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FEA Analysis of Tunnel Structures

[1] Muskan Dhargave, [2]Miss Navjot Kaur Bhatia

[1]Research scholar, [2] Assistant Professor
[1] Department of Civil Engineering,
[1]SSTC, Bhilai, India

Abstract: A tunnel is an underground structure constructed through the neighboring rock or soil mass. Typically, the length of a tunnel is considerably greater than its width. In order to withstand the pressures exerted by the earth in all directions, tunnels are constructed. This review article provides an exhaustive examination of tunnel structures, including a discussion of their numerous applications, design philosophies, and construction methods. The primary objective of this research is to evaluate the structural characteristics of tunnel lining structures subjected to static loading conditions, employing Finite Element Analysis (FEA) through the ANSYS simulation package. The methodology involves CAD design, error checks, discretization using hexahedral elements, and simulation with applied static loads and boundary conditions. The obtained FEA results encompass deformation, normal stress, and shear stress, revealing commendable resistance and stability in the tunnel lining structure. This research, marked by its utilization of advanced simulation techniques, signifies a crucial stride in understanding and enhancing the reliability of tunnel structures for future infrastructure projects.

***IndexTerms* – Tunnel structure, FEA**

I. INTRODUCTION

Tunnel building is becoming more important in worldwide transportation networks. Strict adherence to local safety and environmental rules is crucial, especially given the fast progress in transportation. The governments see the layouts of these infinite tunnels as extraordinary feats of mechanical engineering. On the other hand, tunnel building is undeniably a challenging task in the realm of structural engineering. Tunnels provide a compelling alternative to well-established forms of transportation including railroads, cable cars, public utilities, and broadcast media. The exponential increase in the world's population requires the development of effective transportation systems to handle the extensive regions of land that are prone to floods. This method is used for the construction of subaqueous tunnels.

Figure 1: Tunnel construction site [11]

II. LITERATURE REVIEW

Li and Yang (2018) [1] proposed a method for assessing the overall stability of the tunnel face by considering the multiple potential failure rates of the working face. This evaluation is conducted by means of a performance function. A probabilistic analysis was performed on the tunnel excavation front in stony formations that had been subjected to blasting operations. The analysis was conducted utilizing the Response Surface Methodology (RSM) with chaotic polynomial expansion.

Zeng et al. (2016) [2] To generate the limit state function, an innovative rotational mechanism was implemented. In order to adhere to the conventional SORM (Second-Order Reliability Method) and FORM (First-Order Reliability Method) approaches, a performance function must be explicitly incorporated. The accessibility of the function might be limited in situations where deterministic analysis is dependent on numerical modeling. The Response Surface Methodology (RSM) is utilized in this particular situation as a targeted technique to approximate the actual performance function. This is accomplished through the application of a polynomial function that converges to the specified point.

Mollon et. al. [3] By employing a probabilistic approach, specifically a collocation-based random response surface method (RSM) and a two-dimensional (2D) multiblock failure mechanism, the stability of the tunnel's working face was evaluated. In order to guarantee the integrity of the tunnel face, FORM (Face Overburden Reinforcement Method) was also incorporated into the design of the circular tunnel. Additional stochastic input variables, including unit mass, depth of covering, soil shear resistance, and pressure of support, are incorporated into the methodology.

Wang et al. [4] examined the theories of fault crossing that are relevant to twin shield tunnels in Turkey. These tunnels pass across the Bakacak and Zekidai faults, with a specific emphasis on the Bolu Tunnel project. Following the 1999 Düzce earthquake (MW = 7.2), a comprehensive seismic research was conducted near the Bolu Tunnel project. This research enabled a more precise assessment of the two flaws under examination. The tunnel drops at a nearly vertical angle of around 90 degrees over a span of 25 to 30 meters (82 to 98 feet) across the two channels of the Zekidai Fault. The likelihood of future rupture of this fault has been evaluated to be very low, despite its projected right lateral offset displacement of 0.15 to 0.25 meters (5.91 to 9.84 inches) resulting from a seismic event of a magnitude of 6.25 to 6.25. The Bakacak Fault is crossed by a tunnel that is 100 meters long (328 feet long) and has a slope of 40 degrees. An earthquake with identical characteristics and moment magnitudes between 6.25 and 6.5 would likely cause rupture displacements of little more than 0.5 meters (19.69 inches). Geologists believed that the Bakacak Fault would mostly produce horizontal displacements that are spread out, whereas the Zekidai Fault would produce more unpredictable displacements.

