Geotechnical Evaluation of Design Parameters for Use in the Tunnel Boring Machines of Srisailam Left Bank Tunnel with the help of Satellite imageries Mahaboobnagar District, Andhra Pradesh

K.C.C. Raju

Abstract

The Government of Andhra Pradesh has taken up a decision to implement the Srisailam Left Bank Canal Scheme under which it is envisaged to irrigate 3.00 lakh acres in the chronically drought affected areas of Nalgonda district and also provide drinking water to Nalgonda town and fluoride affected villages enroute by drawing 113.28 cumecs (4000 cusecs) of water from Srisailam Reservoir. (This paper deals with the geotechnical evaluation with the help of Satellite Imageries and geological data studied from limited traverses and computing of the parameters required for the tunneling of this 43.420 km long and 9.2 m dia tunnel by the Tunnel Boring Machines available due to environmental restrictions imposed.) This tunnel is aligned in an almost N-S direction up to outlet portal from where water will be led into the proposed Dindi Balancing Reservoir.

The geological studies have indicated that Kakletvagu quartzites of Srisailam Quartzite formation of Cuddapah Super Group are likely to be the tunneling media from entrance portal to Ch. 25.590 km. In the remaining stretch from Ch.25.590 to Ch. 43.420 km, granites belonging to the Archaeans will be tunneling media. The geotechnical evaluation with attendant problems is discussed based on the geology and Rock Mass Classification. The tunnel reaches of the tunnel are grouped under three classes – Class-I- Very Good, Class-II-Good and Class III- Fair and the problems likely to be encountered and support system required has been worked out and provided.

Based on the rock properties worked out from the laboratory testing of the rock samples of both quartzites and granites, the cutters of required strength for the TBMs have been designed. The tunneling media is however grouped into two classes for ease of construction and the prefabricated and pre-stressed concrete lining segments are thus designed.

Introduction

The Government of Andhra Pradesh has commenced the work on the Srisailam Left Bank Canal Scheme to irrigate 3.00 lakh acres in the chronically drought affected areas of Nalgonda district and also provide drinking water to Nalgonda town and fluoride affected villages enroute. Under this scheme it is envisaged to excavate a tunnel of 9.2 m diameter and 43.420 km length with a slope of 1:3200; in an almost N-S direction, designed to discharge 113.28 cumecs (4000 cusecs) of water from Srisailam reservoir starting in the immediate foreshore of Srisailam dam and with its exit in the foreshore of the proposed Dindi Reservoir from where Tunnel No.2 will take-off (Fig.1).

This paper deals comprehensively with all the required geotechnical aspects of the Tunnel No.1 and provides basic inputs for the design of the tunnel, Tunnel Boring Machines (TBM) and the design parameters for two sets of precast segments for use in the lining.

Location and approach

The Neelam Sanjeeva Reddy Sagar Project (Srisailam Project)

Geotechnical consultant

(16⁰ 05': 78⁰ 54'; 56L/16) is located 200 km south-east of Hyderabad City, the Capital of Andhra Pradesh State. The town nearest to the S.L.B.C. Project is Srisailam Project Colony. The nearest Rail Head is Jedcherla on Hydearabad-Bangalore Broad Gauge line of South Central Railway and is about 110 km from the centre of the tunnel line. There is a good network of roads already existing connecting the Srisailam Project with Hyderabad, Guntur and Kurnool.

The nearest airport is Hyderabad which is well connected by air with all important cities of India. It is also an International Airport.

Regional geology and structure

Regional geology

Andhra Pradesh forms part of the South Indian Peninsular Shield. The bulk of the rocks occurring in Andhra Pradesh belong to the Precambrian Age represented both by Achaeans and the Proterozoic Eras; together constitute 85 % area of the State. The rest of the 15 % area is occupied by the rocks belonging to the Phenerozoic Eon.

