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# A Review on Tunnel Design and Analysis.

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***Abstract :*** Tunnel building is significant in infrastructure projects because it improves transportation networks, especially in crowded cities. Long durations, high cost projects, complexity, repeated construction jobs, hazards, and uncertainties are all characteristics of tunnel projects. Many tunnel building techniques have been developed to improve tunnel construction and reduce the influence of tunnels on earth movements and neighboring structures. This study describes a system for utilizing simulation to plan tunnel building. Contractors may use the tool to estimate the duration and cost of tunnel construction. For the creation of this instrument, which can be utilised on the ground with various ways, several building methods and techniques were taken into account. Three components make up the suggested structure: (a) simulation, (b) tunnel analyzer module, and (c) decision assistance approach. This structure may be used to choose the optimum building style using a fuzzy group decision-making method based on time, cost, and other factors stated during the decision-making process. A group of experts and a predetermined set of criteria describe this decision technique, which involves a group of experts evaluating several supporting options.

***IndexTerms – Tunnel Analysis, tunnel construction techniques, computer simulation, dynamic behaviour, Staad Pro.***

## I. INTRODUCTION

In general, tunneling construction processes are quite complex. Many variables are involved which interact with each other and many resourced are used. Hence, it is quite difficult to explain the reasons for scheduled delay and cost over-runs in these processes. In order to understand and improve the tunneling construction processes, and consequently minimize the sources of delay and increasing costs, various types of methods and tools have been developed. In construction models are also used to solve problems like planning and control, project scheduling, cash flow management and resource management. A sensitivity analysis has been carried out on number of the case studies, to analyze the most sensitive tunneling variables affecting productivity. Based on the sensitivity analysis, comparison between the productivity achieved on site and the calculated productivity (theoretical), the validity and effectiveness of the model was assessed. Subsequently, two simulation model were developed using EZstrobe simulation software and similar sensitivity analysis was carried out. It was determined that the simulation models produce logical results, then different resource combinations were examined to evaluate the impact on productivity and cost. Based on productivity and cost, also a comparison was made between the TBM (Tunnel Boring Machine) and D&B (Drill and Blast) excavation methods. This type of techniques can be used in real projects to make decisions as to what excavation method or resources to use in real projects by the project manager

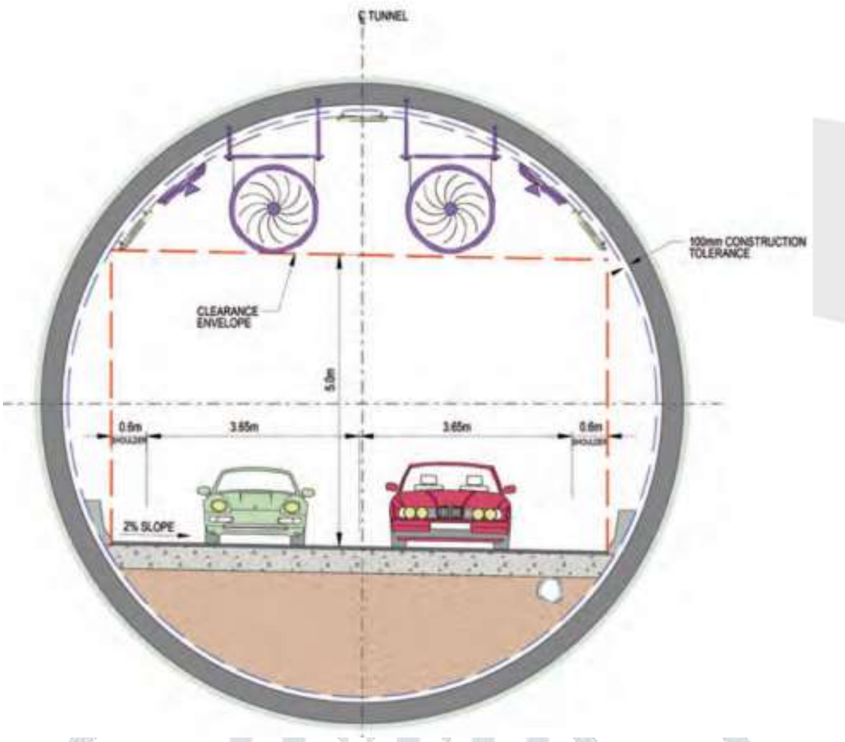


**Fig 1:- Example of Spaceproofing section for TBM –Bored road Tunnel**

## II. Literature review

For researching tunnels that penetrate active fault zones, the studies described in this part detail ways of modeling faults, surrounding terrain, tunnel structures, and fault displacements.

