway No. 1 (Srinagar Sonamarg Gumri Road) in the State of J&K on Design, Build, Finance, Operate and Transfer (DBFOT) Annuity Basis

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Contracting Authority



National Highways&Infrastructure Development Corporation Limited



**MINISTRY OF ROAD,
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Concessionaire:

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Eptisa Servicios de Ingeniería & Eptisa India PVT

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**ESTIMATION OF TUNNEL SUPPORT SECTIONS
VS
GEOLOGICAL DATA**

BRIEF NOTE

ESTIMATION OF TUNNEL SUPPORT SECTIONS vs GEOLOGICAL DATA

DOCUMENT AUTHORS

Name	Position	Task
J.Ruiz	Senior Engineer	Author

DOCUMENT REVISION

Name	Date	Task

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Name	Position	Organisation
A.Saurav		NHIDCL

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1 OBJECTIVE OF DOCUMENT

Object of this note is to estimate lengths of different tunnel support sections required in non excavated sections of ZMORH tunnel.

Tunnel excavation and support procedures and types are determined by rock mass properties. Detailed rock mass characteristics are only determined approximately until complete excavation. Uncertainty in rock properties represents a risk in construction process. In this report we extrapolate rock properties for unexcavated sections of ZMORH tunnel and associated geological risk due to uncertainties considering an lower and upper bound summarized in three possible scenarios: optimistic, medium and pessimistic.

2 CURRENT EXCAVATION STATUS

Actual partially excavated lengths are:

MAIN TUNNEL:

Completely excavated length is 892 meters plus 24 in ventilation Cavern and 1691 meters only in top heading. Top heading excavated sections varies between 40 to 80% with an average 65% of section is excavated

EGRESS TUNNEL:

Total length excavated is 2852 meters

VENTILATION TUNNEL:

Ventilation tunnel and caver are completely excavated with 595 meters length.

AUXILIARY ELEMENT:

Two lay-by sections are excavated in main tunnel and 4 motorable cross passages are completely excavated

3 TUNNEL SUPPORT DESIGN PROCESS

In present report we assume that current detailed design for ZMORH tunnel is maintained for remainder unexcavated sections.

Tunnel excavation and support design is defined in the following two design documents:

- FINAL DESIGNTUNNEL REPORT V. 2.0 August 2017 ILSF&Grusamar
- FINAL GEOTECHNICAL REPORT V.2.1

A brief note about this issue is submitted by IE with reference B/S1-v1 with date 20th January 2019. This report includes a summary of geological data and a description of criteria used in design phase.

4 GEOLOGICAL SUMMARY

The project area of Z-Morh Tunnel is located in permo-carboniferous, metamorphic rocks of sedimentary and magmatic origin, which are regional-geologically related to the Tethyan facies

These facies are subdivided into five lithostratigraphic formations. Along the alignment of Z-Morh Tunnel two of these formations -'Panjal Trap' and 'Zojila formation'– are present.

Zojila Formation.

This geological unit is encountered at the eastern and western section of Z-Morh Tunnel and consists mainly of dark grey, fine-grained, finely foliated graphitic, partly carbonaceous, phyllites, slates and schist, calc-schist and quartz-schists. Due to intensive foliation and slaty cleavage the rock mass is highly anisotropic. The foliation planes spacing is very thin in slates and phyllites (0.1-1.0 cm), to thin in schist (0.5-10 cm).

Tectonic shearing along fracture zones or shear zones increases the degree of fracturing (spacing of foliation planes < 2 cm) resulting in clayey coatings or fillings on discontinuities (shear planes). Thick (several decimeters to several meters), continuous zones of fine-grained fault rock (fault gouge) were not encountered during performed site investigations. But due to morphological features the occurrence of bigger shear zones or faults within this geological unit can be assumed.

Panjal Trap Formation.

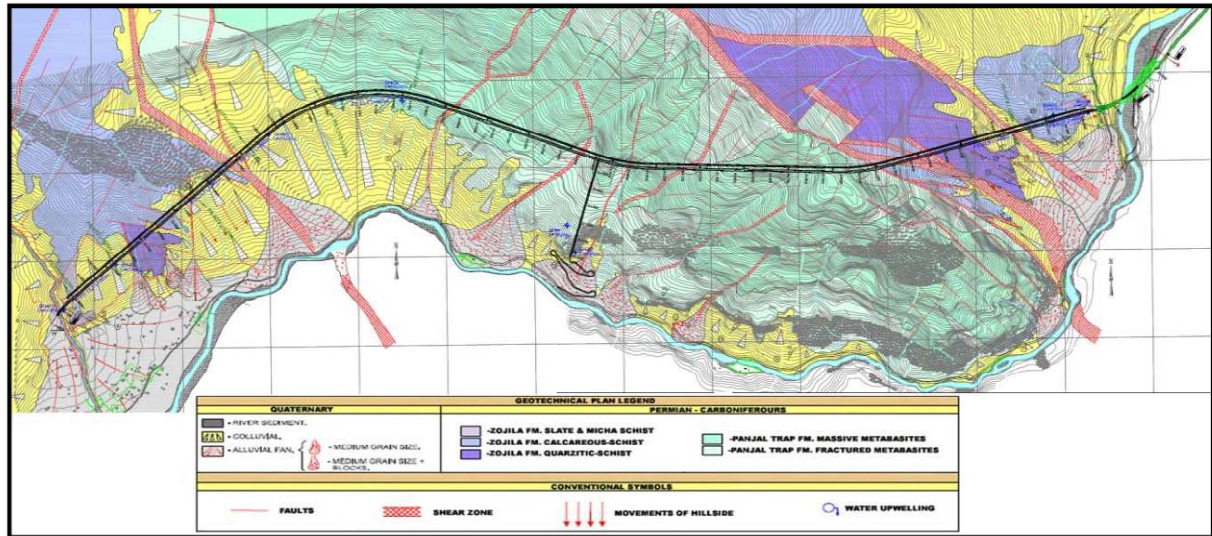
Panjal Trap Formation consist of metamorphic volcanic rocks of basaltic-andesitic origin, this rocks are metabasites. These are hard and compact rock, they are fresh, with slight weathering phenomena (discoloration at surfaces and along discontinuities) near to the surface. The Metabasites spacing massive rocks. are dominated by wide (60-200 cm) to very wide (>200 cm)

These materials have been separated into two groups based on the observed characteristics. In a first group Metabasites observed in surface and recognized as a first layer surrounding the Mass Metabasites is included. Fractured Metabasites, as the name says, present a less competent aspect due to the greater degree of fracturing observed, so that the strength parameters of this group may be lower.

Measurements made in this second installment of the alignment, corresponding to the formation

Panjal Trap, consisting of metabasites, have been grouped according to three sets of fracturing, the guidelines, as seen in the previous stereographic representation are: 308/21, 089/40 and 187/69. The metamorphic bedrock is covered by recent sediments, mainly along the river beds (river deposits) and at the lower valley slopes below the steep rock cliffs of the mountain ridges (slope and rock fall debris).

In the next figure the geological cartography with the alignment and the different materials and structures across the alignment can be seen.



To explain the geology and structure along the tunnel in the following sections:

– **Section 1: from Western Portal to 1+350**

This section includes the stretch from W portal to contact with Zojila and Panjal Trap Formation; in all of this section, the alignment crosses by different materials of Zojila Formation.

– **Section 2: from km 1+350 to 1+450.**

In this section the track goes across the contact point between the calcareous-schist of Zojila Formation and the fractured metabasites of Panjal Trap Formation. The contact point is completely covered by quaternary material.

– **Section 3: from km 1+450 5+175.**

The Panjal Trap Formation (metabasites) is observed from km 1+400 to 5+150. The rocks of this unit are highly resistant, forming a ridge more pronounced in the study area than the other formation.

In this long sector, there are several discontinuities perpendicular to the axis of the alignment, which generate observable jumps in the massif crest so, possibly, are faults. Various dip faults have been detected from the aerial picture, oriented towards the defined track. Based on block accumulation associated to these faults, we can assure that the faults show some kind of activity.

