GUIDELINES FOR INVESTIGATING COMUNICATION TUNNELS

Sushil Kumar*

Abstract

Any underground excavation opened on either ends for carrying the water, industrial effluents, municipal sewage, telephonic cables and passenger traffic is termed as tunnel. With the spurt in traffic movement the importance of tunnel (subway and tube rail) has attained great siginificance on account of negotiating longer distance through shortest possible rate with least disturbance to ecosystem in an economical way. The paper deals with the guidelines for geotechnical investigation of communication tunnels in negotiating the communication routes by road and / or railheads.

Introduction

Communication tunnels are the under ground carriers for smoothening the traffic flow by shortest possible route without any anthropogenic interference. It is established fact that a tunnel is designed on the basis of anticipated geological conditions metwith along its alignment taking into consideration the engineering utility. There is now greater awareness and appreciation among the construction engineers for the vital importance of geological appraisal and the physical properties of the tunneling media, to evaluate quantitatively the tunneling conditions, so that due provisions can be made in the design of these structures and ample precautions can be taken before hand to ensure safety, speed and economy in their construction. It may be recalled here that first geological investigation for tunnels was made by T. Oldham in 1868 while studying the feasibility of a tunnel below the river Indus as a means of communication (Balasundaram) 1971. In the geotechnical evaluation of tunnel, careful considerations are made to study the portal conditions, strength and behaviour of rock/soil through which tunneling is proposed, roof collapse and blow out, flow of rock and release of large volumes of water, support system, delineation of inherent discontinuities such as faults, shear zones, faults, fractures, folds and their anticipated behavior in active seismic zones, behaviour of geothermal gradient in adverse circumstances and thickness of lining wherever necessary.

This paper is confined with theme of sub-surface exploration needed in connection with the underground openings for communication of the vehicular traffic However, it does not include the properties, description and methodology for the evaluation of construction material used in the tunnel construction.

The guidelines outlined here for planning and exploratory work in different stages of investigation and execution in project development may be modified for individual projects subject to site conditions, foundations conditions of the basement geohydrology, frost action and other physico-machanical charàcteristics of the strata and locked-up stresses.

General Considerations

In the design and construction of the communication tunnels some components

* Director, Geological Survey of India, Northern Region, Lucknow-226024

of the structure need special attention to the effect of vibrations in and around the portal, stability of hill slopes in hilly terrain, pressure exerted by the sub-surface water on the opening, geomechanical behaviour of the strata and sensitivity to settlement by live load passing through the tunnel.

The type and extent of exploration would thus be commensurate with the size and importance of the project and the purpose for which opening is required.

Depending upon the type of project the investigation would, therefore, require the following:

i) Base map with contours on 1:50,000 scale with tentative location of the project for general reconnaissance of the area.

ii) Geological mapping of various alternative sites selected during the course of reconnaissance.

iii) Geohydrological setup of the area and water level fluctuations during pre and post monsoon periods.

iv) Chemical quality of the water present in the sub-stratum and lekage of gas etc., if any.

v) Engineering Properties of the overburden and their behaviour in adverse climatic conditions particularly in Himalayan terrain.

vi) Geomechanical properties of the insitu soil/rock mass.

vii) Seismic history of the area and the nature of formations with reference to their proneness to seismic tremors.

viii) Impact of new openings on the surrounding structures and the problems likely to crop out in legislation and their plausible solution if any.

Soil testing may be conducted at the required locations in accordance with the 1S: 2131-1963, and 4.3, 4.4 and 12.2 of 1S: 6955-1973.

To decipher the rocks underneath the drilling may be resorted to NX or larger size so that core losses are minimized and behaviour of joint pattern and fracturing is observed (1S: 6926-1973).

Sub-surface explorations by drifts/ adits through an opening of 1.5 width and 2m height is made to delineate the slump zone. It would require the environmental clearance from the Forest Authorities to establish the portal after clearing the site, muck disposal area, and blasting permission from the local administration within the framework of Mine Safety Rules.

To visualize the behaviour of new opening during and after the commissioning of the project, instrumentation would be required for mitigation and monitoring of shape behaviour and settlement, if any.

For general principles and procedures to be adopted for investigations and sampling reference may be made to 1S: 1892-1979 (code of practice for sub-surface investigations for foundations).

For explorations by pits, trenches, borings, drifts and shafts references may be made to 7 to 11 of 1S: 6955-1973. (code of practice for subsurface exploration for earth and rock dams).