- **FEM of Faults & Surrounding Ground**
  This section will cover a variety of elements and methods for modelling faults, soil, and rock qualities in order to effectively capture tunnel-fault interaction and build the parametric relationships needed for this study. This section is generally arranged from simple soil behaviour modelling to more advanced modelling methodologies. This is done in order to emphasise the complexity and nuances of soil behaviour, as well as the difficulty in effectively modelling it.

**Russo et al. (2002)** Discusses fault crossing solutions for twin shield tunnels across the Bakacak Fault and the Zekidai Fault in Turkey (particularly for the Bolu Tunnel project). Following the Düzce earthquake (MW = 7.2) in 1999, a rigorous seismic survey of the area surrounding the Bolu Tunnel project was conducted, allowing for more accurate modelling of the two faults for the research. The Zekidai Fault drops roughly 90 degrees, and the tunnel crosses it in both tubes for a distance of 25 to 30 metres (82 to 98 feet). Of an estimated right lateral offset displacement of 0.15 to 0.25 m (5.91 to 9.84 in) from a related earthquake with magnitude MW from 6 to 6.25, this fault was assessed as having low potential for future rupture. The Bakacak Fault dips roughly 40 degrees, and the tunnel crosses it for a distance of 100 metres (328 ft). An related earthquake with a magnitude MW of 6.25 to 6.5 is estimated to have caused rupture displacements of up to 0.5 m (19.69 in). Fault ruptures can be concentrated or dispersed, and geologists thought – then justified – that the Bakacak Fault's displacements would most likely be distributed and mostly horizontal, but the Zekidai Fault's displacements could not be properly anticipated. The researchers were able to calculate the shear strain in the fault soil as the ratio of predicted offset to fault width at tunnel level thanks to this earlier assumption. Using contact components between the tunnel liner and the soil, the soil was represented as Mohr-Coulomb (M-C) compression springs.

**Daller & Weigl (2011)** investigated concepts for the new Semmering Base Tunnelin Austria to find a support and construction process which would provide tunnel displacements compatible with the fault system using FLAC2D. This tunnel was constructed through the Graßberg-Schlagl fault system and rock characteristics for this system were determined by triaxial compression tests from core samples. The results from a triaxial compression test on one specimen was back-calculated using the finite element program ZSoil, considering the Hardening Soil (HS) – Small Strain constitutive law as well as the M-C constitutive law to help determine the relevancy of a nonlinear analysis.

**Obrzud (2010)** discusses the significance of using the HS model as opposed to the M-C model in ZSoil and ultimately concluded that the HS model is the more accurate model to use in finite element analysis. The linear-elastic M-C model does not always give reliable and realistic predictions in FEA because soil is only truly elastic at very small strains. The HSStandard Model considers the pre-failure non-linearities of soil behavior while reproducing basic macroscopic phenomena exhibited by soils such as densification, stress dependent stiffness, soil stress history, plastic yielding and dilatancy (Obrzud 2010). Moreover, the advanced version of this model, the HS-Small Strain model, incorporates the above phenomena along with strong stiffness variation as well as the hysteretic, nonlinear elastic stress-strain relationship of a soil (Obrzud 2010). Obrzud (2010) reanalyzed the tunnel excavation of the twin Jubilee

Line Extension Project in London, UK using HS models as well as the M-C model to prove that the HS models give more realistic stress-strain behavior of the soil by comparing results to triaxial lab tests (Figure 2.1). Figure 2.1a shows that at very small strains (< 0.01% axial strain) the HS-Small and M-C Models accurately model the behavior captured during isotropically consolidated undrained extension (CIUE) tests. However, in Figure 2.1b it can be seen that at larger strains, the HS-Model is what actually captures the soil's behavior across the range of strains expected. In fact, the HSSmall model used by Daller & Weigl (2011) also agreed well with lab data constructed from triaxial compression tests compared to the M-C model which did not accurately fit to the data (Figure 2).