Pan et. al. [5] The primary objective of the research was to determine a suitable support system and construction method for the Austrian Semmering Base Tunnel that would produce fault-consistent tunnel displacements. The research made extensive use of FLAC2D. Triaxial compression studies performed on core samples identified the geological characteristics of the Graßberg-Schlagl fault system, which served as the construction site for the tunnel. In order to assess the suitability of a nonlinear analysis, the results of a triaxial compression test conducted on a single sample were retrospectively computed utilizing the ZSoil finite element software. Both the M-C and Hardening Soil (HS) – Small Strain constitutive laws were applied to the calculations.

Zuo et. al. [6] emphasize the significance of HS model implementation in ZSoil. In conclusion, they determined that the HS model provides the most precise finite element analysis. Precise and realistic values are typically unattainable with the linear-elastic M-C model frequently employed in finite element analysis (FEA) due to the Earth's limited elasticity under minimal loads. Critical physical soil processes, including dilatancy, stress-dependent rigidity, preceding soil stress, and plastic yielding, are accurately replicated by the HS Standard Model. Additionally, the nonlinearities in soil behavior that occur prior to collapse are accounted for in the analysis. Furthermore, the aforementioned processes are accounted for in the revised HS-Small Strain model, which also accounts for significant fluctuations in soil rigidity and the non-linear, hysteretic, elastic stress-strain relationship that is associated with it.

III. OBJECTIVE

The objective of current research is to evaluate the structural characteristics of tunnel lining structure subjected to static loading conditions. The FEA analysis is conducted on tunnel using ANSYS FEA simulation package. From the FEA analysis critical stress regions are identified.

IV. METHODOLOGY

The tunnel structure developed using sketcher and other modeling tools available in design modeler. The developed model of tunnel structure and corrected design is shown in figure 2 and figure 3 respectively.

