International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 09 Issue: 09 | Sep 2022 www.irjet.net p-ISSN: 2395-0072

A Review study on the Analysis and Design of Underground Tunnel Support by FEM

[1]Anand Yadav, [2]Jitendra Kumar, [3]Ankush Kumar Jain

[1]M.Tech Student, [2,3]Assistant Professor, Civil Engineering Department
Poornima University, Jaipur,India

---***---

Abstract - Underground structures have recently gained importance all over the world. Successfully completed these projects are based on careful and realistic design, one that is neither optimistic, conservative, and considerate. It is the need of the moment. This article presents a comparative study of media design, such as Terzhagi's load theory. Quantitative methods for rock mass quality (Q), and rock mass assessment on Bieniawski and RS2 Numerical modeling. The results showed that the final support measures such as casting, thickness, rocky dome, length, the frequency, and requirements of steel support are better. Based on engineering reasoning and analytical methods, PSAs for tunnels have been obtained.

Key Words: RMR, Design, Support measures, Rocks

1. INTRODUCTION

1.1 Geophysical studies: Geophysical surveys allow distinguishing terrains and rocks based on their physical characteristics. The information gained from a surface geophysical survey can be used to choose optimal locations for the placement of boreholes, monitor wells or test pits, as well as to correlate geology between wells and boreholes. The information derived from a geophysical survey can also be used to reduce the risk of drilling in unsuitable area. It is very important that the results of Geophysical surveys shall be integrated with the results of other Geological investigations so that accurate interpretation of the Geophysical surveys can be made.

1.2 Geoelectric survey basics: Resistivity Geophysical surveys measure variations in the electrical resistivity of the ground, by applying small electric currents across arrays of ground electrodes. The survey data is processed to produce graphic depth sections of the thickness and resistivity of subsurface electrical layers (sample shown in Figure 1). The resistivity sections are correlated with ground interfaces such as soil and fill layers or soil-bedrock interfaces, to provide detailed information on subsurface geology conditions.

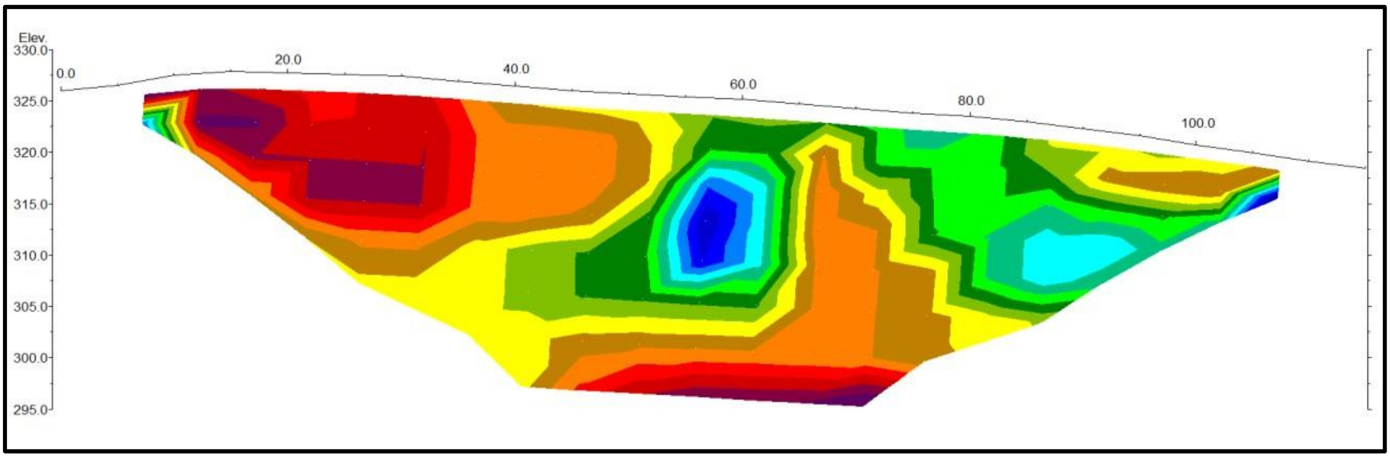

Figure 1: Sample Output of data processing: Electrical Resistivity of Subsurface Layers

Measurement of ground resistivity involves passing an electrical current into the ground using a pair of steel or copper electrodes and measuring the resulting potential difference within the subsurface using a second pair of electrodes. These are normally placed between the current electrodes as shown in Figure-2.