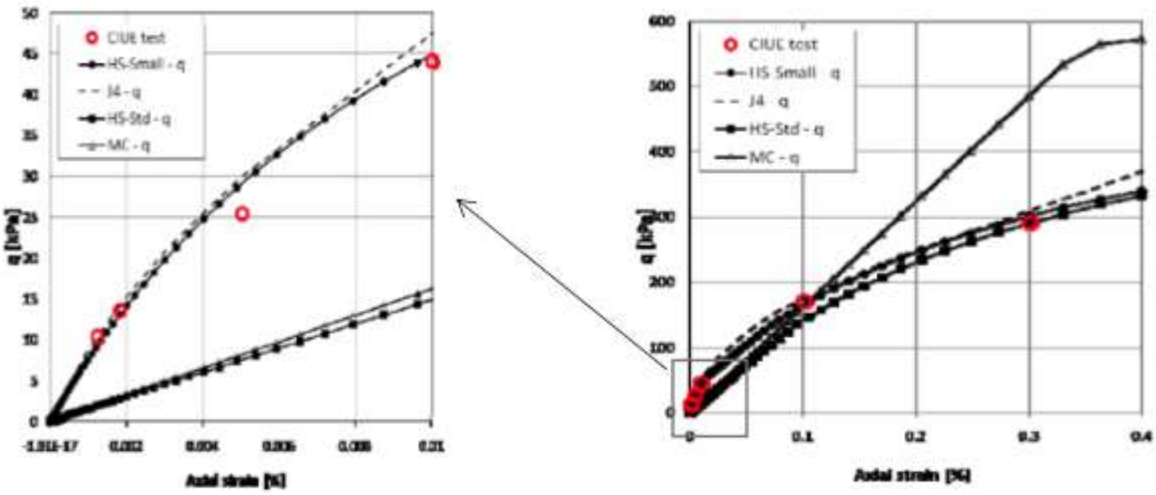


**Fig 2: Stress-strain curves; comparison between non-linear models (HSSmall, HS-Std, and J4), linear Mohr-Coulomb model and laboratory test data points from CIUE tests (Obrzud 2010).**

**Luo & Yang (2013)** performed a finite element analysis using ABAQUS to see the effects on a tunnel by a dislocation of faults. The model consisted of bedrock, concrete lining and fault fractured zones, as shown in Figure 2.3. A lower plate (foot wall) and upper plate (hanging wall) of a thrust fault with reverse thrusting was modeled in ABAQUS with an average dislocation of 0.5 m. The lower plate was restricted from moving while a displacement was added to the upper plate to simulate the vertical dislocation of the fault. Frictional contact surfaces were set between the upper and lower plates as well as between the soil and tunnel lining. In this analysis model, the tunnel and soil were assumed to be ideal elastic-plastic materials. Drucker-Prager yield criterion and the associated flow rule were used to take into account the effects of principal stresses and hydrostatic pressure on yielding of the soil.

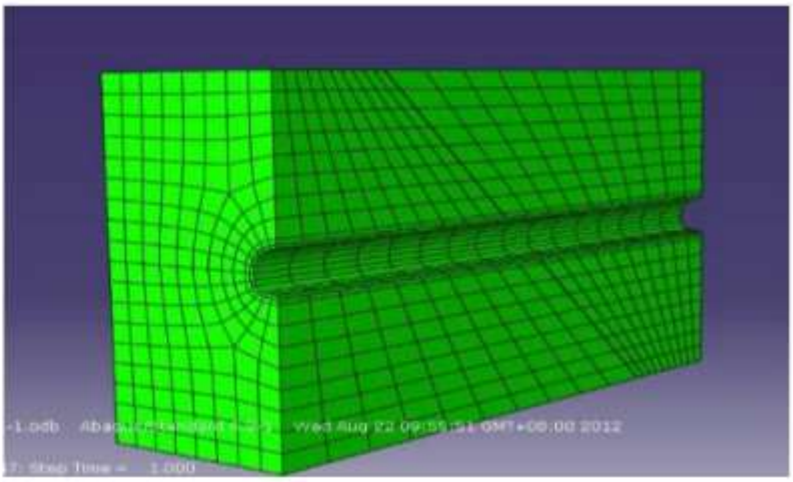

**Fig 3: Cross-section of finite element model under fault dislocation (Luo & Yang 2013).**

**P Anbazhagan et al (2008)** describes the properties of the soil layer with various depths using MASW component. MASW is used to study the behavior of soil and embankments. This paper describes the methodology of Multichannel Analysis of Surface Waves to obtain the soil properties such as density, Poisson's ratio and young's modulus for different layers of soil situated in and around Bangalore. Rayleigh surface waves generated in this are captured by using SURFSEIS software package to arrive at the soil properties for the location.