Those are the chainages where the active faults have been detected:

- around km 7+740, a 20m approximate width;
- around km 8+515, a 25m approximate width;
- around km 8+800, a 10m approximate width;
- around km 9+100, a 40m approximate width.

– **Section 4: from km 5+175 to 6+050.**

In this section both formations, the fractured metabasites of Panjal Trap formation and the calcareous-schist of Zojila formation, get in contact. Throughout the 355m of this section, it has been detected by aerial photography that the track crosses four scales all separated or individualized by faults. The first three are constituted by calcareous-schist material from Zojila formation, while the fourth one, seems to be constituted by quartz-schist; this last fault covers the area from km 10+550 to 10+950, and based on different field testing, contains calcareous-schist and slate and micaceous-schist alternatively.

Wideness and chainage of detected faults:

- around km 10+210, a 15m approximate width;
- around km 10+275, a 120m approximate width;
- around km 10+425, a 30m approximate width;
- around km 10+490, a 30m approximate width.

The stretch from km 10+950 to km 11+050 crosses a fault zone that creates contact between quartz-schist and calcareous-schist materials. The fault width is estimated in 40m, and located between km 10+980 and 1+020.

– **Section 5: from km 6+050 to 6+400.**

In the last kilometers of the track, fracturing is observed perpendicularly to the axis of the track with dips approximately 60° to 90° degrees affecting

The materials of this formation are slates initially and calc-schist constituting the rest of observed outcrops.

E Portal is placed in decimetric thicknesses of colluvial. In this zone creep process has also been observed, which is a slow movement of soil and deposits downhill caused by gravity.

5 DESIGNED SUPPORT

In practice a prevision of support distribution represent to realize a prediction of rock material an their rock mass quality parameters Q and RMR

Section types and application criteria are:

Main tunnel

SEC.	CRITERIA	EXPECTED ROCK TYPE	FORMATION
S-I	RMR>60 Q>4	Quality massive metabasites.	Panjal Trap Formation of Massive Metabasites. Panjal Trap Formation of Fractured Metabasites
S-I'	RMR>60 Q>4	Good quality and very hard rock massifs but subject to high stress due to high overburden.	
S-II	45<RMR<60 4>Q>3.2		Panjal Trap Formation of Fractured Metabasites. Zozila Formation of Quarzitic Zozila Formation of Calcareous
S-II Bis	35<RMR<45 0.8>Q>0.1	Same as S-II with risk of chimney type failure.	Zozila Formation of Calcareous-schist. Zozila Formation of Slate & Michaschist.
S-III	35<RMR<45 0.5>Q>0.2		Panjal Intense Fractured with Panjal Massive. Failure in Panjal Massive.
S-III'	35<RMR<45	hazard of squeezing	
S-IV	25<RMR<35 0.2>Q>0.02		Michaschists and intense fractured Zozila Formation. Fractured zone.
S-IV'	25<RMR<35 0.4>Q>0.01	Squeezing confirmed in low quality rock	
S-V	RMR<25	Umbrella and under forepoling	Portals.

S-V'	RMR<25 Q<0.1	special hazard of squeezing	
S-VI	Q<0.01	Fault breccias and crushed rocks in shear zones.	Great Fault crossing.
S-VI'		breccias or much crushed rocks, enough overburden with severe to very severe squeezing risk.	Great Fault crossing. Soil behaviour with high overburden. Squeezing >5%

Main tunnel Lay-bys

SEC.	CRITERIA	EXPECTED ROCK TYPE
SG-I	RMR>45	Lay-bys must be excavated in competent rock in Zojilla or Panjab
SG-II	35<RMR<45	

Egress

SEC.	CRITERIA	EXPECTED ROCK TYPE
SGE-II	RMR>40	
SGE-II	30<RMR<40	
SGE-III	RMR<30	lowest rock quality stretches of the gallery and portals.
SGE-IIIbis		lower rock quality stretches of the gallery and portals

Drawings with a complete of designed excavation and support section are included un Annex I.

Also a predictive analysis of spatial distribution based on geological profile is carried out in next drawings

6 DATA FROM EXCAVATION vs DETAILED DESIGN

A summary of excavated sections is summarized in the next tables for main an egress tunnel. Ventilation tunnel is completely excavated and not included. New Face 8 also is not representative.

	FACE1				FACE2				FACE3				FACE4				FACE5				AVERAGE			
	m/day	m	day	Ef.	m/day	m	day	Ef.	m/day	m	day	Ef.	m/day	m	day	Ef.	m/day	m	day	Ef.	m/day	m	days	Ef.
S1		0							3.844	519.0	136	43.9%	3.735	500.5	136	42.7%	3.107	43.5	14	35.5%	3.717	1063.0	286	42.5%
S2		0							4.429	62.0	14	63.3%	2.700	27.0	10	38.6%	3.907	230.5	59	55.8%	3.849	319.5	83	55.0%
S2b	2.755	297.5	108	45.9%													3.099	220.0	73	51.6%	2.847	538.0	189	47.4%
S3		0.0			4.045	89.0	22	67.4%									4.827	125.5	28		4.290	214.5	50	71.5%
S3b		0.0																					0.0	
S4	2.245	110.0	49	74.8%	2.667	64.0	24	88.9%													2.384	174.0	73	79.5%
S4b		0.0																					0.0	
S5	1.987	149.0	75	99.3%	0.953	41.0	43	95.3%													1.610	190.0	118	80.5%
S5b		0																					0.0	
S6		0																					0.0	

	FACE1				FACE2				FACE3				FACE4				AVERAGE			
	m/day	m	day	Ef.	m/day	m	day	Ef.	m/day	m	day	Ef.	m/day	m	day	Ef.	m/day	m	day	Ef.
SGE1	5.051	500	99	67.3%	3.111	317	64	41.5%	3.864	483	125	51.5%	3.414	440.5	128	45.5%	4.945	1741	352	65.9%
SGE2	3.557	434	123	59.3%					3	15	5	50.0%					3.508	449	128	58.5%
SGE2b	4.116	391	95	82.3%	3.111	75	25	62.2%									3.883	466	120	77.7%
SGE3	2.676	99	37	89.2%	2.107	67	25	70.2%									2.677	166	62	89.2%
SGE3b	1.625	45.5	28	108.3%													1.625	45.5	28	108.3%

Excavated segments provide very detailed and precise data about rock properties. A comparison between projected and observed data is useful to determine prediction reliability.

A comparison between applied support type and that foreseen in project are summarized in the following tables:

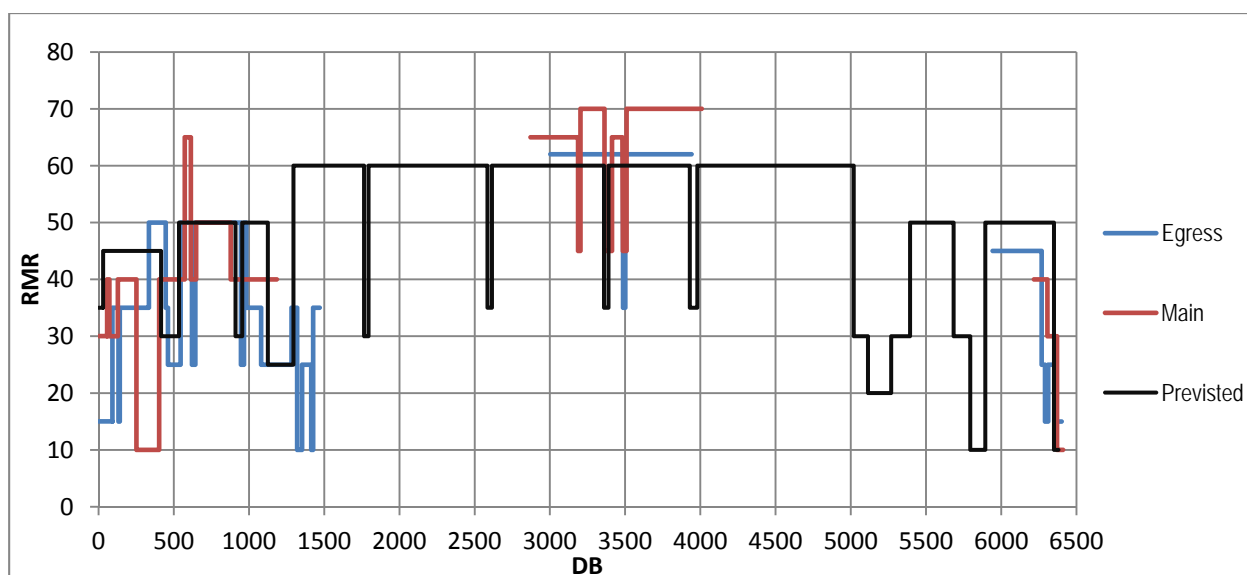
Main Tunnel

SECTION	LENGTH		S-I	S-I'	S-II	S-II'	S-III	S-III'	S-IV	S-IV'	S-V	S-V'	S-VI	S-VI'	SGE-1	SGE-2
0.0	1188.0	1188.0	REAL	40.5		201.5	520.5	126.5		110.0		149.0				40.0
			PROJECT			507.0	375.0	50.0		196.0		30.0			30.0	
1188.0	2847.9	1659.9		1430		75.9		65		89						
2847.9	4039.9	1192.0	REAL	1101		71										20
			PROJECT	1020	10	80		80	2							
4039.9	6183.9	2144.0		469	350	360			380		330		155		100	
6183.9	6411.9	228.0	REAL				31	91		65		41				
			PROJECT			164						64				

Egress tunnel

SECTION		LENGTH		SGE-1	SGE-2	SGE-3	SGE-3b
0	1470	1470	REAL	500	825	99	45.5
			PROJECT	1155	285	30	
1470	3003	1533		1001	453	79	
			REAL	924	15		
3003	3942	939	PROJECT	743	140	55	
				937	480.2	265	319
3942	5943	2001		317	75	76	
			PROJECT	163	275	30	

A schematic graph of observer rock quality RMR and project foreseen is the next graph

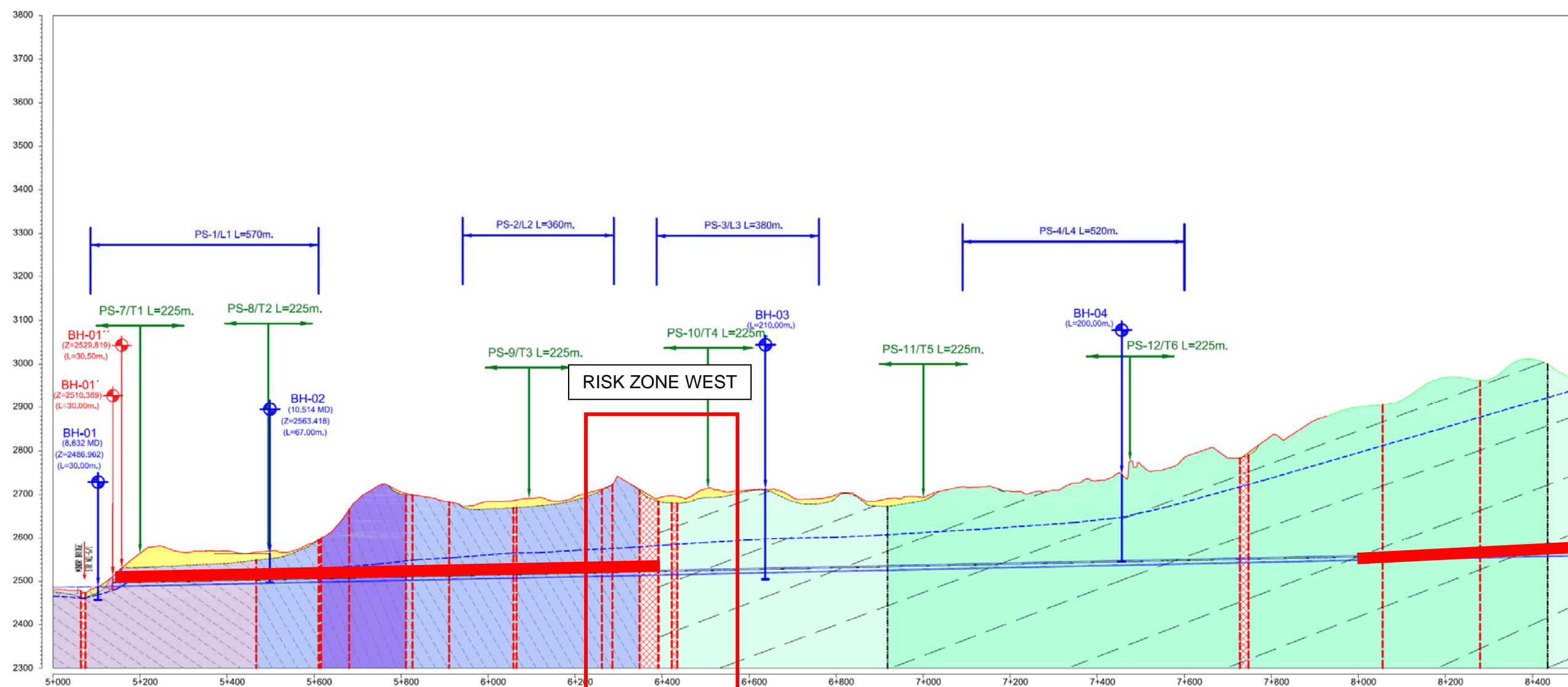


Conclusions from real data are:

- Panjab metabasites are very homogeneous with best rock properties than expected.
- Zojila formation are more heterogeneous than expected with, in average, low rock quality than expected
- In excavated sections metabasite/zojilla contact zones are unexcavated.
- Observed rock quality is better in egress tunnel than in main tunnel in west portal, presenting very significant differences for small separation between tunnels.

Geological profile with uncertainty zones (1 of 2)