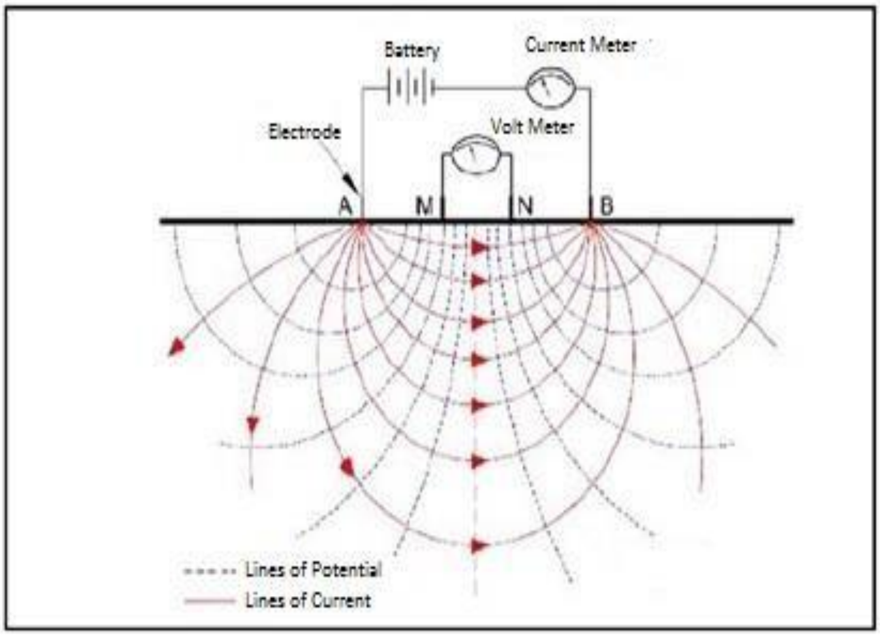

Figure 2: Scheme of Electric Currents across arrays of Ground Electrodes

In geo-electrical prospecting the basic purpose is to determine the electrical resistivity, relative to the formations that make up the subsoil. The resistivity is a parameter independent of the geometrical characteristics of lithological formations covered and is defined as the electrical resistance per unit volume.

All Lithology have a unique range of resistivity values, and they depend on the degree of homogeneity, the degree of alteration and, lithoid rocks, degree of fracturing. In the case of loose soils, such as recent alluvial deposits, the resistivity depends on the size, the fluid contained therein and the quantity of dissolved salts. Exceptions to this rule are the clays that, although compact, always have extremely low resistivity values, and this is mainly due to the characteristics of the crystal lattice of the minerals that compose them and their degree of saturation.

Equipment: Electrical Imaging Setup- The equipment used in this investigation is A.C. resistivity meter WGMD GD-10. This digital resistivity meter has been designed for use in shallow as well as deep resistivity survey. The resistivity meter is consisting of two unit that is main unit and multiplexer unit. Both units are powered by 48 to 98 V chargeable batteries. Current up to 2 Amp can be sent into the ground depending on the subsurface ground conditions.

The developed potential due to resistance offered by subsurface horizons can be measured by instrument in its memory with resolution of up to 0.001 mV. Because the instrument is microprocessor based, by applying the current into the ground, the equipment provides the continuous apparent resistivity for various electrode systems with different array. 60 stainless steel electrodes, cables and accessories were also used.

Figure 3: Instrument used for the 2D resistivity test

2. LITERATURE REVIEW

Xupeng Zhang, Yujing jiang, Kazuhiko Magawa: JAN 2020

- Seismic performances and responses of underground structures subjected to seismic force, a wide collection of case histories was reviewed for damage classification.

- Several databases are available worldwide; however, there are no mature classification standards for damage to tunnels. In this context, a damage classification is proposed to show possible causes of damage.

- Restoration design criteria for the Tavarayama Tunnel have been developed with reference to the restoration design criteria for the Tuya Tunnel. In addition to the width of cracks, crack distribution, and geological conditions considered in the traditional design criteria, two other aspects are included in this criterion, subsidence / outflow of the pavement due to earthquakes and groundwater leakage.

Alessandro Calvi, Maria Rosaria De Blasiis, Claudia Guattari: 2012

- The effects of tunnels on driving performance were examined with a driving simulator and statistically verified. The findings show that when drivers entered the road tunnel, they moved sideways away from the right-hand tunnel wall and slowed down slightly.

- The number of tubes, length, vertical and horizontal alignment within the tunnel, type of construction and other features and facilities of the tunnel) and driver performance investigation should be extended across different traffic configurations (in terms of traffic volume, unidirectional or bi-directional, vehicle percentage heavy) and other road categories, to increase the use of driving simulators in the road design community and to provide practical applications in traffic engineering.