The Regional Geological setting around the Srisailam Left Bank Canal Project shows that Peninsular Gneissic Complex of Archaeans and Srisailam Quartzites would form the tunneling media. Srisailam quartzites are likely to be the tunneling media in the initial reach of 25.590 km of the tunnel of 43.420 km length; while the remaining part of the tunnel would be in granites and associated intrusive dolerite dykes of Archaeans.

The litho-stratigraphic succession of these formations is given in the table.

Table 1: Litho-stratigraphic succesion of Cuddapah Super Group

Group		**Formation**	**Lithology**	**Thickness (m)**
2				
KURNOOL GROUP				
		----------------	---------------- Unconformity ----------------	
		Srisailam Quartzite		
CUDDAPAH SUPER GROUP		----------------	---------------- Unconformity ----------------	
		Cumbum (Pullampet)	Phyllite, slate,quartzite,dolomite,(kimberlite,lamprophyre	
			syenite),Pullampet shale (Ba- rich acid volcanics,tuffs)	2000
			dolomite,quartzite	
	Nallamalai	Bairenkonda (Nagari) Quartzite	Bairenkonda Quartzite,shale,Nagari conglomerate,	1500
			Quartzite and shale with intrusives	4000
		----------------	---------------- Angular Unconformity ----------------	
		Gandikota Quartzite	Quartzite, shale (Sills of Olivine dolerite)	3300
	Chitravati	Tadipatri	Shale, ash-fall tuffs, qurtzite, dolomite with intrusives (flows sills, ignimbrites, tuff)	4600
		Pulivendula Quartzite	Conglomerate and Quartzite	1.75
		----------------	---------------- Disconformity ----------------	
	Papaghni	Vempalle	Stromatolitic dolomite, dolomite, dolomite mudstone,	
			chert breccia, quartzite with basic flows and intrusives	1900
			(Tholeitite and esite, spilite, dolerite)	
		Gulcheru Quartzite	Conglomerate, arkose, quartzite and shale	28 - 210
		----------------	---------------- Eparchaean Unconformity ----------------	
		Granites and associated dolerite dykes	Archaean gneisses / greenstones	

Structure

Andhra Pradesh forms the north-eastern part of the Peninsular Indian Shield. The tectonic elements that characterize the State are:

a) The Eastern Block of Dharwar craton,

b) The Marginal Transition Zone (MTZ),

c) The Godavari Graben and

d) The Eastern Ghat Mobile Belt.

More than 60 % of the State is made up of the eastern part of the Dharwar craton. Over two thirds of the Eastern Block lies within Andhra Pradesh. More than 10% of the cratonic part is occupied by the Proterozoic platformal basins viz., the Cuddapah, Pakhal and Bhima.

The western half of the Cuddapah Basin including the Srisailam plateau displays minimal deformation with sub-horizontal or gentle quaquaversal dips of formations. These dips define the shapes of the Papaghni and Srisailam basins.

Local geology

Geomorphology

Geomorphologically the area encompassing the project can be classified as flat topped hills forming plateaus and valleys. Apart from these, a few small structural hills formed of north-easterly plunging folds are present close to the Krishna River.

The flat-topped hills constituting the plateaus are dominant in the area and are formed of Srisailam Quartzite. The average altitude of the plateau is above 800 m above mean sea level (msl) up to Narasimhulu Vagu. The level from here drops towards Dindi river. The elevation of the plateau south-west of Ghanpur is above 540 m above msl. The plateau level further drops to around 450-500 m above msl north of Dindi river in the Madhawaram-Chitrial area.

The major streams with well developed valleys which occur along the tunnel alignment are Nalla vagu, and Narasimhulu vagu. These and other drainage courses in the area are all east flowing. The Nalla vagu and Dindi rivers appear to have carved their courses along fault/shear zones.

The general drainage in the area is parallel to sub-parallel with rectangular drainage at places. The drainage pattern of the Krishna River and its deep gorge formed of quartzites appears to be lineament/joint controlled and the down cutting of the Krishna River could have kept pace with the upliftment.

