Assessment of the rock mass of escape tunnel -a case study from lift irrigation project, Telangana State, India

Rawat, D. S., Naithani, A. K., Singh, L.G., Jain, P. and Patel, R.
Scientists, National Institute of Rock Mechanics, Bengaluru-560070, Karnataka, India
Babu, R.N.S.
Geologist, Aarvee Associates, Hyderabad-500082, Telangana State, India
Rao, G. S.
Deputy General Manager, Navayuga Engineering Company Limited, Hyderabad, 500033, Telangana State, India

Abstract

Engineering geological investigations were carried out for a 158.65 m long and 8.0 m diameter escape tunnel of Kaleshwaram Lift Irrigation Scheme Package-6 in Telangana State. For this project a deep underground pump house and transformer caverns were excavated, and to approach these structures, the escape tunnel was constructed. Tunneling was done with a drill and blast method using a jack hammer. The purpose of the escape tunnel is to enable people to get away on foot in an emergency due to fire or other accidents. On the ground, the portal of the escape tunnel is at RL +231.5 m and it is connecting at RL +139.0 m to approach the pump house and transformer caverns. The gradients were maintained at 1 in 2.069 and 1 in 1.577, to reach the required reduce level and minimize the length of the tunnel. The escape tunnel was constructed in granitic rock media of the Archean age. In this paper engineering, geological evaluation of rock mass of the escape tunnel is discussed. The support system is also recommended based on tunneling quality index ‘Q’. Weathering grade of rock mass was varying from W-I to W-II. A total of six joint sets plus random joints were mapped. 3D geological mapping was carried out for rock mass assessment and identification of the adverse geological features. The excavated tunnel rock mass encountered was categorized into good to poor categories as per tunneling quality index ‘Q’. Rock mass of portal area was categorized as poor rock class up to 8 m depth, which was supported by ribs. The excavation was very challenging due to its very high gradient.

1. Introduction:

Dr. B. R. Ambedkar Pranahita-Chevella-Sujala-Sravanthi has been split into two projects namely Dr. B. R. Ambedkar Pranahita project and Kaleshwaram project. The prior project consists of packages 1 to 5 and the Kaleshwaram project comprises packages 6 to 28. Dr. B. R. Ambedkar Pranahita project is envisaged to divert 40 TMC of water by constructing a barrage across river Pranahita near the confluence of Wainganga and Wardha rivers at Tummidihetti in Adilabad District for irrigating an ayacut of 2 lakh acres in East Adilabad District. The Kaleshwaram lift irrigation project, envisages diversion of 160 TMC of water by constructing a barrage across river Godavari, at Medigadda near Kaleshwaram in Peddapalli District i.e., below the confluence with river Pranahita and further conveying water to SripadaYellampally reservoir by constructing barrages at Annaram and Sundilla and thereafter providing irrigation facilities for an ayacut of 18.25 lakh acres in 7 districts of Telangana State (Prasad and Rawat 2011).
Package-6 of this scheme is being constructed to lift 146.24 TMC water from the Sripada Yellampalli reservoir to the Medaram tank situated near Dharmaram Mandal in Peddapalli District. The water needs to be lifted from the tunnel bed level at RL+ 109 m

to the Medaram tank at its FRL +230 m. Twin tunnels 10 m finished dia and 9.534 km long have been constructed to supply the water with the design discharge of 624.17 cumecs. Twin tunnels joined the surge pool cavern, from where draft tube tunnels leading to the pump house cavern have been constructed. Water will be lifted from RL+ 109 m to the cistern located at ground level RL +241 m with the help of 7 pumps and through pressure/delivery mains of 5 m finished diameter. Water from the cistern +241 m to the Medaram tank FRL +230 m will move through gravity. To lift the huge amount of water during the monsoon high capacity of pumps (7 x 124.4 MW) are being installed in the pump house cavern. The pump house cavern is 210.6 m long, 25 m wide and 50.3 m high and transformer cavern is 203.4 m long, 16 m wide and 27 m high have been constructed and mechanical and electrical work are being done. The longitudinal direction of the pump house cavern and transformer cavern is N312°. The escape tunnel is connected with both caverns for emergency and central air condition facilities purposes.