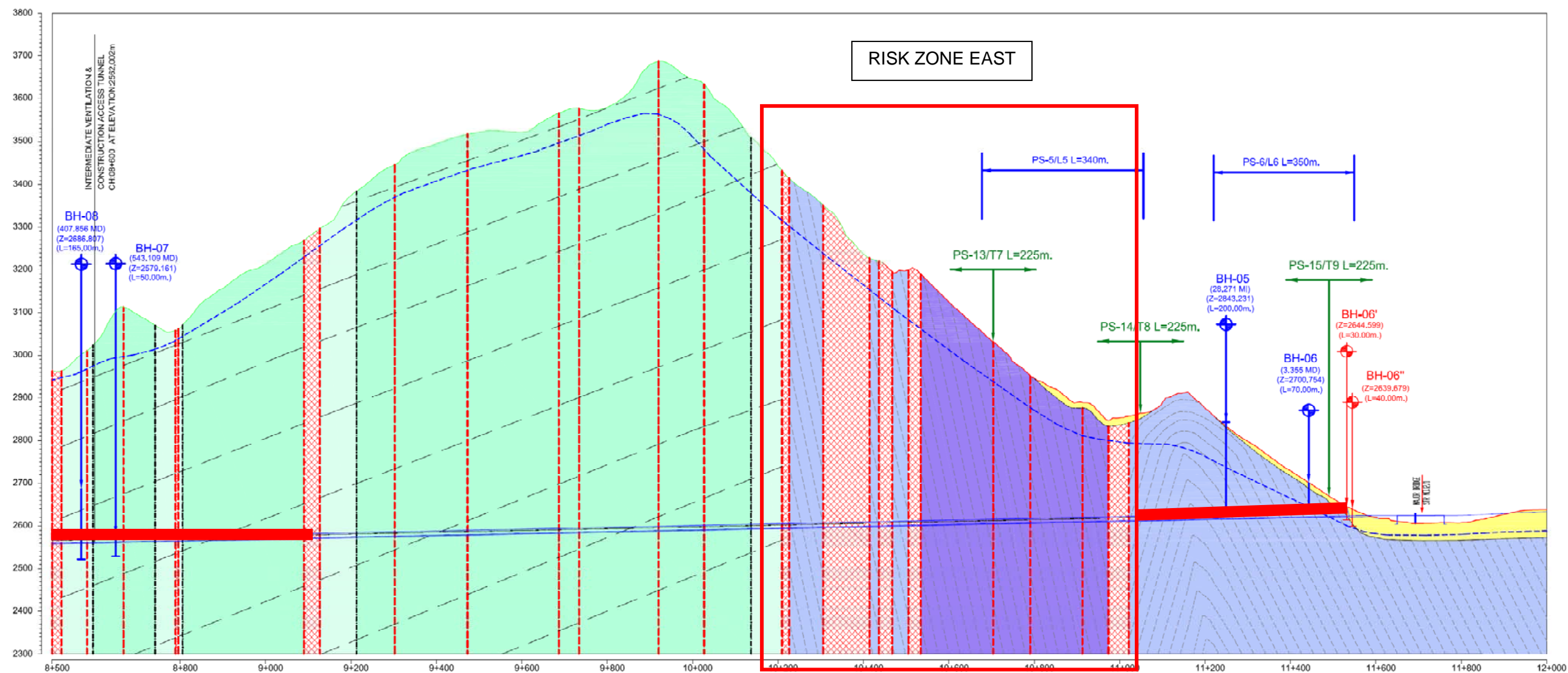
GEOTECHNICAL LEGEND			
QUATERNARY	PERMIAN - CARBONIFEROUS	CONVENTIONAL SYMBOLS	GEOTECHNICAL INVESTIGATION 2013
<ul style="list-style-type: none"> - COLLUVIAL. - ALLUVIAL FAN. 	<ul style="list-style-type: none"> - ZOJILA FM. SLATE AND MICA SCHIST. - ZOJILA FM. CALCAREOUS - SCHIST. - ZOJILA FM. QUARZITIC - SCHIST. 	<ul style="list-style-type: none"> - PANJAL TRAP FM. METABASITES MASSIVE. - PANJAL TRAP FM. METABASITES FRACTURED. - DEDUCED LITHOLOGIC CONTACT. - DEDUCED MECHANICAL CONTACT. - FAULTS. - WATER LEVEL. - SYSTEMATIC JOINTS. - SHEAR ZONE. 	<ul style="list-style-type: none"> - BOREHOLE - SEISMIC PROFILE
GEOTECHNICAL INVESTIGATION 2015			
<ul style="list-style-type: none"> - BORE HOLE 			



CHAINAGE	5+135	5+165	5+550 5+600 5+670				6+045 6+090		6+260	6+430	6+900 6+930		7+720 7+755		8+400						
PARTIAL DISTANCE		30.0	385.0m,		50.0	70.0m,	375.0m,		45.0	170.0m,	170.0m,	470.0m,	30.0	790.0m,	35.0	745.0m,					
OVERBURDEN	20.0		80.0	70.0	90.0	130.0	210.0	180.0	180.0	180.0	170.0	150.0	180.0	150.0	160.0	160.0	210.0	220.0	430.0		
GROUND		SLATE AND MICA SQUISTOS				SCHIST (QUARZITE AND CALCAREOUS)				FAULT FILLING				METABASITES AND ANDESITES							
WATER	DRY			WET		DRY		WET		DAMP		DRIPPING		DRY		DAMP		DRY			
RMR - BIENIAWSKI	35.0		45.0		30.0	50.0		30.0		50.0	25.0		60.0		60.0		35.0	60.0			
Q - BARTON (SRF=2.5)	0.50		1.40		0.20	2.10		0.20		2.10	0.10		10		0.40		10		10		
(%) SQUEEZING	< 1%				< 1%				< 3%				< 1%				< 3%				
EXCAVATION METHOD	S-V	S-II'			S-II	S-IV	S-II			S-IV	S-II	S-IV (FAULT)	S-I		S-III	90% S-I + 10% S-II			S-III	S-I	
TREATMENT	(*)									FRONT DRAIN											
ROCK CLASS		B2			L	A2			L	A2	A2			B2	A1			B2	A1		
OBSERVATIONS																					

Geological profile with uncertainty zones (2 of 2)

GEOLOGICAL LEGEND			
QUATERNARY	PERMIAN - CARBONIFEROUS	CONVENTIONAL SYMBOLS	GEOLOGICAL INVESTIGATION 2013
- COLLUVIAL.	- ZOJILA FM. SLATE AND MICA SCHIST.	- DEDUCED LITHOLOGIC CONTACT.	- BOREHOLE BH-01 (L=30.00m.)
- ALLUVIAL FAN.	- ZOJILA FM. CALCAREOUS - SCHIST.	- DEDUCED MECHANICAL CONTACT.	- SEISMIC PROFILE PS-2/L2 L=360m.
	- ZOJILA FM. QUARZITIC - SCHIST.	- FAULTS.	- SEISMIC PROFILE PS-10/T4 L=225m.
		- WATER LEVEL.	GEOLOGICAL INVESTIGATION 2015
		- SYSTEMATIC JOINTS.	- BORE HOLE BH
		- SHEAR ZONE.	



CHAINAGE	8+536		9+086 9+136		10+176 10+270		10+425	10+550	10+840 10+950		11+050	11+507 11+537	
PARTIAL DISTANCE	36.0	550.0m.	50.0	1040.0m.	94.0m.	155.0m.	125.0m.	290.0m.	110.0m.	100.0m.	457.0m.	30.0	
OVERBURDEN	380.0	510.0	710.0	940.0	1080.0	800.0 750.0	640.0 580.0	380.0	310.0 270.0.	230.0	280.0	180.0	50.0
GROUND	METABASITES OR ANDESITES				SLATE AND MICA SCHIST				SCHIST (QUARZITE AND CALCAREOUS)		SLATE AND MICA SCHIST		
WATER	DRY				WET	MEDIUM INFLOW	LARGE INFLOW	MEDIUM INFLOW	DAMP	MEDIUM INFLOW	LARGE INFLOW	DRY	DRIPPING
RMR - BIENIAWSKI	35.0	60.0	35.0	60.0		30.0	20	30.0	50.0	30.0	<15	50.0	50.0
Q - BARTON (SRF=2.5)	0.40	10.0	0.40	10.0		0.20	0.08	0.20	2.10	0.20	0.01	2.10	10.0
(%) SQUEEZING	< 3%	< 1%	< 3%	NO		< 5%	< 5%	< 5%	< 3%	< 5%	< 5%	< 2%	
EXCAVATION METHOD	S-I	90% S-I + 10% S-II	S-III	50% S-I + 40% S-I' + 10% S-III'		S-IV'	S-V'	S-IV'	S-III'	S-IV'	S-VI'	S-II	S-V
TREATMENT						(****)	(*) - (****)	(****)		(*)	(***) - (*)		(*)
ROCK CLASS	B2	A1	B2	C1		C2	L	C2	B2		L	A2	
OBSERVATIONS	ROCK BURSTING				KARSTIFICATION ?								

7 SECTION TYPE ASSIGNMENT FOR UNEXCAVATED LENGTH

Section type excavation and support distribution in unexcavated tunnel length will be made considering observed data for Zojilla and Panjab formations. Contact zones between Zojilla and Panjab in West and East sides, as well as the fracture zones detected in the surface represent a risk due to their impact on the excavation and support. Real rock quality in fracture zones is now unknown since these areas have not yet been crossed.

Experience indicates that rock quality in these sections may be very low, that there may be large water flows, presenting serious squeezing and collapse risks. These sections requires systematic umbrella and section types S-V to S-VI'

Section type assignment methodology is based in a risk/statistical process based in available data. Steps used in methodology are:

1. Risk and uncertainties identification
2. Value assignation to previous identified parameters defining scenarios.
3. Section type assignation for each defined scenario
4. Statistical analysis of results defined in scenarios.