Stages of Investigations

The investigations and subsurface explorations for communication rail tunnels/ sub ways, tube, and express highway tunnels would therefore, have to be grouped in four stages:

i) Reconnaissance stage mapping of the Project Area on preferably 1:50,000/

1:25,000 scale of the Survey of India Toposheets.

ii) Preliminary stage investigations on large scale map preferably on 1:10,000 or larger than this.

iii) Detailed or pre-design stage investigations by drilling, pitting trenching, drafting and instrumentation etc. on a map of 1:5,000/1: 1,000 scale.

iv) Construction stage investigations for marking final layout of the project work on 1: 500/ 1:200 scale depending upon the length of the tunnel.

The type of information for first three stages of investigation would be almost same but may be more elaborative once the proposal is finalised and ready for execution after getting clearance from Ministry of Environment and Forest (MOEF).

Type of Information's Required in Each Stage of Investigations:

In view of the safety of the structure following information's would be required in each stages of investigations:

Records of the substratum below the excavated foundation level of the tunnel Investigations would require to find out if there are compressible clays or other deleterious layers in thin stipulated depth and their groundwater behaviour after opening is made, pressure of clay minerals leading to squeezing swelling ground etc. In case of rocks their bearing capacity to take the load (dead and live both) in saturated and non saturated conditions. Adequate bearing characteristics need to be recorded after penetrating the substratum below invert level down to 8 m depth.

The characteristics of slopes, disposition of joints and other incipient fractures, discontinuities, shear zones, and movement of glacial avalanches, if any in the snow bound terrain and rock strength by calculating 'Q' Genuine Mountain Pressure (GMP), residual stresses geothermal gradients and seismic coefficient for safe design would form the prerequisite.

Besides normal instrumentation techniques in drift/adit to study rock closure, zone of loosening, compressive strength, deformation modulus (dynamic and static) also needs to be studied in accordance with the 1S: 5249-1977 (Method of test for determination of dynamic properties of soil and also to the requirements of 1S: 1893-1975 criteria for earthquake resistant design of the structures.

Guidelines For Investigating Communication Tunnels:

Reconnaissance Stage Investigations:

The scope of investigation during this stage is confined to the proper geomorphic evaluation of the area in general and the tunnel alignment in particular. The reconnaissance stage geotechnical investigations should be carried out on Survey of India Toposheets on 1: 50,000 scale or 1: 25, 000 scale having contour interval of 20 m so as to establish the broad topographical and geological structure of the foundation material. The proposals for alternatives alignments may be given with their merits and demerits and alignment marked on the toposheet.

In case the tunnel is nearer to the hill slopes or within the rock cut, stability of hill slopes shall be investigated and represented in the text of the report by maintaining schematic diagrams. The area prone to glacial avalanche attack should be highlighted and magnitude of the problem discussed.

In frost and permafrost regions the study of soil/overburden and joint infilling, frost heave etc need to be examined to visualize the effect of climatic changes on the rock/ soil.

The pressure exerted on the tunnel foundation and on their walls by artesian body, if any, water charged cavernous limestone or synformal depression saturated with water, needs to be thoroughly investigated and highlighted in the report.

Preliminary stage Geotechnical Investigations:

During this stage based on the geological reconnaissance of the area regional geological setup is studied on a larger scale and data for the formulation of the project are collected. The coverage of exploration shall be adequate for examination of the cost and evaluation of benefits. This stage also includes studies for preliminary choice of the tunnel alignment. This stage of investigation would require the following exploration:

(a) Regional Geological Mapping on 1:10,000 scale and preparation of observed geological section along the tunnel alignment to foresee the geological surprises, if any.

(b) Establishing the bed rock configuration by Geophysical Survey.

(c) Test drilling at the portal sites and along the alignment using coring and noncoring methods and their geomechanical properties in the geotechnical laboratory.

(d) Standard Penetration Tests (SPT) and field density test on overburden.

(e) Laboratory tests on undisturbed samples of cores (NX size) to determine physicomechanical properties and shear parameters of the strata.

(f) Determination of depth to water in the borehole and evaluation of field permeability, observation of temperature, and discharge of springs etc.

In case tunnel has to pass through alluvial terrain/regolithic soil the investigations may be oriented to decipher the layers of salt, peat, quick sand or clays having swelling minerals in black cotton soil.

Detailed Preconstruction Stage Geotechnical investigation:

These investigations on 1:5000 / 1:2000 scale maps are required to obtain data for detailed design of the portals and to evaluate rock load over the crown of the tunnel by adopting age old Terzhagi method or Barton's rock mass classification by calculating 'Q' and supports there of as mentioned in IS: 5878 (Part -IV) -1971 (Tunnel Supports).

A close co-ordination between the design engineer, field geologist and site engineer is essential in this stage of investigation.