**M. Sekhar et al (2009)** explains in detail about the topography, groundwater level, depth of hard rock and the tunnel alignment along the east-west section of the metro rail project. It deals about the impact of groundwater system for proposed metro tunnel. From the studies, it has been concluded that the ground water table will be at a depth of 5m approximately which will have a greater influence on the stresses acting on the underground tunnel.

**B.S.Sudhir Chandra (BMRC)** explains the salient features of twin tunnel construction along the east – west corridor of 18.1kms and north-south corridor of 24.2kms. In a total length of 42.3kms, the elevated section is 33.48kms and underground section is 8.82kms. The dimension of the tunnel's inner diameter is 5.6 m and boring diameter is 6.44 m with a reinforced concrete lining thickness of 280mm. The depth of the tunnel from the ground level is 15 to 18.3m approximately and centre to centre distance of he twin tunnel is 15.04m. Tunneling is done by using slurry TBMs and earth pressure balanced TBM method and cut and cover method is used for stations. Two drilling machines namely Helen and Margarita are used for tunneling this section which has a drilling capacity of 11m per day.

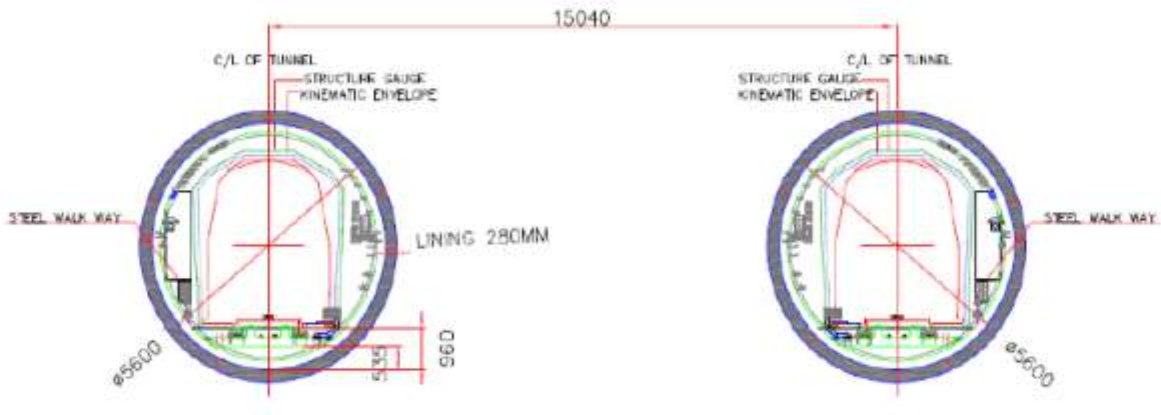


**Fig. 4. Cross-section of Bangalore Metro Underground Tunnel.**

**Huabei Liu et al (2009)** investigates various factors that influence the magnitude of damage on an underground tunnel based on the explosive weight, burial depth, type of soil layers and the characteristics of blast pressure. The dynamic ground-structure interaction, structure damage, nonlinear response of ground media, three dimensional effects, and fluid–structure interaction defines the complicated characteristics of the problem.

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## III. CONCLUSION

Based on the studies presented, several aspects of fault and tunnel modeling can be drawn from and used in the modeling in this thesis. In modeling geotechnical materials, it seems the most advanced modeling and analyses adopt the Drucker-Prager constitutive la however much of rock mechanics is based the Mohr-Coulomb model so FEA will follow the M-C constitutive law.

Also, since faults can range in width, faults will be modeled as a discrete plane with concentrated deformation as well as faults of varying widths where distributed displacements can be applied. Based on findings that show strike-slip fault movements impose the greatest stresses in tunnel liners, fault displacements will be applied as strikeslip displacements. Concrete tunnel liner will be modeled following the material model to account for the nonlinearity of concrete behavior. Individual concrete segments will be modeled to mitigate damage to the permanent tunnel liner and focus damage at the joints..

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