Geology

The area encompassing the S.L.B.C. Project is formed of Peninsular Gneissic Complex of Archaeans and sedimentaries of the western margin of Cuddapah basin. The sedimentaries belong to Srisailam formation overlying the granites with an unconformity with thin conglomerate at a few places. The stratigraphic succession in this area is as given below.

On the basis of lithology, the Srisailam formation is divided into three sub-divisions. These are (i) Igalpenta Quartzite, (ii) Tapasipenta Siltstone and (iii) Kakletvagu Quartzite.

The Igalpenta Ouartites are known to be an intercalated sequence of quartzites and shales. The quartzites are reddish brown, grey and pinkish white in colour. They are ferruginous and glauconitic. They are generally massive. They are generally sub-

Table 2: Stratigraphic succession in the project area

SRISAILAM FORMATION	Igalpenta Quartzite Tapasipenta Siltstone Kakletvagu quartzite
———Unconformity———	
ARCHAEANS	Granites with intrusive basic dykes

horizontal, the dip towards N to NNW. These quartzites are not encountered in the proposed tunnel alignment.

The Tapasipenta siltstones are red to purple in colour, ferruginous, calcareous, flaggy and thin bedded. The beds are sub-horizontal with dips of the order of 5^0 to 10^0 towards SE. These occur as a thin strip of 1.5 to 3.00 km width away from the entrance portal and are not likely to be encountered in the proposed tunnel.

The Kakletvagu quartzites overlie the granites of Archaeans with an unconformity marked at places with conglomerate at the contact zone. The base of the quartzite is often pebbly, indicating the shallow nature of the basin initially.

The Kakletvagu quartzites are extensively exposed along the tunnel alignment are the main rock type to be met with in the Tunnel No.1. They are brownish to grey in colour, hard and massive to blocky in nature. The thickness of the individual beds is about 0.50 m, in general. The quartzites are often ferruginous. They are horizontal to sub-horizontal in disposition with northerly or southerly dips, and exhibit gentle culminations and depressions. These culminations and depressions appear to be related to basement configuration rather than to any major tectonic activity.

The Kakletvagu quartzite is jointed. All the major and minor sets of joints are vertical in disposition. The major sets of joints are 0.50 to 1 m apart. The minor joints are more than one metre apart and appear to be discontinuous. Although these joints are open at surface, they close down and become tight with depth. These joints are tabulated.

Based on the detailed interpretation of Landsat imageries with limited ground data, the quartzites are further sub-divided and presented as Fig.2. These sub-groups are described under the chapter on geotechnical evaluation assigning relevant classification for designing support system.

The Granites belonging to the Archaeans are likely to be met with along the alignment of the tunnel at about 2.590 km, north of Tirumalapur and this contact zone is at an elevation of around 545 m above msl. These granites are grey to pink in colour and appear to be generally porphyritic.

These older granites (Archaeans) are intruded by younger granites at places. These younger granites are equi-granular in texture and appear more like granulites. Dolerite dykes are quite common in the older granites and this intrusion of dykes appears to be in two phases.

The older dykes are sheared and weathered and often permeated by quartz and pegmatite veins. These are generally subdued in topography and flush with the surrounding topography. The younger dykes on the other hand are fresh and hard and stand out as ridges and linear hillocks. These two generations of dykes trend in N-S to NNW-SSE and NE-SW directions (Fig.2). These are not observed to be intrusive into the quartzites indicating that they are pre-Cuddapah in age.

Table 3: Major & minor sets of joints in kakletvagu quartzites

Sr. No	Strike	Dip	Remarks
1	N-S	Vertical	Open at surface- often with ferruginous encrustations
2	E-W	Vertical	Open at surface- often with ferruginous encrustations
3	NW-SE	Vertical	Open at surface- some places filled with ferruginous encrustations
4	NE-SW	Vertical	Open at surface- some places filled with ferruginous encrustations
5	NNE-SSW	Vertical	Minor – open at surface
6	NNW-SSE	Vertical	Minor – open at surface
7	WNW-ESE	Vertical	Minor – open at surface
8	ENE-WSW	Vertical	Very minor

The granites are traversed by faults and shears at a number of places. The Nallavagu and Dindi river courses seem to be running along the faults/shear zones.

