# Geotechnical Considerations for Design and Construction of Highway Tunnels Through Weak Rocks of North Cachar Hills, Assam

S.K. Mathur

**Abstract**

*Construction of highway tunnels in the Nagabasti hills between Jatinga and Maibang is envisaged on the existing single lane road between Lumding and Jatinga / Haflong. These highway tunnels will form part of rehabilitation and upgrading the existing road in ruined condition to 4-lane highway in North Cachar hill district of Assam. The alignment of the tunnels passes through Tertiary Group of rocks comprising moisture sensitive and low dipping sandstone, siltstone, shales, carbonaceous shales, mudstone etc. The sedimentary sequence of rocks show wide variation in strength and deformabiiity characteristics due to varying grades of weathering and are affected by major tectonic activity in the area like Haflong-Disang thrust. The paper presents estimates of the strength parameters of rock mass constituting tunneling media. Based on the field data, rock mass classification parameters of the tunneling media and the geotechnical oriented design and construction problems are also outlined in the paper.*

*The rock mass behavior shows the need of providing appropriate support system and construction methodology for anticipated poor, very poor and exceptionally poor rock zones. Different types of support system including pipe roofing / umbrella arch, steel sets, self drilling rock bolts, plain and fibre reinforced shotcrete, grout injection depending upon the stand up time may be required. The design of support system may have to be separated into two principal components 1) provision of an initial support system keeping in view the anticipated stand-up time of the strata & 2) selection of secondary permanent support system to meet the design life of the project. During construction phase, systematic monitoring of the ground behavior and its comparison with predictions is deemed necessary for checking the adequacy of the design.*

## Introduction

A number of railway tunnels have been constructed or are under construction in the Tertiary belt in the North Cachar Hill district of the North Eastern Region of India. The sedimentary sequence of rocks exhibit wide variation in lithology and tectonic characteristics which greatly influence the design of support system of tunnels. Construction of highway tunnels may also be necessary for up gradation of existing Lumding – Halflong road. 4-Lane configuration of the NH-54 in the area is deemed necessary as this road provides alternative links from Assam to Tripura, Mizoram and Manipur. This paper presents significance of geological and geotechnical considerations in planning and design of highway tunnels in the Nagabasti hills between Jatinga and Maibang along the existing road. The paper also discusses the appropriate support system for the different litho tectonic units which constitute the tunnelling media. Highway and railway tunnels are complex systems which require high level inputs from wide range of number of disciplines including geology, geotechnics, rock mechanics and soil mechanics and other civil, electrical and mechanical design considerations. The study and analysis on the subject was carried out by the author during reconnaissance of the area for the proposed tunnels for broad gauge conversion of Lumding – Badarpur and upgradation of lumding – Haflong road.

Consultant Intercontinental Consultants and Technocrats Pvt. Ltd., A-8, Green Park, New Delhi-110016, India

## Geological conditions along the tunnels

Rocks of the areas belong to Tertiary Group of rocks. The area around the existing highway comprises scanty outcrops and mainly occupied by alluvial deposits. The outcrops of sandstone, shale, siltstone, clay-shale are however seen along the road cuttings. The low dipping rocks trending E-W are folded and highly weathered down to depth of more than 30m. The geological structures and tectonic frame work of the area show presence of many thrusts and faults especially Halflong – Disang Thrust. The tectonic elements in the region have caused several damaging earthquakes. The tectonic features are not identifiable in the area. The material constituting the hill slopes where construction of tunnels mainly comprise rock zones in different stages of weathering. There is a distinct variation in the degree of weathering from top of the excavated road cuts to the bottom of the hill. The sandstone beds are thickly bedded as well as thinly bedded having two main sets of steeply dipping joints which are occasionally smooth and slicken sided. The shales are iron stained and are predominantly arenaceous shales, carbonaceous shales and ferruginous shales. The splintery and highly jointed nature of fissile shales with thin sandstone and siltstone beds is anticipated to be very poor to extremely poor tunnelling media and may cause excessive over break if the underground excavations through these soft rocks are done without provision of remedial measures. Clay coated and slicken sided persisting bedding planes result in planar or gravitation fall of wedges by the intersection of the weak bedding. The shear strength of the rock surfaces of the area are prone to deterioration as a result of changes in moisture. The overall strength of rock mass is also greatly influenced by the weathering. Marinos & Hoek (2000) has presented a review of the estimation of rock mass strength based on combination of structural and surface conditions. The Geological Strength Index (GSI) classification system greatly respects the geological constraints that occur in nature and gives great emphasis to the geological features of the heterogeneous rocks which extensively occur in the North Cachar hills where highway tunnels are envisaged.