The escape tunnel is to escape the people in the emergency from the pump house and transformer caverns. It worked as exhauster for the deep pump house and transformer caverns during excavation. From this escape tunnel, with minimum time, one can reach into these deep caverns. Due to the high gradient, excavation was very difficult and hauling using bucket/trolley was risky.

2. Project site:

The project site is geographically falling between (18°47’19”N: 79°18’16”E) and (18°43’33”N: 79°13’06”E) in Peddapalli District. Salient features of the escape tunnel are given in Table 1.

Table 1
Salient features of the escape tunnel package 6, site of Kaleshwram Lift Irrigation Project

1.	The orientation of escape tunnel	N090-100^0
2.	Purpose of tunnel	Emergency escape and central AC facilities for the pump house and transformer caverns
3.	Length of the tunnel	158.65 m
4.	The diameter of tunnel	8.0 m
5.	Excavation method	Drill and blast with a jack hammer
6.	Drilling time/ face	5-7 hours
7.	Mucking time/ blast	10-15 hours
8.	Blasting cycle	25-36 hours
9.	Blasting pull	0.8-1.2 m
10.	Rock bolt length	2.5 m
11.	Rock bolt diameter	25 mm
12.	Type of shotcrete	Dry shotcrete
13.	Bucket capacity	2.7 m^3
14.	The width of the bucket rail track	0.8 m

15.	Total power consumption for bucket movement	125 KVA
16.	Maximum possible depth of drill holes	2.5 m
17.	Maximum explosive used/blast	30 -40 kg
18.	Total nos. of ribs at portal	9 ribs with 1 m space (c/c)

3. Regional and Project geology:

The area around the escape tunnel forms a part of Peninsular Gneissic Complex and is mostly occupied by older granitoids, younger intrusive granite and basic intrusive (Prakash and Sharma 2011). Regionally the escape tunnel area falls in seismic Zone-II of the seismotectonic map of India (IS code No. 1983 (Part-1)-2002). The area exhibits a gently undulated, rolling topography dotted with isolated hillocks/ inselberg. The whole area around the escape tunnel is covered by brown/reddish brown sandy silty soil. The overburden consists of brown /reddish brown sandy, clayey, gravelly soil. The rock exposed in the nearby area of escape tunnel is coarse-grained grey granite.

4. Excavation Methodology:

Excavation of the escape tunnel was done with a jack hammer for drilling and this method is generally applied for small drill and blast (DBM) or where mechanical drilling machine cannot approach (Picture 1, 2 and 3). The gradient was maintained at 1 in 2.069 from chainage 0.00 m to 69.367 m and 1 in 1.577 between chainage 69.367 m to 146.0 m (Figure 1), and due to this limitation drilling was performed with the help of jack hammer.

The excavation was done with heading and benching methodology. For face drilling two jack hammers were applied and each jack hammer was operated by three crew members. For the construction cycle i.e. drilling, loading, charging, blasting, defuming and mucking of each face required approximately 25-36 hours if there is no mechanical breakdown/problem was reported during a construction cycle. The mucking activity was the maximum time taking and difficult activity during tunneling. Mucking was performed with the trolley/bucket which had to move on the rail track where operation activity was very difficult with high gradients. Mucking was loaded manually by the crew and minimum 10-15 hours were required. After mucking process scaling was performed manually for removing loose parts from excavated rock mass.

5. Geotechnical evaluation of the escape tunnel:

3D geological mapping was carried out for the identification of adverse geological features and plotting of joints on 1:200 scale (Figure 2). The 3D geological map gives an idea of the rock mass. Adverse geological features are important information about rock mass where immediate or permanent rock support is required (Rawat et al. 2016). For the characterization of the rock mass into different weathering grade, ISRM (1978) classification was used. The assessment of 'Q' (Barton et al. 1974 and 1980) for the encountered rock mass was done. Maximum 15 m excavation was permitted and after that 3D geological mapping was done on a compulsory basis because with an increasing depth approach to crown becomes difficult to support the rock mass.