7.1 Risk and uncertainties identification

A per analysis of geotechnical profile following uncertainties are identified in order of priority

- Contact Zojila formation/Panjab formation and fractured contact zone in East area
- Contact Zojila formation/Panjab formation and fractured contact zone in West area
- Possible shear/fracture area in East Zojila formation
- Properties of Zojilla formation rock
- Uncertainties in Panjab metabasites
- Unexpected shear areas

In previous profiles three first mentioned uncertainty areas are indicated.

7.2 Value assignation

For each main uncertainty in geometry tree possible values are considered. For rock properties only two sets are considered.

Contact Contact Zojila formation/Panjab formation and fractured contact zone in West area and shear/fracture area in East Zojila formation are considered together in the analysis.

The rest of uncertainties are considered separately.

Values adopted for Zojila and Panjab are considered from a statistical analysis of rock data obtained from excavation

Values used are indicated in the following three tables

East zone

CASE	CONTACT 1 POSITION	CONTACT 1 LENGTH	CONTACT 2 POSITION	CONTACT 2 LENGTH	FAULT LENGT
B1	4700	300	5900	100	400
B2				150	450
B3				200	500
B4		400	6000	100	500
B5				150	550
B6				200	600
B7		500	6100	100	600
B8				150	650
B9				200	700
B10	4900	300	300	100	400
B11				150	450
B12				200	500
B13		400	400	100	500
B14				150	550
B15				200	600
B16		500	500	100	600
B17				150	650
B18				200	700
B19	5100	300	300	100	400
B20				150	450
B21				200	500
B22		400	400	100	500
B23				150	550
B24				200	600
B25		500	500	100	600
B26				150	650
B27				200	700

West zone

CASE	CONTACT POSITION	CONTACT LENGTH	ZOJILLA FORM.	PANJAB FORM.
A1	1500	100	294	1271
A2		175	294	1196
A3		250	294	1121
A4	1600	100	394	1171
A5		175	394	1096
A6		250	394	1021
A7	1700	100	494	1071
A8		175	494	996
A9		250	494	921

7.3 Rock parameters and section type assignment

Variability in rock quality in each formation is considered based on observed data and section functionality

	S-I	S-I'	S-II	S-II'	S-III	S-III'	S-IV	S-IV'	S-V	S-V'	S-VI	S-VI'
FAULT					5%		20%	5%	25%	10%	25%	10%
							15%	5%	25%	10%	30%	15%
ZOJILA	20%	10%	30%	5%	20%	5%	5%		5%			
			40%	10%	30%	5%	10%	5%				
PANJAB	90%	10%										
	80%	10%		5%		5%						

7.4 Results

Results obtained for main tunnel

	S-I	S-I'	S-II	S-II'	S-III	S-III'	S-IV	S-IV'	S-V	S-V'	S-VI	S-VI'	SG-1	SG-2
EXTREME	1861	281	349	132	261	107	162	50	150	50	138	63	200	0
OPTIMISTIC	1752	266	334	133	282	106	187	57	180	61	169	77	160	40
MEAN	1639	251	318	138	303	105	212	65	210	73	199	91	120	80
PESIMIST	1528	236	306	135	325	105	238	72	240	84	230	105	80	120
EXTREME	1418	221	289	136	348	104	263	80	270	95	261	119	40	160
PROJECT	1699	350	436	0	65	380	89	330	0	155	0	100	200	

Lay-by sections always are in rock with RMR>35. Position of each lay-by may be modified +/- 50 to 100 meters in order to avoid these sections in poor quality rock.

Crossing passages, accordingly are always in rock with RMR>35.

For bad quality rock, project section type foresees are medium-optimistic

And for egress tunnel:

	SGE-1	SGE-2	SGE-3	SGE-3b
EXTREME	2314	520	465	235
OPTIMISTIC	2182	529	539	284
MEAN	2051	537	612	334
PESSIMIST	1905	551	692	386
EXTREME	1759	565	772	437
PROJECT	1938	933	344	319

In Zojila formation the best observed properties in egress tunnel are considered.

7.4 Statistical analysis

All results has been statistically processed in order to obtain their variance for a 90% of confidence range of 90%:

Main Tunenel

S-I	S-I'	S-II	S-II'	S-III	S-III'	S-IV	S-IV'	S-V	S-V'	S-VI	S-VI'
1639	251	318	138	303	105	212	65	210	73	199	91
13.73%	12.12%	9.25%	2.31%	14.38%	1.80%	24.12%	23.44%	28.96%	31.43%	31.43%	31.43%

Egress Tunel

SGE-1	SGE-2	SGE-3	SGE-3b
1905	551	692	386
5.14%	1.72%	9.42%	11.29%

That indicates a high variability in sections assigned to rock with poor mechanical properties. Pessimistic scenario is associated to a more moderate risk

8 CONCLUSIONS

Distribution of section types proposed for unexcavated sections of ZMORH tunnel, with a reasonable geological risk are the following:

MAIN TUNNEL

S-I	S-I'	S-II	S-II'	S-III	S-III'	S-IV	S-IV'	S-V	S-V'	S-VI	S-VI'
1608	236	426	135	325	105	238	72	240	84	230	105

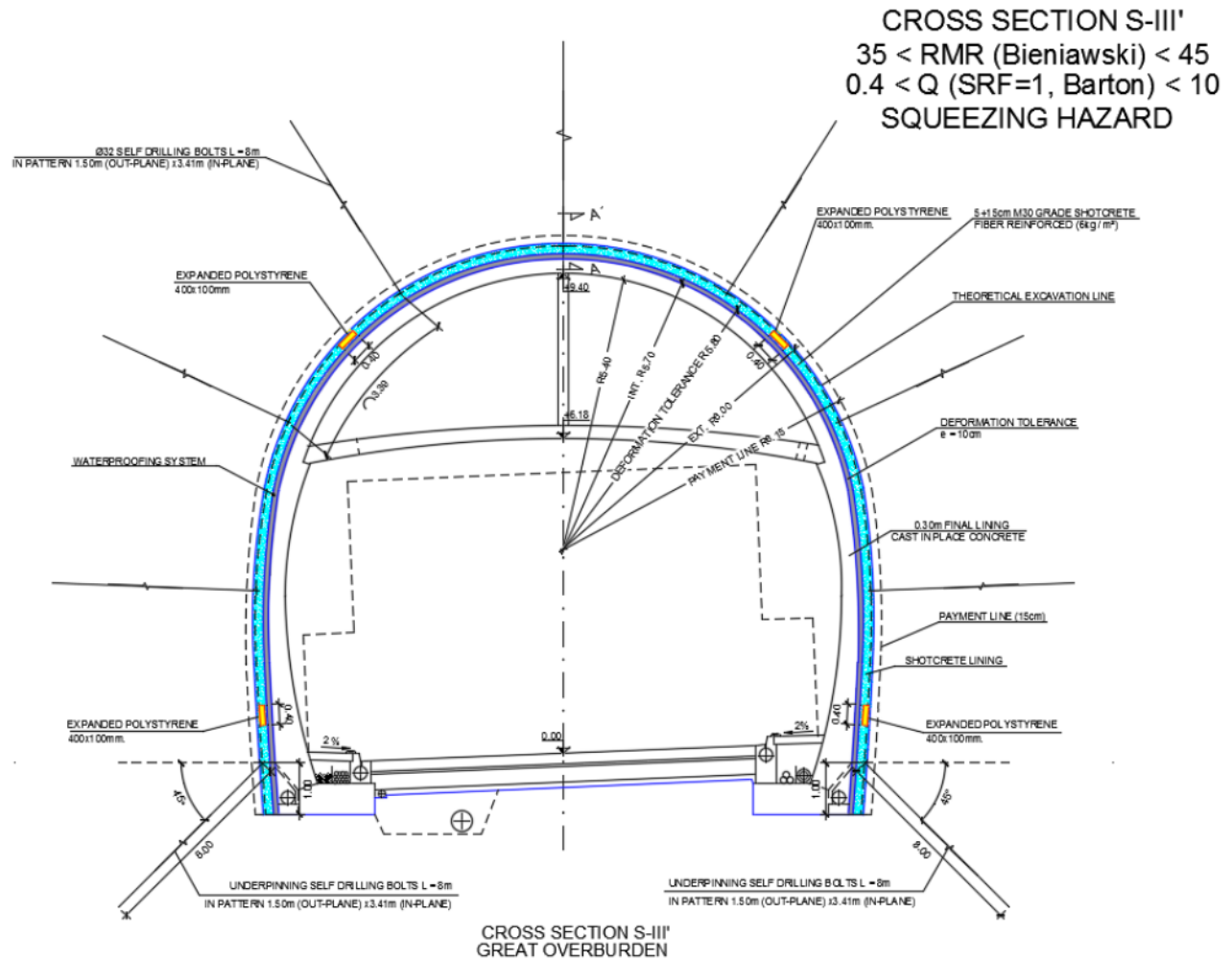
EGRESS TUNNEL

SGE-1	SGE-2	SGE-3	SGE-3b
1981	570	639	344

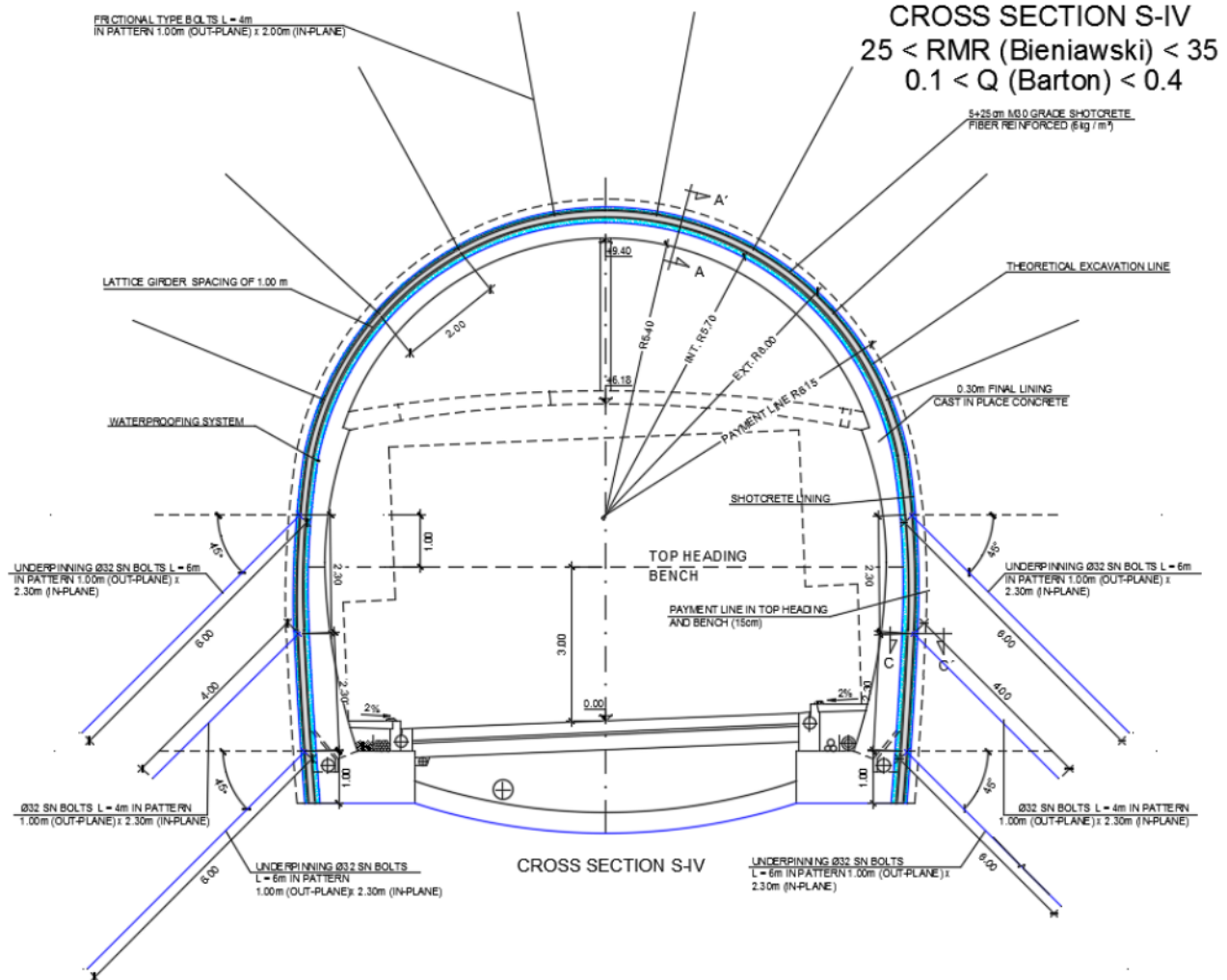
These lengths are, in any case, an approximation based in a “state of the art” statistical approach. Real values can be different due to todays unobserved geological elements.

A.6 SUPPORT S-III'