## Rock mass classification

Rock mass of the area can be broadly classified into following three main rock mass behavior types for transportation alternative of highway and railway tunnels in the area under discussion: -

Type – 1, comprising thickly bedded sandstone with thin shale/ siltstone which may be categorized as poor rock.

Type – 2, Comprising mainly thinly bedded sandstone and siltstone with thin shale/ mudstone beds which may be categorized as very poor rock.

Type – 3, Comprising mainly soft laminated and fissile shales and heavily broken rock zones which may be interpreted as exceptionally poor rock.

The detailed rock quality designation may have to be established by detailed geological and geotechnical studies including geological mapping, seismic refraction surveys, geohydrological evaluation, exploratory core drilling of drill holes, in-situ and laboratory tests which would provide quantitative estimation of strength and deformability characteristics of the tunneling media.

The main risks during tunnelling through the weak rocks are encountering squeezing rocks and fault zones. These may require pre-emptive constructive measures such as drainage and appropriate support system. The strength parameters are also required for deciding on the construction methodology. Various gases may be encountered in the Tertiary Group occurring in North Cachar Hills of rocks during tunnel excavation. The gases like methane, hydrogen, carbon di-oxide etc. may be safety hazards for men unless they are detected and counter measures are taken.

It is pertinent to point out that inadequacy of geotechnical investigations and lack of appreciation of geological problems associated with tunnelling through weak rocks of this area have resulted in excessive cost escalation and considerable delay in completion of the Lumding – Badarpur Broad Gauge Railway Project in this area. The Jammu & Kashmir Railway Project where the 125Km track between Katra and Banihal involving construction of number of tunnels through very weak and exceptionally weak dolomites and shear – faultzones have also posed serious construction problems due to treacherous geological conditions of the area and inadequate site investigations. Such circumstances may result in changes in the design and construction methodology after thorough geotechnical re-evaluation of the project. Delay in completion of the project has also increased the cost of project.

The proposed highway tunnels in North Cachar area are expected to be about 20m to 140m approximately below the ground surface. The main geotechnical design considerations in such shallow tunnels are to minimize the disturbance to the surface and appropriate design solutions for control of deformation and face stability. The ground traversed by the shallow tunnels generally has poor geotechnical characteristics near portals which may require specialized methods of excavation including umbrella arch, fore poling, series of grouting injections during pipe roofing etc. for ensuring the stability of roof and smooth and expeditions construction. (John, O. Bickel, et.al - 2004).

## Anticipated geotechnical problems and their solutions

The geological problems of tunneling through weak rocks of the area under discussion are reliable estimates of the strength and deformation characteristics of weathered and jointed sandstone, siltstone and clay-shales and soft mudstone. The sedimentary sequence of rocks belonging to the Tertiary Group of rocks have wide variation in the interlocking of grains of rock mass depending upon the weathering and the tectonic deformation. The RMR of these rock types may vary between 10 & 50 depending upon weathering and other geotechnical characteristics.

The structurally controlled failure may occur where the bedding planes and other discontinuities are unfavourably oriented with respect to the excavation face of the tunnels through jointed rock mass. The fault zones and shear zones are also expected due to complex geological structure of the region and they may also pose problem of ingress of water during tunnel excavation. Their crossing present great risk if they are not detected in advance. Three main parameters including (i) the hydraulic head, (ii) the permeability of rock mass and (iii) the locations of hydraulically active zones may have to be determined ahead of tunnelling.

## Proposed support system

The proposed support system based on the anticipated rock mass behaviour of the three main rock mass behaviour types of the area are given in Table 1.