A number of natural springs are noticed along the river course. Profuse quartz veins often tygmatically folded occur along the course of the river. The fracturing and jointing is fairly intense. These are all considered to be the manifestations of faulting.

Dindi river is known to be following a fault zone. Shearing in the granites is prominently observed in the river course. The base of the quartzites north of Dindi river is at about R.L. 400 m; 100 m lower than what is observed south of Dindi river which is at about R.L. 500 m. At the Srisallam dam, the deep drilling has indicated that quartzites continue even below R.L. 0.00. These facts show that the central block lying between Dindi river and Nallavagu is an up-thrown block making it horst between two faults.

Geological appraisal of the tunnel no.1

Tunnel no.1

The salient features of the Tunnel No.1 are tabulated.

The Tunnel No.1 is 43.420 km in length. The contact between the Kakletvagu quartzite and the granites is exposed around Ch.29.50 km along the alignment. This contact as already stated is an unconformity. This erosional surface as per field indications would be sloping very gently towards south. Based on the field studies and the geological setting, the slope is considered to have an angle of 5^0 towards south. In such a case, the granite interface with quartzite overlying it would be at about R.L.260 m from Ch.25.90 km onwards, which means that granite would be the tunneling media from Ch.25.90 km to Ch.43.420 km.

Granites with associated dolerite dykes would form the tunneling media of the tunnel from the granite/quartzite interface. Granite is generally considered to be good to very good media for the tunnels. The horizontal joints will not be present in the granites and the normal jointing is not likely to be any problem in tunneling.

Major faults like the Narasimhulu Vagu fault and others may pose problems in the reaches with intense shearing and fracturing. Profuse ground water is likely to be encountered in such zones.

The lithological units interpreted along the tunnel alignment and depicted in the geological map (Fig.2) are tabulated:

The slope of interface between Basement consisting of granites and gneisses belonging to the Peninsular Gneissic Complex and Srisailam Quartzites of Cuddapah Supergroup has not been accurately determined, which required drilling a few

Table 4: Salient features of the two tunnels of sibc

Sr. No.	DETAILS	TUNNEL NO.1
1	Shape of tunnel	Circular
2	Finished diameter	9.20 m
3	Straight Length(Approximate)	43.50 km
4	Carrying capacity	113.28 cumecs (4000 cusecs)
5	Surface fall	1 in 3200
6	Velocity	1.951 m/sec
7	Lining	Cement concrete
8	Invert level at tunnel entry	+ 251.351 m
9	Exit level of tunnel	+ 237.762 m
10	F.R.L. of Srisailam reservoir	+ 269.75 m
11	Minimum drawdown level of Srisailam Reservoir for Head Regulators of SLBC	+ 260.30 m
12	F.R.L. of Dindi Balancing Reservoir	+ 245.00 m

Table 4: Lithological formations interpreted along the tunnel alignmnet

Sr.No	Formation	Chainage in km		Length in km
		From	To	
1	Quartzite with shale (Quartzite dominant)- **3G**	0.00	7.900	7.900
2	Quartzite with shale (Shale dominant)- **3F**	7.900	14.000	6.100
3	Quartzite with shale (Calcareous)-**3E**	14.000	18.200	4.200
4	Quartzite with shale (Shale dominant)- **3D**	18.200	19.300	1.100
5	Quartzite with shale (Quartzite dominant)- **3C**	19.300	26.150	6.850
6	Quartzite with shale as ridges at the margin of basin- **3A**	26.150	29.500	3.350
7	Granite	29.500	29.850	0.350
8	Quartzite as capping over granite-**3A**	29.850	31.850	2.000
9	Granite	31.850	34.075	2.225
10	Quartzite as capping over granite-**3A**	34.075	38.500	4.425
11	Granite	38.500	38.800	0.300
12	Quartzite as capping over granite-**3A**	38.800	40.400	1.600
13	Granite	40.400	43.420	3.020

holes. However, based on the interpreted surface geology, projections of pairs of contacts, formational dips of quartzite and drilling data of Srisailam Dam, three alternative sections have been studied and the interfaces worked out. The interface with 2^0 of slope is worked as at Ch.19.705 km.