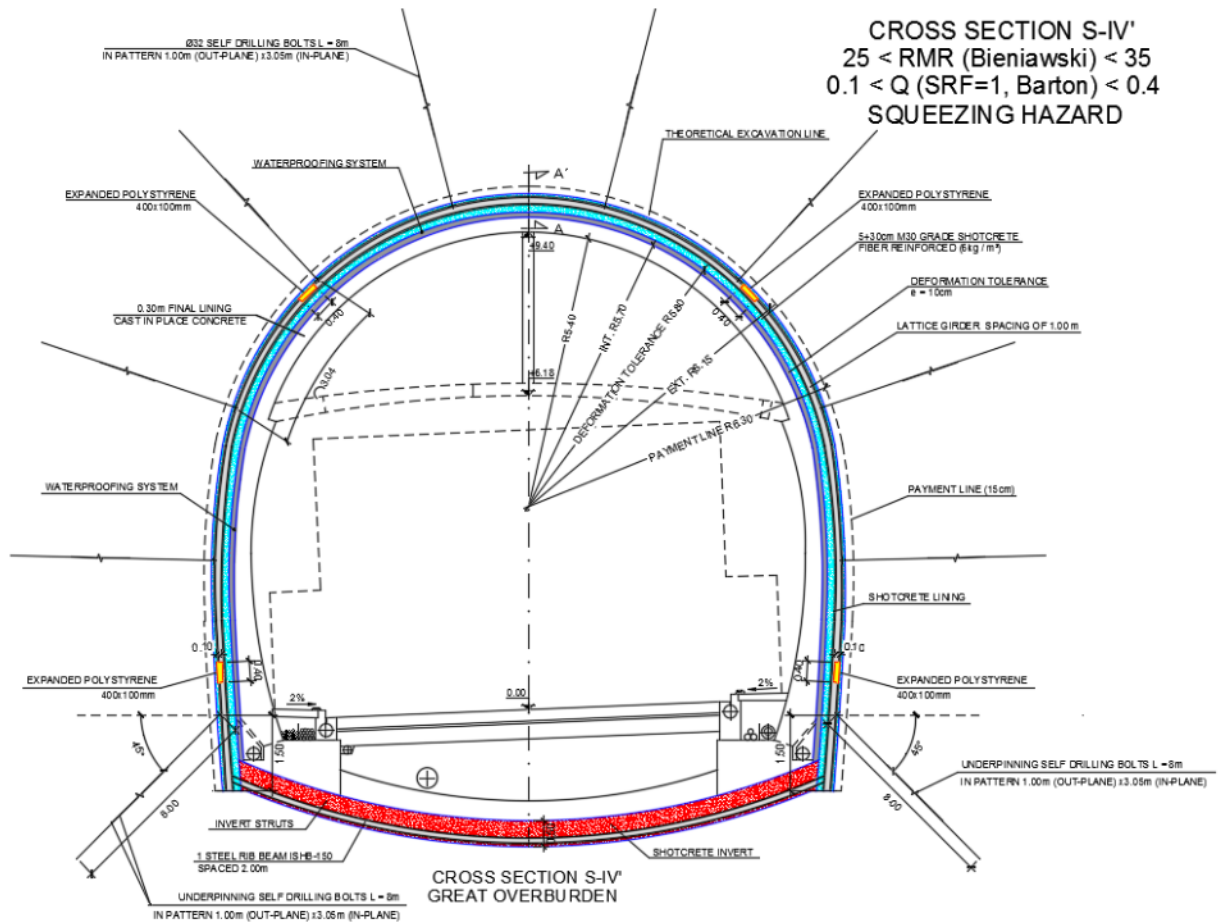
8



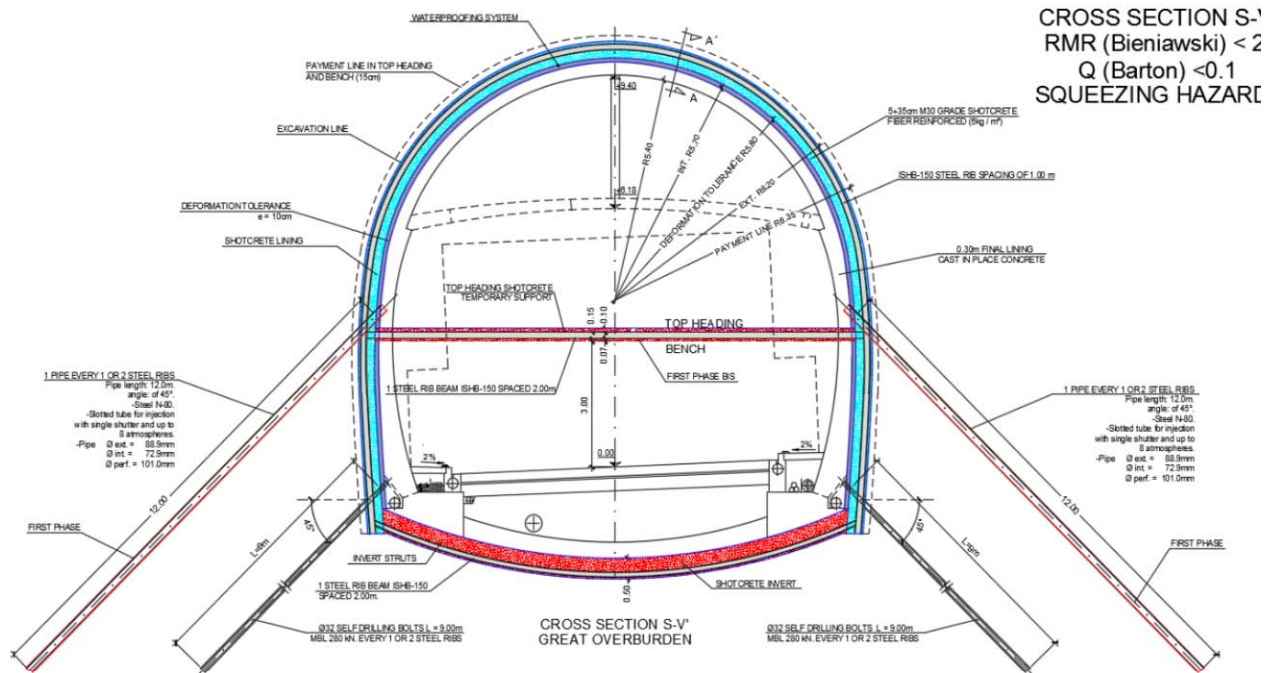
A.7 SUPPORT S-IV



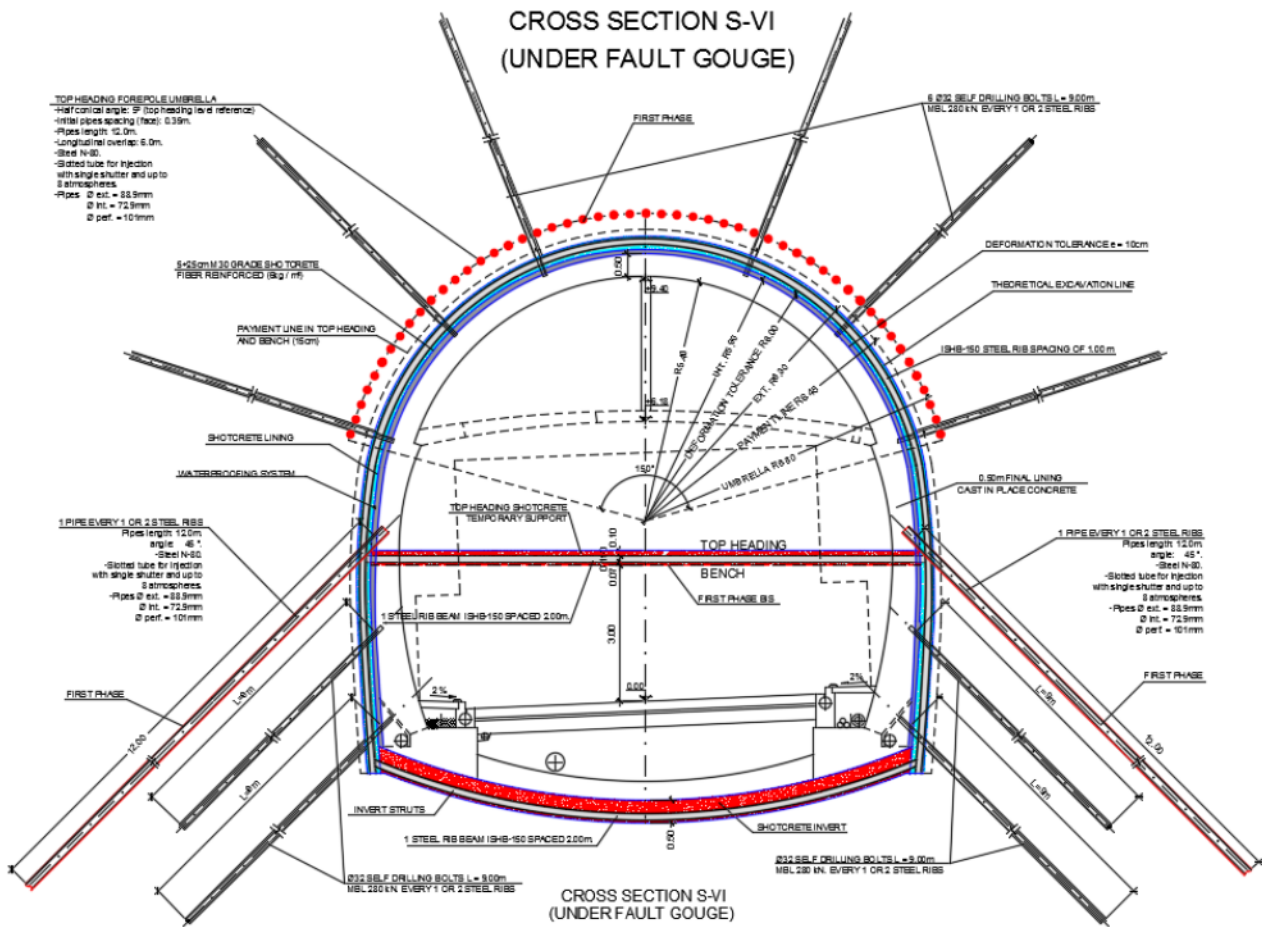
A.8 SUPPORT S-IV'



A.10 SUPPORT S-V'