Picture 1 Manual mucking with bucket/trolley using rail track

Picture 2 Excavated view of the escape tunnel and rail track

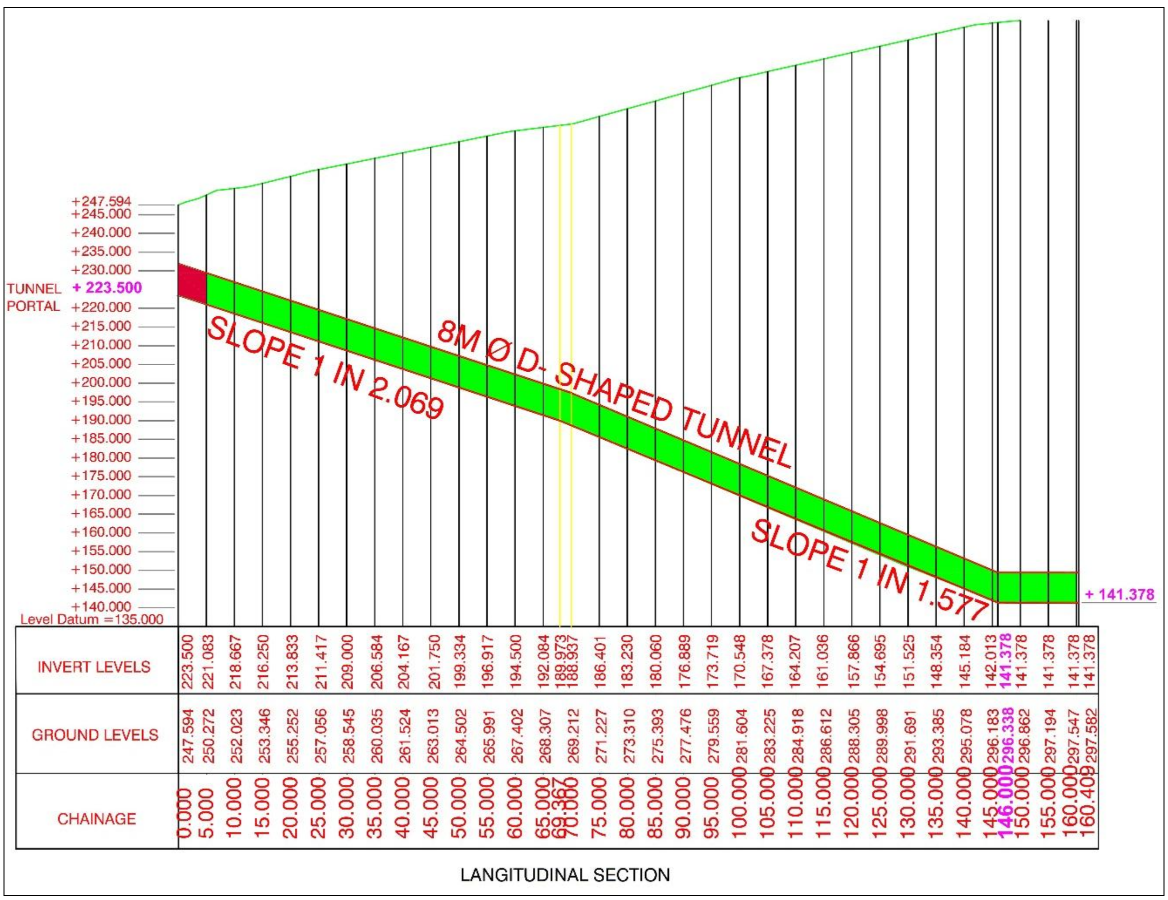