Investigation at this stage will include the following.

(a) Detailed geological cum drift map of the area on 1:500/1:200 scale with the layout of the portal, tunnel alignment, working adits etc. superimposed over it.

(b) Geophysical survey to delineate bed rock configuration and moisture content, sonic velocity, poisons ratio etc. brochales drilled should be electrically logged for

SP-Resistively, Temperature, Gamaray.

(c) Intensive exploration by drilling and pitting, trenching, shafts etc. to fill up the gap in exploration.

(d) Ascertaining the groutability of the foundations through trial grouting of specified reaches in accordance with the IS: 5878 (Part-VII) -1972

(e) Specific field tests like blasting tests IS: 4081-1967 to determine whether the material is likely to liquefy under seismic disturbance and field shear tests wherever found necessary.

(f) Geohydrological characteristics of the foundation, their environment and pumping of water in karstic terrain, permeability characteristic etc.

Construction Stage Geotechnical Investigation:

This stage would require the final feasibility of the project on techno-economic consideration. Any amount of exploration by drilling, exploratory adits and instrumentation to evaluate the load likely to come up in case of steel support tunnels, the depth of loosening by installing borehole extensometers, shear transducers to see the dilating behaviour of tunnel walls etc need to be examined in the exploratory adits.

The plan should be handy and prepared on 1:500/1:200 scale with marking of tunnel portal sites, muck disposal sites and measures to stabilize the portial uphill face with the help of perforated grout anchors/shotcreting on chain link fabric etc.

In traffic tunnels normally the water rich reaches are left open without any lining so that pressure is released and no harm is paid in the tunnel walls/size.

New techniques of tunneling by TBM, shield method, NATM etc need to be recommended subject to the site conditions and availability of funds. Instrumentation may be recommended when tunnel is supported by steal ribs.

Indian Examples of Communications Tunnels:

Traffic tunnels used for railways, highways, subways, transportation etc. have occupied more importance due to galloping population and fast developing vehicular traffic. The shift of rural populace towards the metropohtan cities and urban agglomeration seems to invite more intensive search for subsurface openings in the years to come. The 20th century, has witnessed many railway, road and highway express traffic tunnels in J & K, H.P., Delhi, U.P. Maharashtra, Orssia, W.B., Bihar and Goa. These communication tunnels have pierced the rocks formations of Precambrian Vindhyans, Deccan traps Siwaliks and laterites. The traffic tunnels have also been excavated in softer rock formations and unconsolidated sediments. Tube railways in Calcutta though constructed by cut and cover boxes and subways in Delhi Mumbai and Howrah in the alluvial country /fill material have made rapid studies in the field of sub surface openings.

The accelerated growth of this technology is gaining momentum to negotiate the critical surface reaches with a view to shorten the length of the route, avoid landslide prone zones and reducing unwanted cut in the rock,/behaviour with the nature.

Numerous examples of such tunnels constructed in India are tabulated below.

Table : Communications Tunnels/ Subways/ Highways / Tube Rail in India

S.N.	Name of the Project	Type of openings	Year of construction	Tunnel length Dia (m)	Geological Formation encountered	Geological Age
1	Metro Tube Rail in Delhi	Part Tunnel part cut & cover and partly on surface	Partly completed	Two corridors 16.5 Km each	Recent Alluvium and Delhi quartizite of Ajabgarh Foramton	Precambrian and fill Material
2.	Metro Tube Rail in Kolkata, W.B.	Partly cut and cover and Partly on the surface connecting Dumdum with Tolly ganj.	Completed	Two Tubes 16.5 km long box shaped concret lined Tunnel, 8.97m wide 4.4 m high	Silty peaty clayey beds of Gangetic Alluvium and Fill material	Recent to Holocene
3.	Nandini Tunnel Jammu, J & K	Traffic tunnel on J & K Highway	Completed	Two Tubes 118.4 m and 122 m in length and 5.49 m dia Horse shoe shaped	Siwalik rocks comprissing sandstone clay and shale	Mio-pliocene
4.	Jammu Udhampur Train route J & K	Railway Tunnels	In Progress	252.60 m long tunnel on Dhar Dhampur road 18 km short of Udhampur town	Lower Siwalik formation alternate bands of sandstone and clay stone	Mio Phocene
5.	Banhil Tunnel on J & K highway	Jawahar Tunnel 3 km. (9800 feet)	Completed	Two Tubes 2539m and 2546.7 m in length and 5.49m dia, horse shoe shape	Pir Panjal Range comprising Agglomeratic slates Panjal Traps Jiwan limestone with minor shales and Quartizite bands.	Upper Carboniferous to Permain