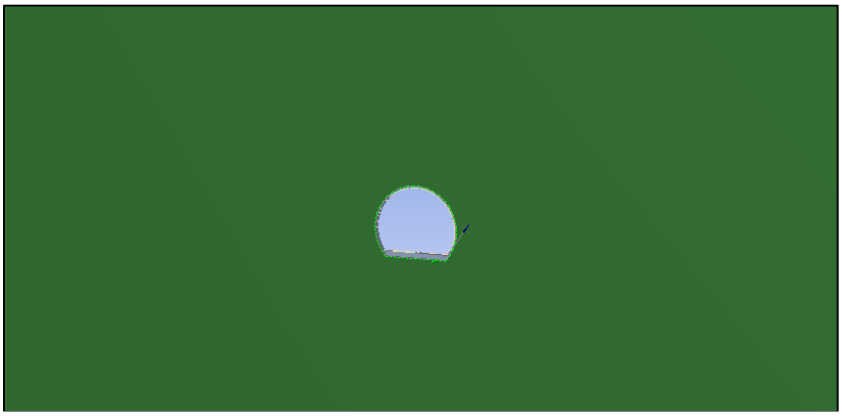

Figure 2: CAD design of tunnel with enclosure

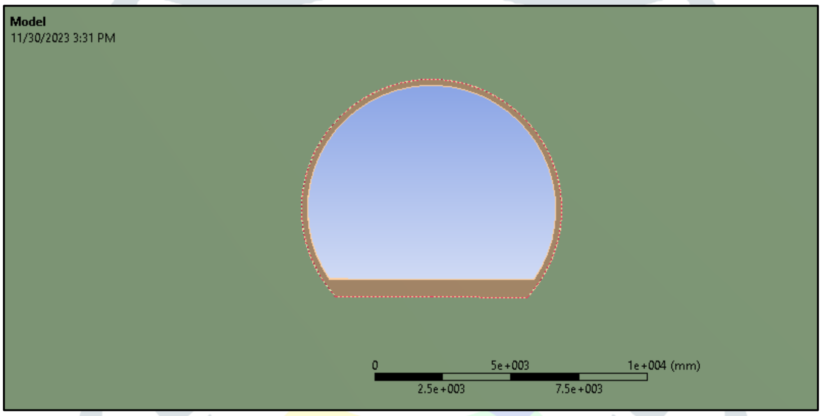

Figure 2: Imported CAD design of tunnel with enclosure

The developed model of tunnel design is checked with errors and surface imperfections. The model of tunnel design is discretized using hexahedral element type. The meshed model of tunnel domain is shown in figure 3.

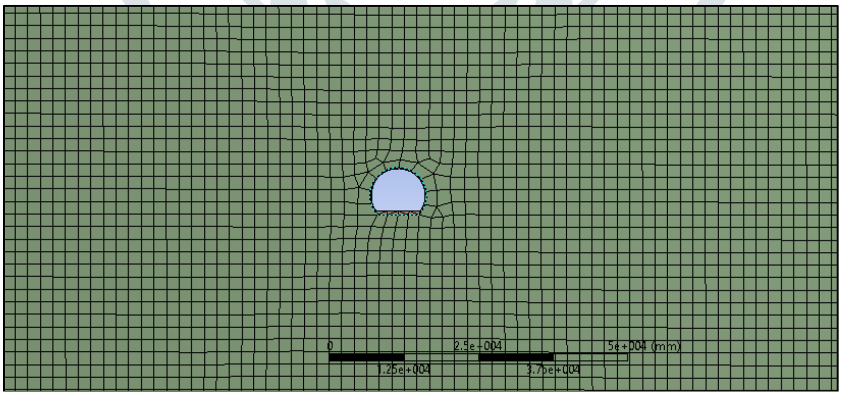

Figure 3: Meshed model of tunnel using brick shape elements

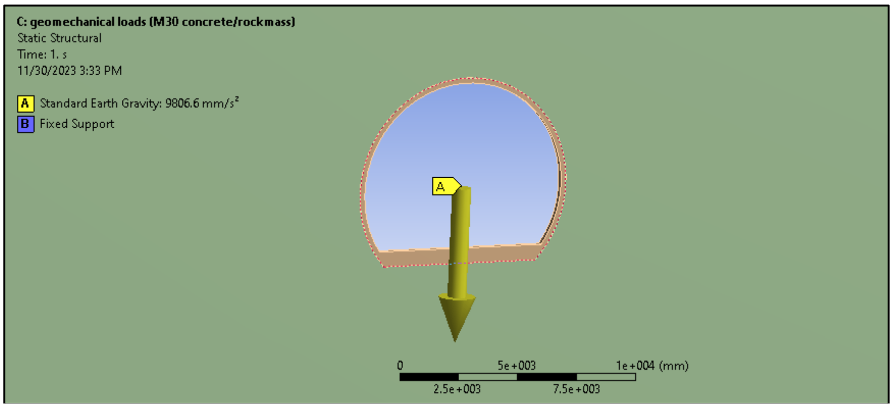

Figure 4: Loads and boundary condition on computational domain

The static loads and boundary conditions are applied on the tunnel lining structure with topological terrain as shown in figure 4. The loading conditions include fixed support at the bottom of tunnel structure and gravity load in vertically downward direction. After defining structural loads, the simulation is run which involves determination of nodal displacements are different nodes and interpolation along entire element edge length.

V. RESULTS AND DISCUSSION

The results are obtained from FEA simulation which includes deformation, normal stress, shear stress. The normal stress is maximum at the top left end of the computational domain. The deformation obtained is more than 302mm. The deformation is lower at bottom zone with magnitude of 147mm.