Figure 1 Longitudinal view of excavated escape tunnel

Volume XLII, Nos. 1 & 2
June-December 2017

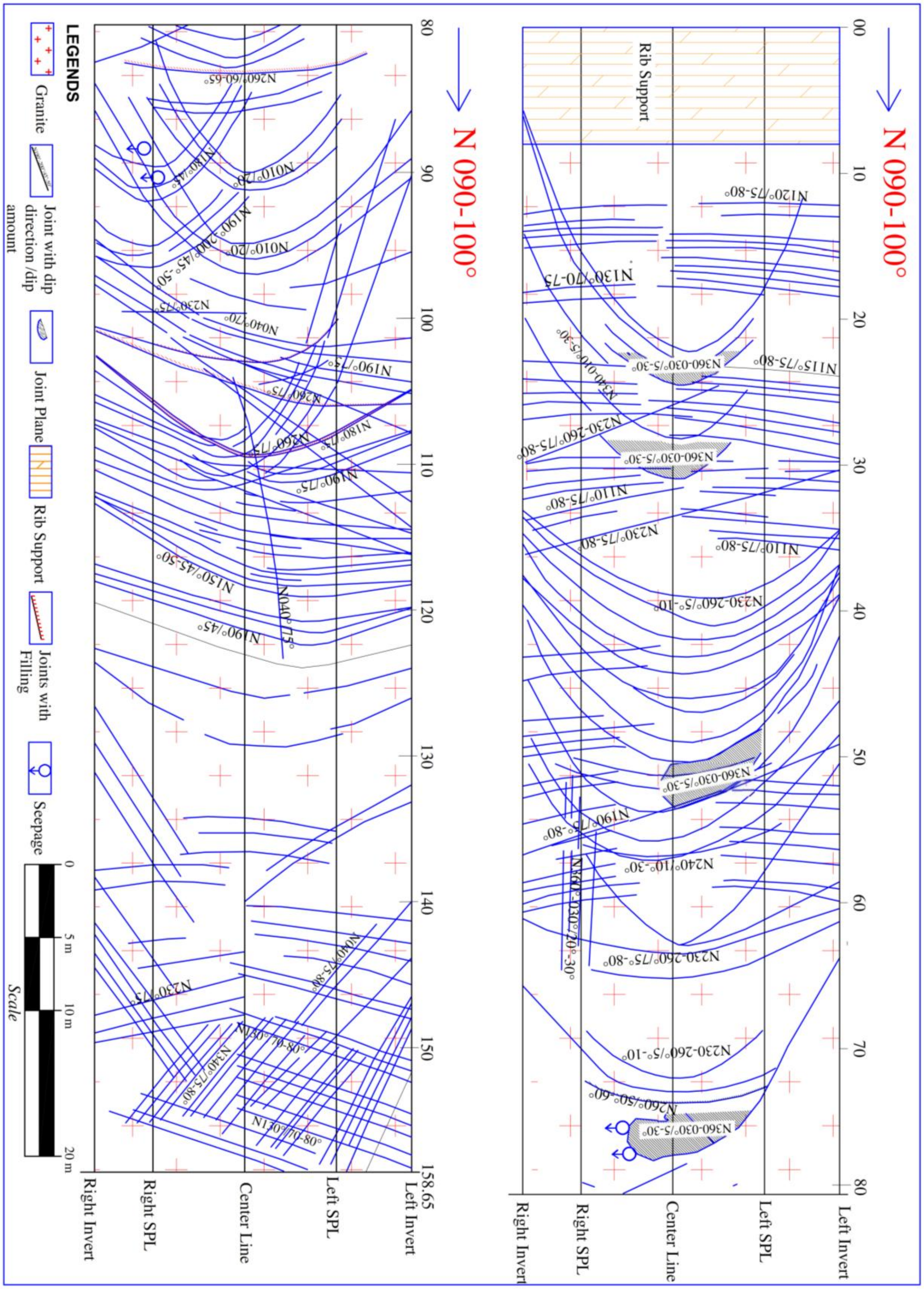
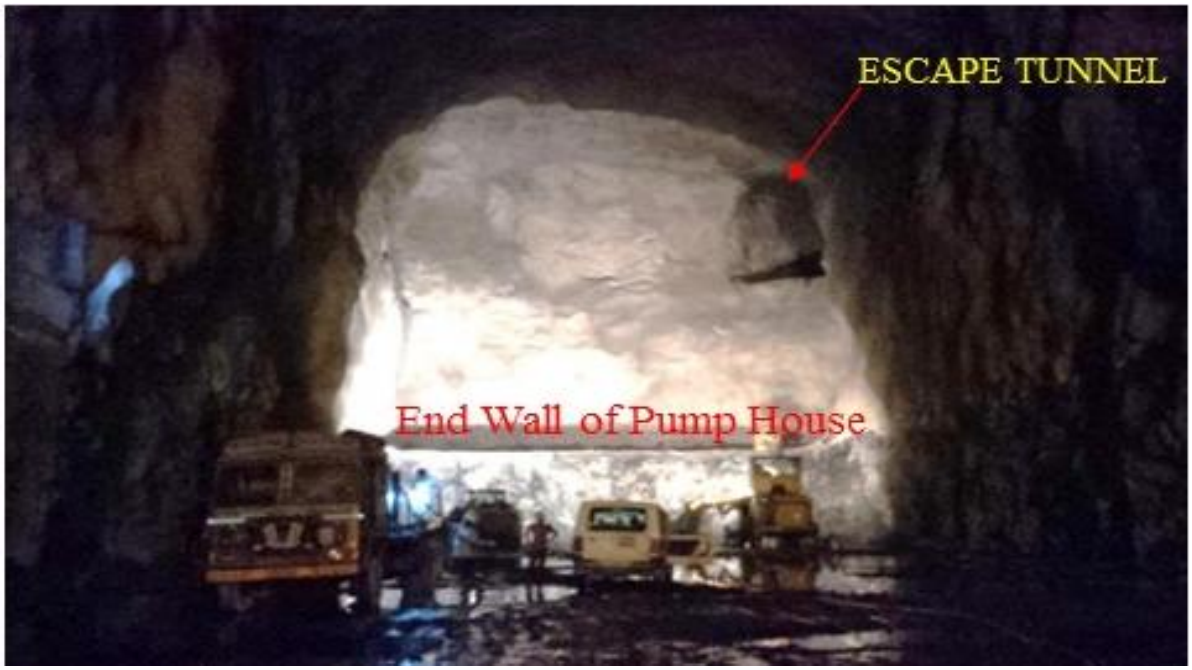