Tunneling methods

Conventional methods of drilling and blasting and Tunneling Boring Machines (TBM) are the methods available. For an ideal TBM application, geotechnical exploration is required to compute Rock Mass Characteristics, which would form rational basis for design, excavation and in the absence of such data for this project, recourse is taken to interpretation of Satellite Imagery with limited traverses to obtain ground data, collection of identical rock samples and working the joint pattern to compute and provide identical data which could be applied for this project.

The tunneling conditions in quartzites and granites are dealt in more detail in the following chapter. The entire tunnel reach of 25.590 km in quartzite is categorized into three classes and anticipated problems and the required support system are discussed. Rock properties that affect tunneling fall into six broad groups and these are:

(i) Rock strength,

(ii) Chemical Composition,

(iii) Discontinuities

(iv) Rock bedding

(v) Hydrology and

(vi) Depth of rock cover.

All the six parameters are known with respect to the Quartzites and Granites. These are very briefly dealt with.

The crushing strength of quartzites is given in Table No.4. With regard to the chemical composition, quartzite is a metamorphic rock and normally mono-mineralic with silica as dominant mineral and the chemical composition is SiO_2 The hardness of quartz is 7 on Mohr scale. Thin section studies revealed the mineral constituents to be detrital grains of quartz, minor feldspar and very minor flakes of mica which are metamorphosed and almost fused to form solid quartzites.

In addition to the above data, some other

Table 4 : Rock mechanics propoerties quartzites of srisailam dam

SR NO	B.H.NO	SIZE OF CORE	COMPRESSIVE STRENGTH (DRY) in psi	ELASTIC MODULUS IN Ex10^6 in psi	MOISTURE CONTENT	COMPRESSIVE STRENGTH (SATURATED) in psi	ELASTIC MODULUS IN Ex10^6 in psi (wet)	ABSOPTION	
1	39	4.15	29,220	6.74	0.14	-	-	-	
2	39	4.15	37,800	9.54	0.06	37,000	6.19	0.45	
3	31	5.38	36,000	12.61	------	-----			
4	31	5.38	52,700	8.91	------	44,600	8.91	1.06	
5	41	5.38	64,800	14.27	------	-----	-----	----	
6	41	5.38	54,980	-----	------	62,000	7.38	----	
7	37	5.38	37,400	13.11	-------	-----	-----	----	

Table 5 : Rock properties of quartzites of srisailam project

Sr No	Rock Property	Values
(I)	Density	50 to 2.80 gm/cm^3
(ii)	Compressive strength (Dry)	849 to 2299kg/cm^2
(iii)	Compressive strength (Wet)	989 to 1915 kg/cm^2
(iv)	Tensile Strength	2.4 to 4.3 kg/cm^2
(v)	Youngs Modulus of elasticity	1.5 to 7.3 x 10^5 kg/cm^2

properties of the Srisailam Quartzites made available by Geotechnical Laboratories of G.S.I. are also utilized and tabulated.

The studies revealed that the rock cover varies from 212 m to 484 m in the Tunnel No.1 except at few places which appear to be critical. Such a crossing is at Ch.9.625 km, where Mamidirevu Vagu crosses the alignment. Here the bed level appears to be at R.L.210 m and with the vagu valley at R.L.250 is about 200 m. Two alternatives could be considered for this valley. The first alternative would be to shift the alignment sufficiently upstream and then revert back to the original alignment. The second alternative would be to porvide conduit type of concrete tunnel and cover it and start wherever the good rock cover of 2D is available.