S.N.	Name of the Project	Type of openings	Year of construction	Tunnel length Dia (m)	Geological Formation encountered	Geological Age
6.	Malabar Traffic Tunnel, Maharashtra	Traffic Tunnel forming chowpati with Napean sea	Completed	Two Tubes 8.95m dia 20m a part, with a length of 610 m and 346m	Argillaceous shales carbonaceous variants sedimentary tuff, Tuffaceous breecia, Tuff pyroclast overlain by basalt	Cretaceous
7.	Bhopal-Khandwa Rail Rout, M.P.	Railway Tunnel 2 in upline and 3 in downline	Complete		Vindhyan Super Group compresing Quartzite and shales	Precambrian
8.	Kokan Railway Project Goa	Bombay to Mumbra 1 km long Tunnel and mumerons small Tunnels between Goa and Mumbai	Completed		Deecan Traps and Laterites	Cretaceous
9.	Loonvala-Neral on Bombay-Poona Railway Line, Maharashtra	Loona vala-Neral section of C.Rly.	Completed	25 Tunnels few hundred m is length partly lined, water oozing out in few of them.	Deecan Traps	Cretaceous
10.	Khopoli-Khandwa road, section, Maharastra	Rood Tunnel at Khandala	Completed	One Tunnel	Deecan Traps	Cretaceous
11.	Igatpuri-Kasara Bombay main line Maharastra	Rail Tunnels in Igathuri Kasara section	Completed	Plenty of Tunnels	Deecan Traps	Cretaceous

S.N.	Name of the Project	Type of openings	Year of construction	Tunnel length Dia (m)	Geological Formation encountered	Geological Age
12.	Bombay-Poona Express Highway Maharashtra	Panval and Dehu road one Tennel 1.1 km other few hundred m.	Completed	3 nos upline and 3 nos downline road traffic Tunnels	Deecan Traps	Cretaceous
13.	Poona-Bangalore Highway, Maharashtra and Karnataka	Near Katraj, Near Poona, Near Khambatta	Completed	Numerons small Tunnels on highway	Deecan Traps	Cretaceous
14.	Lucknow-Dehradun Railway Track, U.P.	Railway Tunnel Near Raiwala	Completed	2 nos.	Siwalik rock	Mio-Pliocene
15.	Lucknow-Dhanbad Section of E.Rly. Bihar	Between Gaya and Hazaribagh Railway Tunnel	Completed		Chotta Nagpur Plateau Gneisses	Precambrian
16.	Siliguri-Darjeeling Hill Cart road W.B.	Railway Tunnel Before Ghoom	Completed		Darjeeling Gneiss	Precambrian
17.	D.B.K. Railway Tunnel in Eastern Ghats AP (saddle & offspur tunnels	Railway Tunnels 62 nos Anantgiri Ghat section of D.B.K. Railway Tunnel project	Completed		Paragneisses of Eastern Ghats Khondalities Leptynites Calc Granulites, Pegmatites Quartzeties.	Precambrian

S.N.	Name of the Project	Type of openings	Year of construction	Tunnel length Dia (m)	Geological Formation encountered	Geological Age
18.	Railway Project Rayaghada to Kumbhikota Tunnel Orissa	Railway Alignment 150 mm long having 10 Tunnels	Completed	10 Tunnel Alignments for a Total length of 1.4 km on 1 in 100 grade (5nos) and 1 in 50 grade (5 n.) varying between 100 and 150 m in length.	Khondalites and Garnetiferous biotite Gneiss	Precambrian
19.	Aizwal Township Tunnel, Mizoram	For vehicular Traffic	Investigations in Progress	One	Tipam Sandstone and shales	Mio-Plicena

REFERENCES

Balasundaram, M.S, (1971): Seminar on Engineering and Geological problems in Tunelling, pt1 October 22-23, 197 pp 1-19.

Bureau of Indian Standards (1963): Soil Testing IS:2131 and IS: 6955-1973.

Bureau of Indian Standards (1973): Soil Testing IS:6926 Drilling.

Bureau of Indian Standards (1979): Code of practice for sub surface investigations for foundations IS: 1892-1979.

Bureau of Indian Standards (1973): Code of practice for subsurface exploration for earth and rock dams IS: 6955-1973.

Bureau of Indian Standards (1977): Method of test for determination of dynamic properties of soil IS: 5249-1972.

Bureau of Indian Standards (1971): Tunnel supports IS:5878n (part iv) 1971.

Bureau of Indian Standards (1972): Groundability of the Foundations IS:5878 (Part vii) – 1972.

Bureau of Indian Standards (1967): Blasting Tests IS:4081(1967).