Figure 2 3Dimensional geological mapping of the escape tunnel



Picture 3 Meeting point at junction of the escape tunnel in pump house

Excavation of portal area was done at RL +231.5 m where two joint sets plus random joint were mapped. Joint roughness (Jr) encountered smooth planar and joint alteration encountered slightly altered in nature. Joint volume (Jv) were counted 12 and the stress reduction factor (SRF) was taken 2.5 for the portal area (0.0 to 8.0 m). Q was estimated 3.17and categorized into poor rock class. The rock mass was supported with total 9 numbers of ISMB200 ribs with 1 m c/c spacing. The ribs supported area was backfilled with M30 grade concrete.

A total of six joint sets plus random joints were encountered in the entire tunnel (Table 2). Joint N360-030°/5-30° on the crown level is persistence in nature and joints volume was also observed moderate to high (Figure 2). On the crown level, these joints were observed as slabbing. All encountered joints were studied and shown in (Figure 3-5).

Joint sets at every 5 m circumference were taken for Q value calculation and a maximum of two joint sets plus random joints were considered for the entire tunnel. RQD was calculated based on the joint volume of rock mass which is ranges 75.5-95.2. Joint volume (Jv) ranges between 6-12 and Joint roughness (Jr) of the entire tunnel were observed rough irregular planar to smooth planar in nature. Joint alteration (Ja) of the entire tunnel area encountered fresh to slightly altered in nature. The excavation was done with dry tunneling media and only a few locations i.e. at chainage 74 to 78 m and 88 to 90 m, damp to dripping conditions were observed. The stress reduction factor was taken 1.0 between 9.0 and 158.65 m chainage. Tunneling quality index ‘Q’ is ranging from 11.48 to 18.9 between 9.0 to 158.65 m chainage. Encountered rock class and percentage of the escape tunnel is given in (Table 3).