The granite is equi-granular normally, but in the present project area, they are porphyritic. The range of strength properties of granites are given below:

The granites in general are composed of quartz, feldspar, amphibolotes, pyroxenites and mica. Feldspars constitute 60 to 65 %, quartz will be in the range of 15 to 25 %, amphibolites and pyroxenes will be in the range of 10 to 15% and mica and other minerals will be 1 to 2 %.

Quartz as already mentioned has hardness of 7 on Mohr scale, Feldspar 6, amphibolites and pyroxenites 6 and mica about 3.

The granites possess three sets of major vertical joints. These are spaced sparsely at 1 to 1.5 m apart.

Ground water is found in the secondary pores that are in the form of joints and fractures in the granites. Thus ground water in general will not pose much problem except along fracture and shear zones which may have to be observed and proper corrective measures taken.

Rock properties of granite

(I)	Density	2.62 to 2.96 gm/cm^3
(ii)	Compressive strength (Dry)	1085 to 2224 kg/cm^2
(iii)	Compressive strength (Wet)	989 to 1915 kg/cm^2
(iv)	Tensile Strength	58.92 to 195.80 kg/cm^2
(v)	Youngs Modulus of elasticity	1.5 to 7.3 x 10^5 kg/cm^2

Rock mass classification

Detailed Project report including sub-surface exploration has not been done for this major tunnel scheme. However, detailed geotechnical exploration carried out recently for the Left Bank Power House including the Headrace Tunnel and tailrace Tunnel are available. As the rock types met with in these two stretches are similar to the tunneling media in the Kakeletvagu formations, the data and the rock mass classification, briefly described in the following paras, may be applied to this tunnel to the extent applicable.

The established modes of classification mainly (i) Bieniawski's Geomechanics Classification (Rock Mass Rating) and (ii) Barton's Q-system are adopted. The R.M.R. method is useful to evaluate the standup time of the excavations with out any supports and the Q-system provides the data on the maximum unsupported span possible in the rock mass being excavated. This classification provides an overall picture of rock mass for various reaches.

Geotechnical evaluation of tunneling conditions

The tunneling is expected to be mainly in dry condition except where the tunnel crosses major stream courses, particularly where they have scoured along major fault and shear zones.

As regards the rock cover, it varies from 212 m to 484 m except a few places which appear to be critical. Such a crossing is known at Ch.9.400 to Ch. 10.00 km, where the tunnel alignment crosses Mamidirevu Vagu. Here the bed level appears to be 15 m above the crown of the tunnel. This stretch needs special attention and dealt with in the later paras.

Quartzites known as Kakletvagu quartzite formation would form the tunneling media for the Tunnel No.1. These are mostly massive in nature with beds of 0.50 to 1.0 m thickness. There are four major sets of vertical joints traversing the quartzites. These are spaced at 0.5 to 1.0 m apart and known to be close and become fairly tight with depth.

Based on the review and analysis of geo-topography of the terrain as available in 1: 25,000 scale maps of Survey of India and Geotechnical Reports on the Srisailam Left Bank Power House, the quartzites likely to be encountered in the tunneling have been grouped into three Rock Mass Classes of Bieniawski's. They are :

(i) Class I- Very Good

(ii) Class -II Good and

(iii) Class-III- Fair

Based on the data provided, the tunneling has commenced with two TBMs fitted with double shields to provide immediate support and then precast reinforced segment lining of 300 mm as the tunnel excavation proceeds. This procedure does not permit any temporary support system in case of adverse geological conditions. Rock strengthening measures, however can be adopted prior to tunneling for that stretch. Such treatment could be in the form of consolidation grouting or curtain grouting of the crown to consolidate highly fractured and loose rock or to control heavy seepage.

Rock Mass Classes I and II are grouped together and one set of precast segments are designed. These are designed to withstand rock loads of 5m. The second category of precast segments are designed to overcome the loads of the order of 15 m.