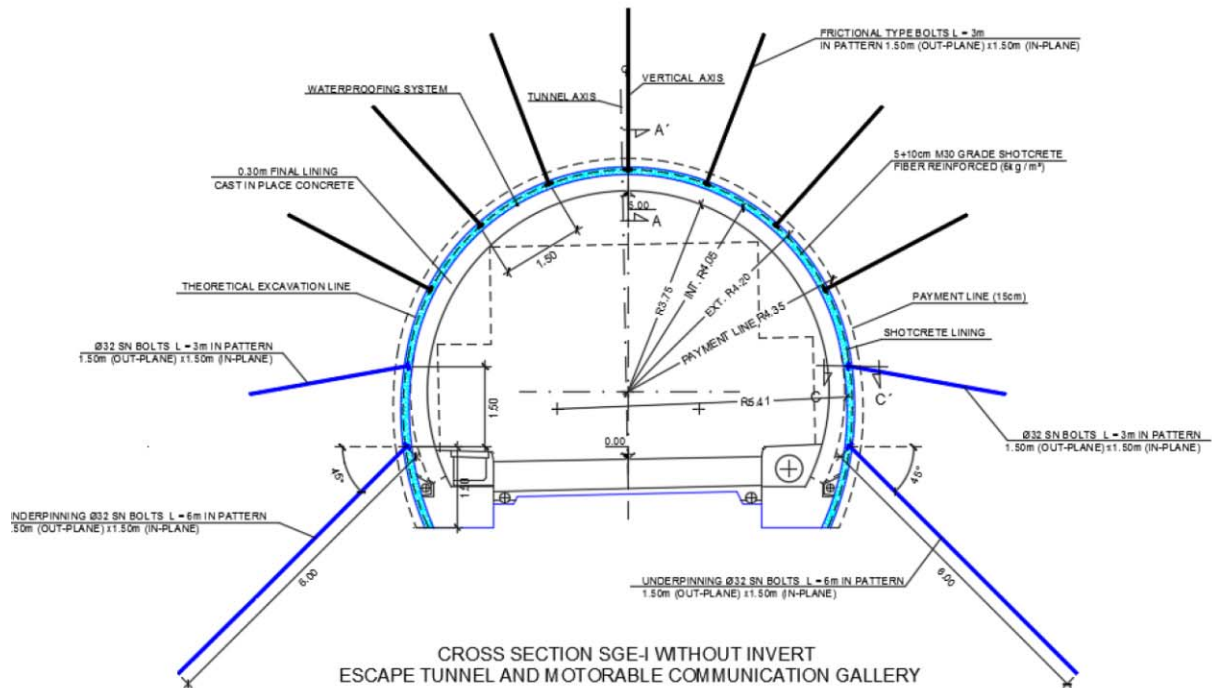


A.11 SUPPORT S-VI



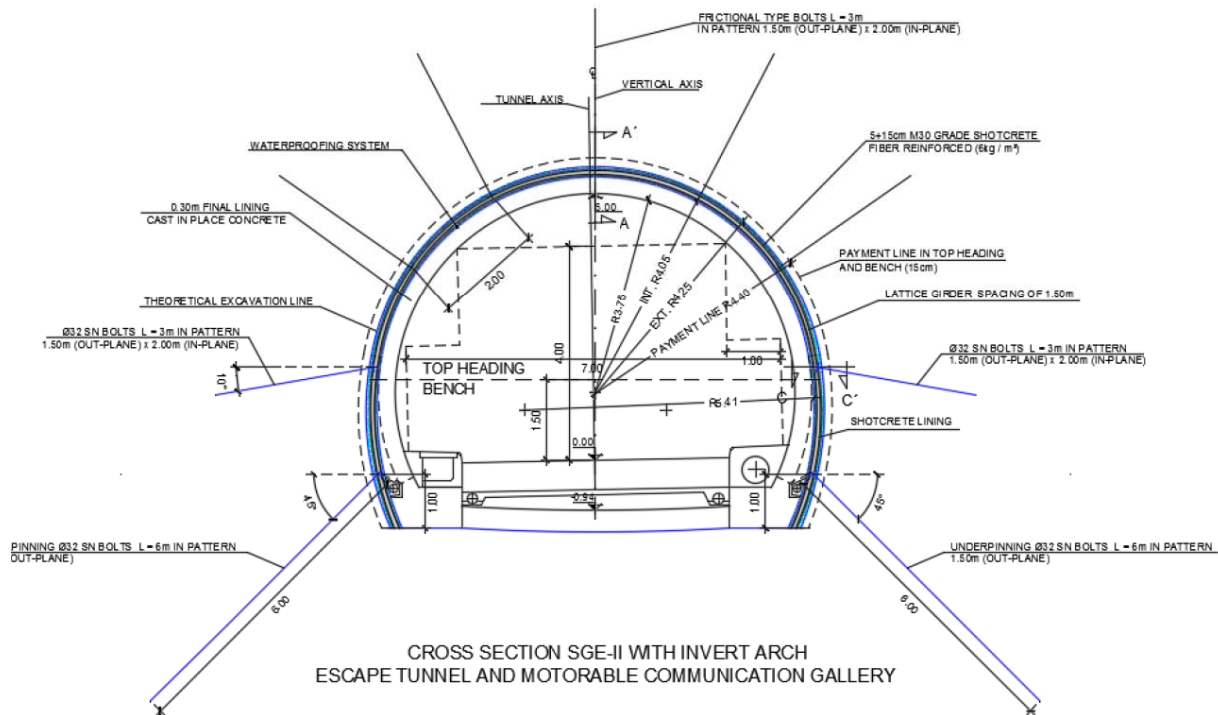
A.15 SUPPORT SGE-I

CROSS SECTION SGE-I RMR (Bieniawski) >40 Q (Barton) >1



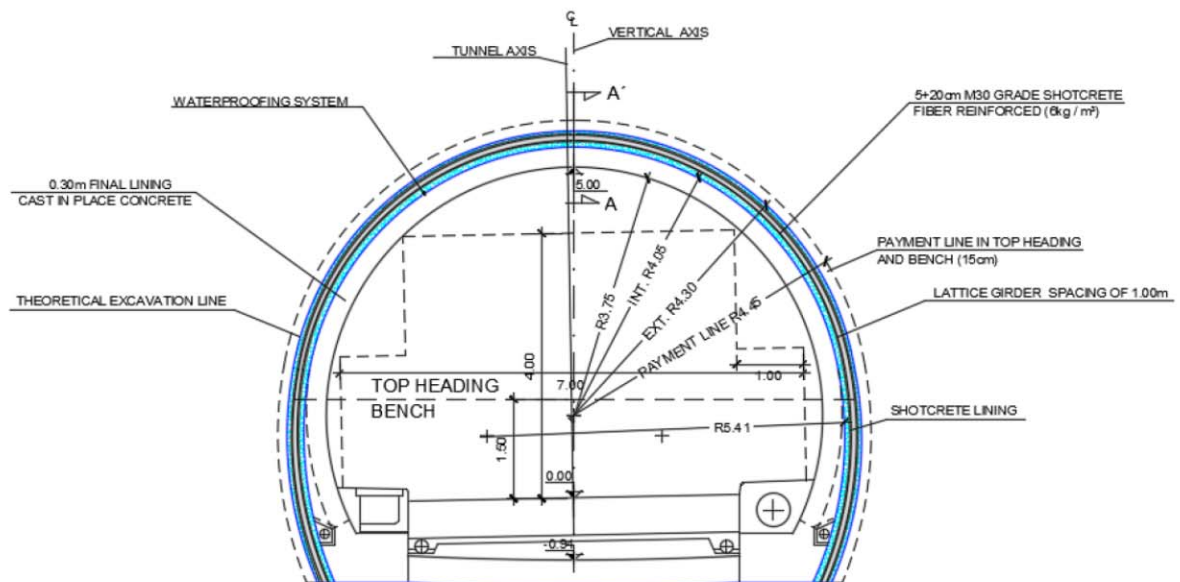
A.16 SUPPORT SGE-II

CROSS SECTION SGE-II
 $30 < \text{RMR (Bieniawski)} < 40$
 $0.08 Q (\text{Barton}) < 1$



A.17 SUPPORT SGE-III

CROSS SECTION SGE-III UNDER FOREPOLE UMBRELLA RMR (Bieniawski) <30 Q (Barton) <0.08



CROSS SECTION SGE-III WITH INVERT ARCH
ESCAPE TUNNEL AND MOTORABLE COMMUNICATION GALLERY