Xueji Wang, Gang Liu: 2016

- The underwater float is a new kind of car tunnel. Similar principles are derived from the design and construction of the bridge, referring to the findings of previous research and the simplification of the Iyengarra channel, when combined with a specific project context. This increases the efficiency of the project, and makes the planting process and technical complexity in the management environment. Therefore, there are still other issues for further study, including:

- Impact of earthquake and underground earthquake, Although the pier can be thought of as a non-slip push-pull pedestal and the end of an auxiliary pedestal, to prevent the operation of water, and so on. The complex dynamic response of the supporting pits and piers during construction and operation, caused by sea flow on the riverbed and wind and vice versa, is necessary for further research and experimentation.

Bella Nguyen, Ioannis Brilakis: April 2016

- A comprehensive compilation of the nature and scope of bridge and tunnel impact problems, followed by previous practice and research. We have noted that effective OHV prevention measures exist in the form of passive and ad hoc regimens, but we emphasize that they are not sufficient for a comprehensive solution.

- Vision-based methods have so far received little attention as potential solutions to BrTS management problems. Despite its potential importance, there is limited computer vision research on OHV detection, and there is no vision-based system on the market. If we can keep the benefits of the laser beam system in an affordable single-camera setup, it will eliminate the need for additional external infrastructure. It will also reduce overall installation costs by an order of magnitude smaller than traditional systems by creating transmitter / receiver poles and redundant loop systems.

Kairong Hong: Dec2017

- Over the past three decades, Chinese engineers have accumulated a wealth of experience in underwater tunnel construction, have mastered a full range of technologies to build long underwater tunnels, a strong technology base and new capabilities. We now have the technological ability to build underwater tunnels for almost any purpose in complex geological and environmental conditions.

- To increase risk control in underwater tunnel construction and project investment, as well as to ensure the operational safety of underwater tunnels, we recommend inspecting the deep-sea operating platform at sea, studying underwater tunnel geology inspection technology for strengthening and intensively studying driving speed and safety. underwater tunnels from Single Gate, improved operational risk control technology, ventilation and energy saving technology for underwater tunnels.

3. METHODOLOGY

3.1 Methodology of Drilling: The work of core drilling is carried out with Long year/ L&T make L-38/ Vol-90/ Voltas make or equivalent models of hydraulic feed, engine driven machines, mounted on skids duly provided with rotary head. A drilling to the bottom of a core barrel, which is turn is attached to the bottom of a string of hollow drill rods, is rotated at a high speed with a downward thrust by the hydraulic drilling rig. On rotation with downward thrust, the coring bit cuts an angular space in the strata and an intact core enters the barrel, to be removed as a sample.

Water is continuously pumped down the drill rods with the help of triplex water pumps of Voltas/ Royal beam make (model TD-200 & TD-400) having suitable feeding capacity for drilling up to required depth. This water emerges under pressure through holes in the bit on barrel. The drilling fluid (water) cools and lubricants the bits and carried up the cuttings to the surface. The drilling rig is provided with necessary facilities to regulate the spindle speed, bit pressure and water pressure during core drilling to get good core recovery. Casing pipes of suitable size are lowered in the borehole end seated on bedrock or in a firm formation to prevent casing in of the borehole. The recovered core is pleased in wooden core boxes with proper markings according to scale as per IS: 4078-1980. All the core drilling observations are recorded in the field registered as per IS: 5313-1980.

4. MODELING AND ANALYSIS

4.1 Permeability tests: Permeability is an important hydrological parameter required to determine the porosity and fractureness of rock mass. Method used for determination of permeability depends on the strata. In situ Permeability was determined by: -

(I) Constant Head Method tests were carried out in over burden as per IS: 5529 (part-I)-1985.

(II) Cyclic Single/ Double Packer test were carried out in bedrock as per IS: 5529 (Part-II) -1985.

4.2 Standard Penetration test: The standard penetration test (SPT) is an in-situ dynamic penetration test designed to provide information on the geotechnical engineering properties of soil. The test uses a thick-walled sample tube, with an outside diameter of 50 mm and an inside diameter of 35 mm, and a length of around 650 mm. This is driven into the ground at the bottom of a borehole by blows from a slide hammer with a mass of 63.5 kg (140 lb) falling through a distance of 760 mm (30 in).

The sample tube is driven 150 mm into the ground and then the number of blows needed for the tube to penetrate each 150 mm (6 in) up to a depth of 450 mm (18 in) is recorded. The sum of the number of blows required for the second and third 6 in. of penetration is termed the "standard penetration resistance" or the "N-value".