Table 2
Details of joint sets mapped during excavation

Joint Sets	Dip direction/ Dip Amount	Spacing (cm)	Persistence (m)	Roughness	Aperture (mm)	Infilling	Ground Water
Joint-1	360-030/5-30	20-300	>15	Rough Irregular Planar	Tight-2	Non softening material	Dripping at Ch. 74, 78 and 88 to 90 m on right side crown.
Joint-2	230-260/75-80	50-200	>8	Rough Irregular Planar	Tight-3	None	Dry
Joint-3	110-130/70-80	30-100	5-10	Smooth planar	Tight-2	None	Dry
Joint-4	240-270/5-30	30-300	15-20	Rough Irregular Planar	Tight-2	None	Dry
Joint-5	260/50-75	30-200	>8	Smooth Undulating	2-3	Non softening material	Dry
Joint-6	040-070/70-80	35-120	5-10	Rough Irregular Planar	Tight-2	None	Dry
Joint-7	190-210/75-80	Random	10-20	Rough Irregular Planar	Tight-2	None	Dry
Joint-8	170-200/45-50	Random	5-10	Smooth Undulating	Tight-2	None	Dry

Table 3
Rock class percentage encountered from the escape tunnel

Site Location	Total Excavated Length (m)	Rock Class 1 Q: 40-100		Rock Class 2 Q: 10-40		Rock Class 3 Q: 4-10		Rock Class 4 Q: 1–4		Rock Class 5 Q: 0.1-1	
		Length (m)	%	Length (m)	%	Length (m)	%	Length (m)	%	Length (m)	%
Escape Tunnel	158.6	-	-	150.6	95	-	-	8.0	5	-	-

6. Rock support system:

Excavation/ rock support was done based on the Norwegian Method of Tunneling (NMT) and site geological condition. As per design drawing, fair and poor rocks need to be supported with rock bolts and rib support respectively. Horizontal joints with aperture >2 mm mapped on the crown portion were immediately supported with spot bolts of 2.5 m length. From chainages 19 to 30, 47 to 50 and 65 to 85 m the area was supported with immediate spot bolts in view of sub-horizontal joints. Spot bolts installation were also done immediately after each blast, wherever rock mass was observed unstable/vulnerable at various tunnel reaches. After each blasting, muck was leveled wherever rock mass observed unstable and then rock bolts were installed. Initial eight meters of the portal area of the escape tunnel was supported by ribs of ISMB 200 and back filling was done with M30 grade concrete. The rock mass for this tunnel reach (0.0 to 8.0 m) was classified into the poor rock. 95% area of escape tunnel was supported with spot bolts where rock mass was classified as a good rock (Figure 6). The diameter of the rock bolts used was 25 mm. Two layers of 50 mm + 50 mm thick dry shotcrete were applied after the entire tunnel excavation of escape tunnel i.e. up-to 158.65 m with the help of scaffolding.