The support system indicated in Table 1 is based on evaluation of field conditions for the purpose of preparation of cost estimates for the preliminary design purposes. The structural stability analysis may have to be done after precise estimation of the geotechnical parameters during detailed design stage and execution phase of the project. The rock mass classification forms the backbone of the geotechnical recommendations with regard to support system requirements.

## Geotechnical Investigations

The alignment of the tunnel is very important and advantage of the geological and topographic considerations be taken while optimising the alignment during Feasibility Studies. The cut & cover sections adjacent to the minor tunnels are also very important and affect the cost and functionality of the project. Detailed evaluation of geological

**Table 1:** Proposed support system based on rock mass behaviour types

| Rockmass Behaviour Types | Q Values | RMR Values | Required support system in addition to 50cm thick concrete lining as permanent support |
|---|---|---|---|
| Type 1 – Mainly comprising sandstone beds, categorized as poor rock | 1.3 to 6.6 | 40 to 60 | i) Plain shotcrete 50mm thick<br>ii) Rock bolt 3m long 25mm dia, 1.5m c/c<br>iii) Permanent steel support rib 750mm c/c with concrete lagging |
| Type 2 – Mainly comprising thinly bedded siltstone with shale and thin sandstone beds, intensely jointed categorized as very poor rock | 0.12 to 6.4 | 30 to 59 | i) Plain shotcrete 50mm thick<br>ii) Steel fibre reinforced shotcrete 75mm thick<br>iii) Rock bolt 4m to 5m long, 25mm dia, 1.5m c/c<br>iv) Permanent steel support, rib 750mm c/c with concrete laggig |
| Type 3 – Mainly comprising soft shale laminated/ splintery highly weathered rock zones & shear zones categorized as very poor to extremely poor rock | Less than 0.1 | Less than 30 | i) Plain shotcrete 75mm thick<br>ii) Steel Fibre reinforced shotcrete 100mm thick<br>iii) Wire mesh<br>iv) Self drilling rock bolt 4m to 5m long, 25mm dia, 1m c/c<br>v) Permanent steel support, rib 500mm c/c with concrete or steel lagging depending upon stand up time<br>umberella arch, pipe roofing or forepoling may be required depending upon the geotechnical characteristics of the strata. |

conditions and physico mechanical characteristics of tunneling media can have a significant impact on the cost of the tunnel and the timely completion of the project. The descriptive geological model of the region and establishing the geological and structural conditions along the selected tunnel alignment for construction are essential for identification of geological risks associated with transportation tunnel projects. Convergence measurements are deemed necessary during construction stage and post-construction stage of the project to ensure that the design criteria are satisfied and to confirm the overall structural stability and adequacy of support system.

## Conclusions

The geological evaluation reveals that the key parameters for the design of shallow tunnel through weak rocks of the area requires control of ground deformation and optimizing support based on poor geotechnical characteristics of sedimentary sequence of rocks of the area. The most appropriate construction method in such geological circumstances is top heading & benching and pipe roofing for providing umbrella arch in the segments near the portals. Detailed exploration probe during drive is required to be continued during construction of tunnel through weak rocks to have minimum departures from the anticipated conditions and ensure timely completion of the project. Convergence measurements is the best design tool to decide on the adequacy of the support system and monitoring the safety of the project.

## Acknowledgement

The author is grateful to Shri K.K. Kapila, Chairman & Managing Director, Intercontinental Consultants & Technocrats Pvt. Ltd. for giving permission to present the paper and providing all facilities in carrying out the reported work.

The author is also thankful to Shri. R.C. Bhandari, General Manager, Intercontinental Consultants & Technocrats Pvt. Ltd. for valuable discussions.

## References

John O.Bickel, et.al. (2004) : Tunnel Engineering Hand Book, Chapman & Hall Inc. New York, published in India by CBS Publishers and Distributors, New Delhi.

Marinos, P. and Hoeke (2000): GSI: A Geologically Friendly tool for rock mass strength estimation. International conference on Geotechnical Engineering (Geo Engg. 2000), Technomic Publication Co. Inc., Melbourne, Australia.