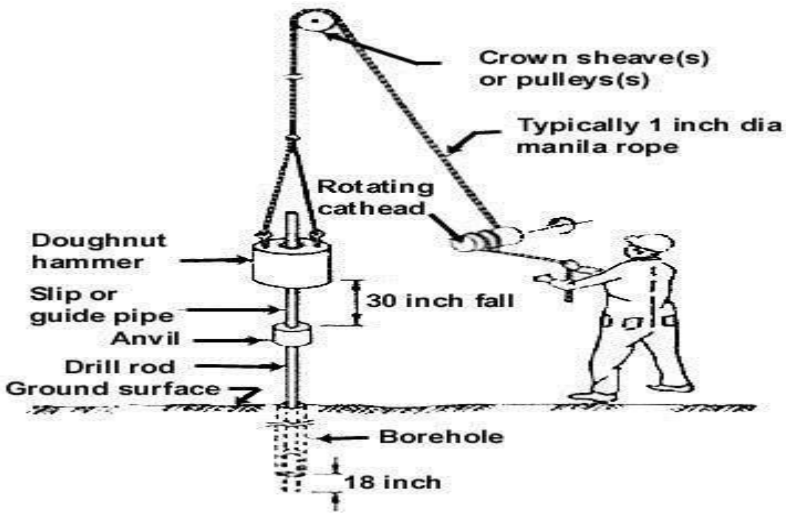

Figure 4: SPT Technique

4.3 Analytical Modelling Approach: During the analytical modelling approach, separate partial factors of safety were used for loads and resistance of construction components as per the following table:

Table 1: Partial factors of safety for analytical modelling approach

Element	Abbreviation	Factor of Safety
Dead Loads (Rock mass)	γF	1.35
Sprayed Concrete	γC	1.50
Rock Bolts – Skin Friction	γS F	1.15
Rock Bolts – Steel Tendon	γS	1.15

4.4 Finite-Element Modelling Approach: Within the finite-element modelling approach only the sprayed concrete lining was considered as tunnel support.

5. CONCLUSION

During investigation stage, the tunnelling media was classified on the basis of observation made by surface mapping, drill hole data and resistivity survey. In order to achieve realistic values of ground types and ground behaviour types, details of rock mass characteristics were recorded from the surface outcrop and borehole data and accordingly projected in the tunnel grade. However, there are structural limitation to project the discontinuities/ share zones at the tunnel grade but affords have been made to justify the geological uncertainties to be encountered during tunnelling.

As displacements already start to develop before excavation and their velocity is likely to be highest right after excavation, the importance of timely (maximum 2-3h after excavation) zero reading is emphasized at this point. The following figure shows a typical course of displacement during tunnel advance.

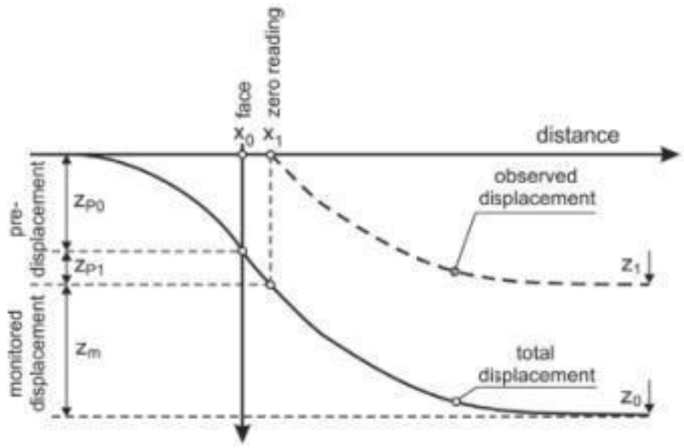

Figure5: Excerpt from OEGG guideline "Geotechnical Monitoring in Conventional Tunnelling" 2014

The observation of displacement measurements is essential in order to recognize shear zones or sections with squeezing ground behaviour at an early stage in order to react by adapting the support measures accordingly. Based on the initial displacement (within 24 hours from zero-reading), the following table shows recommended threshold values for the adaption of support classes for the upcoming rounds:

Table 2: Threshold values for initial displacement (first 24h), corresponding support classes

Measured initial displacement*	Adapt support class to:
> 50 mm	IV-A
> 65 mm	IV-B
> 80 mm	IV-C
> 120 mm	IV-D