The Rock Mass Classification of Tunneling media as worked out is tabulated.

The evaluated tunneling conditions and the tunnel classification into three classes is tentative and is based on the geo-topographical setting. There could be large variations in the width of shearing and fracturing along the fault/shear zones suspected along the stream courses.

The summary of Rock Mass Classification and the category of Precast Segment lining are also tabulated.

Table 7: Rock mass classification of tunneling media

Sr.No.	Chainage in km		Length in km	Rock Mass Class	Remarks
	From	To			
1	0.000	3.700	3.700	Class II-Good	Minor seepage expected
2	3.700	3.750	0.050	Class III-Fair	Tanganarevupenta vagu
3	3.750	7.000	3.250	Class II-Good	Dry Condition
4	7.000	7.750	0.750	Class III-Fair	Fault-major
5	7.750	9.400	1.650	Class III-Fair	
6	9.400	10.000	0.600	Class III-Fair	Mamidirevu vagu
7	10.000	11.350	1.350	Class II-Good	
8	11.350	11.450	0.100	Class III-Fair	
9	11.450	19.750	8.300	Class II-Good	
10	19.750	20.100	0.350	Class III-Fair	Nallavagu fault
11	20.100	21.100	1.000	Class II-Good	
12	21.100	21.350	0.250	Class III-Fair	Nallvagu fault
13	21.350	25.590	4.240	Class II-Good	
14	25.590	31.350	5.760	Class I-Very Good	
15	31.350	31.750	0.400	Class III-Fair	
16	31.750	36.550	4.800	Class I-Very Good	
17	36.550	36.650	0.100	Class III-Fair	Narasimhulu vagu
18	36.650	38.900	2.250	Class I-Very Good	
19	38.900	38.950	0.050	Class III-Fair	
20	38.950	42.900	3.950	Class I-Very Good	
21	42.900	43.100	0.200	Class III-Fair	
22	43.100	43.420	0.320	Class I-Very Good	

Conclusions

The Tunnel No.1 of the S.L.B.C. will have quartzites belonging Kakletvagu formation of Srisailam Quartzites of Cuddapah Super Group as tunneling media in the reach from the Entrance Portal located on the left river edge of Srisailam Reservoir to Ch. 25.590 km. In the remaining reach, granites belonging to Peninsular Gneissic Complex are likely to be tunneling media.

This tunnel is under construction with two Double Shield Tunnel Boring Machines (TBMs) from the entrance and exit portals to draw 113.28 cumecs (4000 cusecs) through 9.2 m dia and 43.420 km long tunnel; the longest irrigation tunnel, to irrigate 3 lack acres in the chronically drought affected area of Nalgonda district and also to provide drinking water to fluoride affected Nalgonda town and neighbouring villages.

The paper discusses the geology and geotechnical evaluation of the tunneling media with attendant problems likely to be encountered during tunneling mostly based on the geological maps, Satellite Imagery with limited ground truth and a few traverses due to environmental restrictions imposed. The Rock Mechanics data; especially Rock

Table 8: Summary of rock classification

Sr No	Class	Length in km	Percentage of Tunneling	Category of Segment Lining
1	Class I	25.860	58.9	Category I of Precast Reinforced Segmant Lining
2	Class II	13.540	30.8	-do-
3	Class III	4.500	10.2	Category II of Precast reinforced Segment Lining

Mass Classification applied in the case of recently constructed Left Bank Power House is used. The tunnel reaches have been grouped into three classes as Class I- Very Good, Class II-Good and Class III-Fair. The problems likely to be encountered and remedial measures within the ambit of TBM System of tunneling are discussed.

The Rock Mass Classes I and II have been grouped together and 300 mm thick precast reinforced segments are designed to withstand loads of the order of 5m over the crown of the tunnel. Likewise, the lining segments to withstand loads of the order of 15 m are designed for the Rock Mass Class III- Fair.