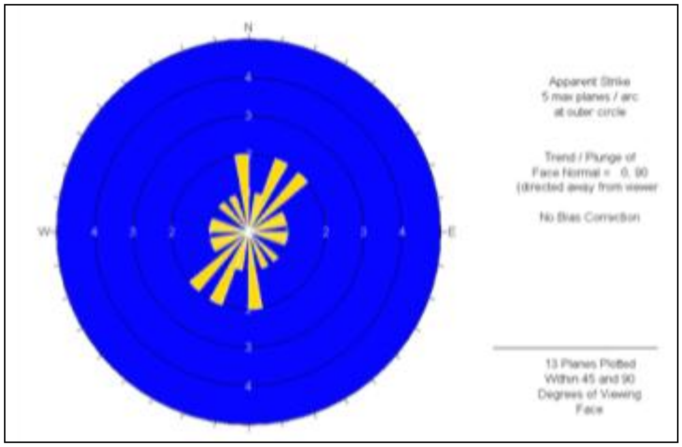


Figure 3 Rosette plot of joints

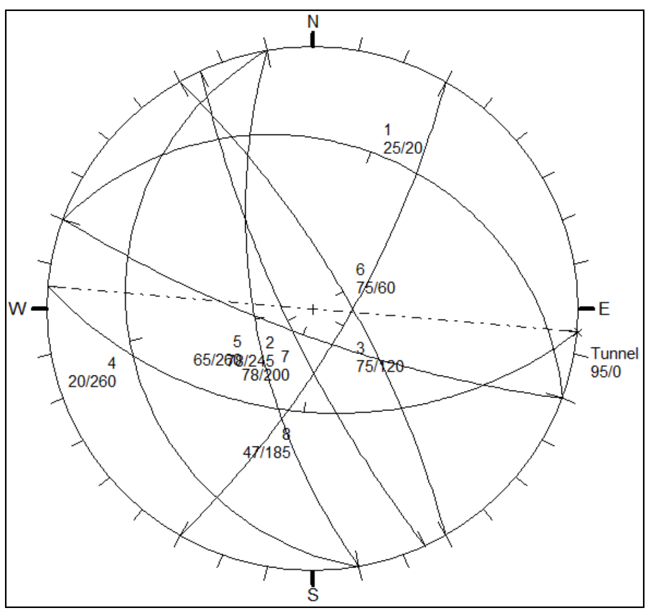


Figure 4 Stereo plot of joint sets

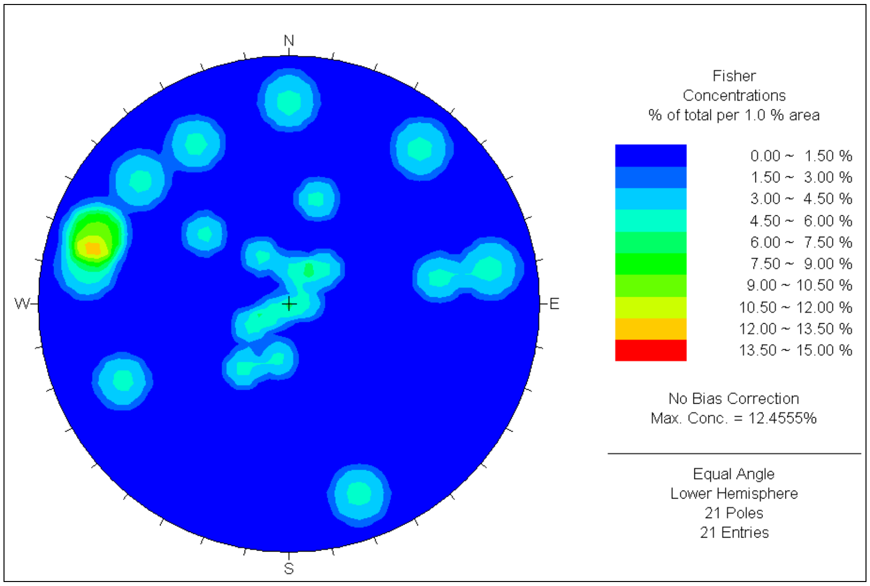


Figure 5 Density stereogram of joint sets poles

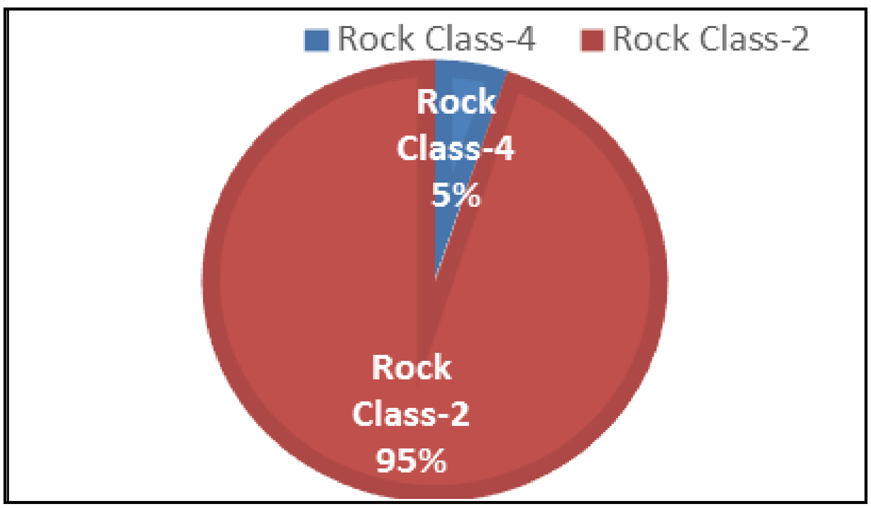


Figure 6 Graphical representation of rock class

7. Conclusions:

The main purpose of the escape tunnel for this project is to reach a deep excavated pump house and transformer caverns which are 50.3 and 27.0 m deep respectively. To reach these structures from the main access tunnel the length is more than 1500 m, and in any emergency alternate shortest route is required to escape the people from these deep underground caverns. During the excavation of deep underground caverns, providing ventilation is one of the challenging issues at the deep level to exits fumes. Fumes is the pollution by heavy machinery and blasting activity. With the help of an escape tunnel, the ventilation duct was easily managed and the ventilation fan worked more efficiently to exhaust the toxic gases due to its short length. This is an alternate way to reach the deep excavated areas during the excavation of caverns. Only 158.65 m tunnel length was excavated to reach the required level at the pump house and transformer caverns, but the gradient becomes high. The additional purpose of the escape tunnel is to connect the electrical cable from the switchyard and central air conditional system from the central plant to the pump house and transformer caverns. The excavation was challenging but it was completed without any unforeseen event because of the detailed engineering geological investigations and teamwork by Civil, Mechanical and Electrical Engineers.

8. Acknowledgements:

The first five authors are thankful to Mr. Sivakumar Cherukuri, Director NIRM (Additional Charge) for permission to send the manuscript for publication and encouragement. This paper is prepared from the project work sponsored by NECL, so we sincerely thank the Management of NECL for the same. We also sincerely acknowledge the support extended by Mr. P.V. Rama Rao, Director, Mr. Jala Chandrudu, Senior DPM; Mr. Ranga Babu DPM, Mr. M. Ahamed, site Engineer and Mr. Ganga Raju, Senior Surveyor from M/s NECL.

References:

1. Barton, N., Lien, R. and Lunde, J., (1974). Engineering classification of rock masses for the design of tunnel support. *Rock Mech.*, 6, (4) 189-236.
2. Barton, N., Loest, F., Lien, R. and Lunde, J. (1980). Application of the Q- system in design decisions concerning dimensions and appropriate support for underground installations. *Int. Conf. on Sub-surface Space, Rock Store, Stockholm.* Vol. (2) 553-561.
3. IS code No. 1983 (Part-1)-(2002). Criteria for earthquake resistant design of structures, part 1-general provisions and building. *Bureau of Indian Standards*, New Delhi, 36
4. ISRM (1978). Suggested methods for the quantitative description of discontinuities in rock masses. *Int. Jour. of Rock Mech. Science and Geomech. (Abstract), Pergamon.*, 15, No. (6) 319-368.
5. Prakash, D. and Sharma, I.N. (2011). Metamorphic evolution of Karimnagar granulite terrane, Eastern Dharwar Craton, South India. *Geol. Mag.*, (48), 112-132.
6. Prasad, G.J.S. and Rawat, B.P. (2011). Report on feasibility stage geotechnical investigation for twin tunnel from the Sripada Yellampally reservoir to Nandimedaram tank, Dr. B.R. Ambedkar Pranahitha - Chevella Sujala Shravanthi package-6 Karimnagar District, Andhara Pradesh. *Unpublished Geol. Sur. of India report, FS 2008-09 & 2010-12 Southern Region, Hyderabad.*
7. Rawat, D.S., Naithani, A.K., Patel. Rajesh and Samuel, P. A. (2016). Prediction of adverse geological features based on the construction stage geological mapping: a case study of underground cavern, Karimnagar, Telangana State, India. *Indian Jour. of Power and River Valley Development*, 103-109.