Table 3: **shows recommended measures for common problems during excavation**

Problem	Recommended Measures
Low-Cover Sections (≤ 50 m overburden)	Stiff Tunnel Support (SC-IV-A or -B), implementing invert and temporary invert in top heading. Timely completion of tunnel profile (short distance between excavation of top heading – temporary invert and bench – invert, respectively). If necessary, reduce distance between excavation stages
Water ingress to tunnel	Install adequate tunnel drainage system (no open ditches, but closed pipe system), convey ponded water away from tunnel face, execute drainage drillings in direction of advance
Instability of tunnel face	Subdivision of excavation steps, immediate sealing of tunnel face with shotcrete, if necessary, use wire mesh and grouted SD-rock bolts for stabilization
Falling or sliding of wedges and blocks in tunnel roof	Use grouted fore-poling (general) and friction anchored rock-bolts (blocks)

"Re-start" of displacements	Visual observation, increase in reading frequency of geotechnical measurements, drilling of additional (longer) rock bolts, implement invert. Take measures as per action plan.

6. REFERENCES

General papers

1. Xuepeng Zhang Jan 2020 "Mountain tunnel under earthquake force: A review of possible causes of damages and restoration methods"
2. Alessandro Calvi 2012 "Sustainability of Road Infrastructures An Empirical Study of the Effects of Road Tunnel on Driving"
3. Gang Liu 2016 "2nd International Symposium on Submerged Floating Tunnels and Underwater Tunnel Structures Research on strait crossing solution of submerged floating tunnel (Underwater continuous girder bridge)"
4. Bella Nguyen April 2016 "6th Transport Research Arena April 18-21, 2016, Understanding the problem of bridge and tunnel strikes caused by over-height vehicles"
5. Kairong hong Dec 2017 "Typical Underwater Tunnels in the Mainland of China and Related Tunneling Technologies"
6. Liangwen wei 2016 "Research on Tunnel Engineering Geological Exploration System Based on Tunnel Seismic Predication and Ground-penetrating Radar"
7. Zhong Zhou Jan 2019 "Influence Zone Division and Risk Assessment of Underwater Tunnel Adjacent Constructions"
8. Jun Yan, Wen kang May 2021 "Research on Surface Subsidence of Long-Span Underground Tunnel"
9. Nandolia Usama July 2020 "Comparative Analysis of Underground & Underwater Tunnel"
10. Yuanpu Xia July 2018 "Entropy-Based Risk Control of Geological Disasters in Mountain Tunnels under Uncertain Environments"
11. Min Yang and Guafeng Li Feb 2022 "Failure Characteristics and Treatment Measures of Tunnels in Expansive Rock Stratum"
12. Bin Gong Sep 2018 "The Seepage Control of the Tunnel Excavated in High-Pressure Water Condition Using Multiple Times Grouting Method"
13. Weixing Qiu March 2022 "A multi-source information fusion approach in tunnel collapse risk analysis based on improved Dempster–Shafer evidence theory"
14. Chuangang Fan Aug 2021 "Experimental study on the effect of canyon cross wind on temperature distribution of buoyancy-induced smoke layer in tunnel fires"
15. Irfan Ahmad Shah and Mohammad Zaid Dec 2022 "Behaviour of Underground Tunnel under Strong Ground Motion"
16. Yu Wang 2021 "Calculation of drainage volume during tunnel construction based on the control of negative effects of ecosystem"
17. J.M Molina Garcia pardo Feb 2009 "Propagation in Tunnels: Experimental Investigations and Channel Modeling in a Wide Frequency Band for MIMO Applications"

Standards

1. IS 456 (2000), Plain and reinforced concrete – Code of practice

2. IS 1786 (2008), High strength deformed steel bars and wires for concrete reinforcement – specification

3. IS 1893 (reaffirmed 2016) Criteria for earthquake resistant design of structures – Part 1: General Provisions and Buildings (no information on tunnels)

4. IS 4880 (1972, reaffirmed 2000) Code of practice for design of tunnels conveying water Part I-IV

5. Eurocode 0: Basis of structural design, EN 1990: 2013-03-15, European Committee of Standardization

6. Eurocode 1: Actions on structures, EN 1991-1-1: 2011-09-01, Part 1-1: General actions – Densities, self- weight, imposed loads for buildings, European Committee of Standardization

7. Eurocode 2: Design of concrete structures, EN 1992-1-1: 2015-02-15, Part 1-1: general rules and rules for buildings, European Committee of Standardization

8. Eurocode 7: Geotechnical Design, EN 1997: 2014-11-15, Part 1: General rules, European Committee of Standardization.