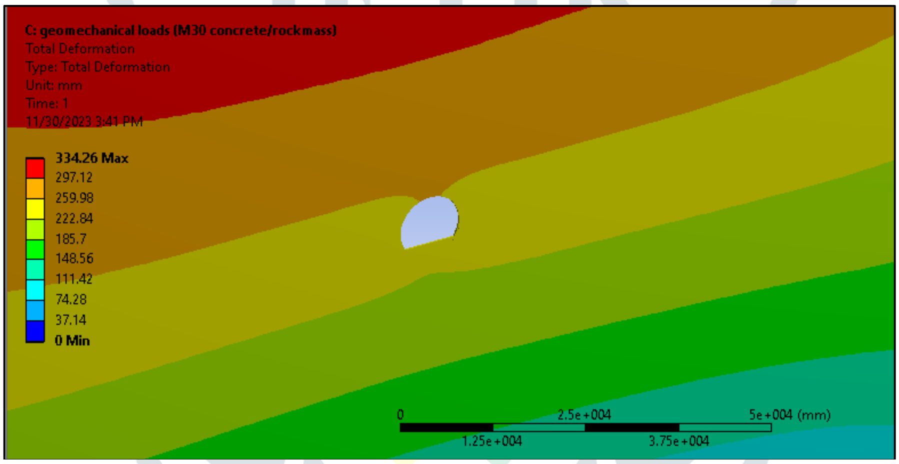

Figure 5: Induced deformation on tunnel structure

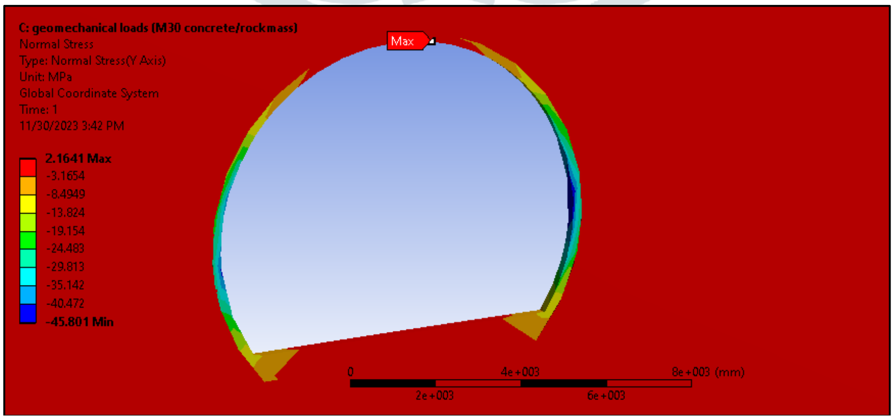

Figure 6: Normal stress on tunnel structure

The normal stress induced on tunnel structure and terrain structure is shown in figure 6. The side walls of tunnel lining have lower normal stress with magnitude of 29.8MPa. The stresses on top right and bottom left is 3.16MPa. The shear stress distribution plot is obtained for tunnel structure as shown in figure 7. The tunnel structure shows higher magnitude at top right and bottom left end of the tunnel lining structure.

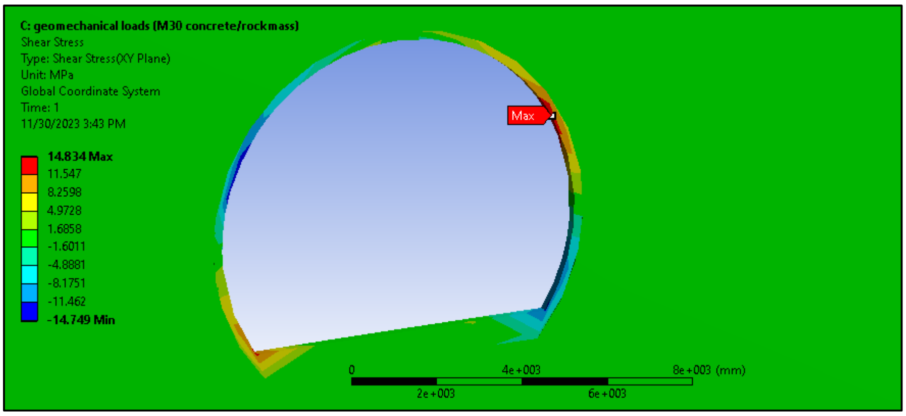

Figure 7: Shear stress on tunnel structure and terrain

VI. CONCLUSION

After conducting comprehensive research on tunnel structures utilizing ANSYS simulation software, the findings reveal crucial insights into the mechanical behavior of tunnel linings. The analysis focused on evaluating normal stress, shear stress, and deformation, providing a holistic understanding of the structural integrity under various loading conditions. The results indicate that the tunnel lining demonstrates commendable resistance to both normal and shear stresses, showcasing its robustness in withstanding external forces. Additionally, the observed deformations remain within acceptable limits, affirming the structural stability of the tunnel. These outcomes are pivotal for enhancing the design and construction of tunnels, ensuring their durability and safety. The utilization of ANSYS simulation has proven to be instrumental in predicting and optimizing the structural performance of tunnel linings, contributing valuable information for future infrastructure projects and facilitating advancements in tunnel engineering practices. As we celebrate the first anniversary of this research endeavor, it stands as a testament to the strides made in understanding and improving the reliability of tunnel structures through advanced simulation techniques.

REFERENCES

[1] Li, T., Yang, X., 2018. Probabilistic stability analysis of subway tunnels combining multiple failure mechanisms and response surface method. Int. J. Geomech. 18 (12), 04018167

[2] Zeng, P., Senent, S., Jimenez, R., 2016. Reliability analysis of circular tunnel face stability obeying Hoek-Brown failure criterion considering different distribution types and correlation structures. J. Comput. Civ. Eng. 30 (1), 04014126.

[3] Mollon, G., Dias, D., Soubra, A.-H., 2009a. Probabilistic analysis and design of circular tunnels against face stability. Int. J. Geomech. 9 (6), 237–249.

[4] Wang Q, Xin ZX, Jiang B, Sun HB, Xiao YC, Bian WH, Li LN. Comparative experimental study on mechanical mechanism of combined arches in large section tunnels. Tunn Undergr Space Technol 2020;99:103386

[5] Wang Q, Jiang B, Pan R, Li SC, He MC, Sun HB, Qin Q, Yu HC, Luan YC. Failure mechanism of surrounding rock with high stress and confined concrete support system. Int J Rock Mech Min Sci 2018;102:89–100.

[6] Yu ML, Zuo JP, Sun YJ, Mi CN, Li ZD. Investigation on fracture models and ground pressure distribution of thick hard rock strata including weak interlayer. Int J Min Sci Technol 2022;32(1):137–53.

[7] Use, T.H.E., Cape, O.F. & Treesshrubs, E. 2018. Geotechnical Engineering Design of a Tunnel Support System - A Case Study of Karuma (600MW) Hydropower Project (April 2017): 227

[8] Voit, K. & Kuschel, E. 2020. Rock material recycling in tunnel engineering. Applied Sciences (Switzerland) 10(8).

[9] Wei, Liangwen. 2016. Research on tunnel engineering geological exploration system based on tunnel seismic predication and ground-penetrating radar. Chemical Engineering Transactions 51: 1123–1128.

[10] Abdul Rahman Mahmud. 2021. Soil Erosion and Sedimentation Control Using Biological Method. International E-Conference on Applied Sciences, Society and Economics 2021 (ICASSE2021) (May): 153–159.

[11] Babar Khan, S. Muhammad Jamil, "Effects of different empirical tunnel design approaches on rock mass behaviour during tunnel widening" Heliyon 5 (2019) e02944, https://doi.org/10.1016/j.heliyon.2019.e02944