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A REVIEW ON STRUCTURAL DESIGN AND ANALYSIS OF CONCRETE TUNNELS

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Abstract
Tunnels are one of the prominent structures used for transportation. The current research reviews the existing work on tunnel design and analysis. These studies are based on use of both experimental and numerical techniques. The fundamental principles underlying tunnel design, geotechnical considerations are presented. The advantages, limitations of different techniques, processes are presented. Various case studies are presented to illustrate the application of these approaches in different geological and geotechnical contexts.

Keywords:
Tunnel, Structure, Concrete, Seismic loading

I. Introduction

A tunnel refers to subterranean pathways or conduits that are excavated beneath the earth's surface while minimizing any disruption to the soil or rock layer above. There exist various types of tunnels and they can be classified based on their characteristics.
• The mining of ores takes place in tunnels.
• They are additionally utilized for transport like road buses, trains, trams as well as canals.
• Tunnels are used to transport water and disinfectants.
• Tunnels are also used for Light turn of events.
• Underground chambers are typically connected by a network of interconnected tunnels and shafts, and are frequently used for things like underground hydroelectric power plants, mineral processing plants, pumping stations, car parks, oil and water storage, water storage, water treatment plants, and warehouses.
• Tunnels have been utilised by the military for special needs.
The process of designing or setting up a tunnel depends on a number of things, such as the landscape, the location of groundwater, the tunnel's diameter and length, its size, the materials used to support tunnel drilling, the tunnel's final use, its shape, and the need for risk management.

II. LITERATURE REVIEW

Li and Yang (2018) [1] proposed a technique that utilises a performance function to evaluate the global stability of the tunnel face, taking into account all possible failure rates of the working face. A probabilistic analysis was conducted on a tunnel face that was blasted through rocky masses using the RSM based on polynomial chaos expansion.

Zeng et al. (2016) [2] They established the limit state function utilising an innovative rotational mechanism. It should be noted that conventional applications of FORM and SORM necessitate the presence of an explicit performance function. The accessibility of this function may be limited in cases where deterministic analysis relies on numerical modelling. The present scenario involves the utilisation of RSM as a unique methodology for estimating the authentic performance function by employing a polynomial function in close proximity to the design point.

Mollon et. al. [3] The stability of the tunnel's working face was analysed probabilistically through the utilisation of a collocation-based random RSM and the two-dimensional (2D) multiblock fail mechanism. Furthermore, the circular tunnel face stability was designed utilising FORM. The methodology involves the utilisation of supplementary stochastic input parameters, including but not limited to soil shear resistance, unit mass, depth of coverage, and pressure of support.

Wang et al. [4] conducted research on the fault crossing concepts applicable to twin shield tunnels that traverse the Bakacak Fault and the Zekidai Fault in Turkey, with a particular focus on the Bolu Tunnel project. Subsequent to the Düzce earthquake (MW = 7.2) in 1999, an exhaustive seismic investigation was carried out in the vicinity of the Bolu Tunnel initiative, thereby facilitating a more accurate delineation of the two faults under scrutiny. The tunnel exhibits a downward inclination of around 90 degrees while passing through the Zekidai Fault's two channels, covering a distance of 25 to 30 metres (82 to 98 feet). Notwithstanding its projected right lateral offset displacement ranging from 0.15 to 0.25 m (5.91 to 9.84 in) resulting from a seismic event of magnitude between 6 and 6.25, this fault has been assessed to pose a low probability of experiencing future rupture. The Bakacak Fault, which has a slope of 40 degrees, is traversed by a tunnel that extends for a distance of 100 metres (328 feet). It is expected that an earthquake with interrelated characteristics, having moment magnitudes ranging from 6.25 to 6.5, resulted in rupture displacements of a maximum of 0.5 metres (19.69 inches). Geologists held the belief that the Bakacak Fault would exhibit primarily horizontal displacements that were widely distributed, and that the Zekidai Fault's displacements were unpredictable. Subsequently, this belief was validated. The researchers were able to compute the shear strain in the fault soil by utilizing the aforementioned initial assumption, which involved determining the ratio of the projected offset to the fault's width at the tunnel level. The soil was represented as Mohr Coulomb (M-C) compression springs through the utilization of tunnel lining and soil contact components.

Pan et. al. [5] The study conducted aimed to determine a suitable support and construction approach for the Semmering Base Tunnel in Austria that would produce tunnel displacements that are consistent with the fault system. FLAC2D was utilized in the investigation. The geological characteristics of the Graßberg-Schlagl fault system, which served as the site for the construction of this tunnel, were assessed through triaxial compression tests conducted on core samples. In order to assess the suitability of a nonlinear analysis, the outcomes of a triaxial compression examination on a solitary specimen were retroactively computed utilizing the ZSoil finite element software, while accounting for both the Hardening Soil (HS) - Small Strain and M-C constitutive laws.

Zuo et. al. [6] address the significance it is to use the HS model in ZSoil instead of the M-C model. They come to the conclusion that the HS model is the more accurate model to use in finite element analysis. Due to the fact that earth is only truly elastic under very small loads, the linear-elastic M-C model used in FEA does not always give correct and reasonable forecasts. The HS Standard Model reproduces basic physical soil phenomena like densification, stress-dependent stiffness, soil stress history, plastic yielding, and dilatancy. It also takes into account the nonlinearities of soil behavior before failure. Also, the HS-Small Strain model, which is an improved form of this model, includes the above processes as well as large changes in stiffness and a soil's nonlinear, hysteretic, elastic stress-strain relationship.

Cape et al. [7] use the MASW component to describe how the soil layer changes at different depths. Using MASW, scientists study how dirt and banks behave. This piece explains how to use a multichannel study of surface waves to figure out the density, Poisson's ratio, and Young's modulus of different soil layers in and around Bangalore.

Kuschel et. al. [8] used ABAQUS to do a finite element analysis to study how fault displacement affects a tube. Using the SURFSEIS software programme, the Rayleigh surface waves made in the area are recorded and used to figure out the soil factors for the area. In ABAQUS, a thrust flaw with backward thrusting was designed with an upper plate (the hanging wall) and a lower plate (the foot wall) that moved an average of 0.5 m. The vertical movement of the crack was simulated by moving the top plate while keeping the bottom plate still. There are places where the top and lower plates, the ground, and the tube walls all rub against each other. In this mathematical model, the tube and the earth were seen as the best materials that were both flexible and strong. The effects of primary loads and hydraulic pressure on soil yielding were taken into account using the Drucker-Prager yield criterion and the flow rule that goes with it.

Wei et. al. [9] comprehensive description of the geography, groundwater level, hard rock depth, and tunnel alignment along the east-west segment of the metro train project. It discusses the impact of the proposed metro tunnel on the groundwater system. According to the studies, the groundwater table will be approximately 5 metres below the surface, which will have a substantial effect on the stresses imposed on the underground pipe.

Abdul et. al. [10] explanation of the key elements of twin tunnel construction along the 24.2 km north-south and 18.1 km east-west corridors. The elevated part is 33.48 km long and the subterranean segment is 8.82 km long out of a total length of 42.3 km. The tunnel has an inner diameter of 5.6 meters, a boring diameter of 6.44 meters, and a reinforced concrete lining thickness of 280 millimeters. The twin tunnel measures 15.04 meters from center to center and ranges in depth from 15 to 18.3 meters roughly. Slurry TBMs are utilized for tunneling, as well as the earth pressure balanced TBM technique and the cut and cover method for stations. This portion of tunnel is being dug out by two drilling machines named Helen and Margarita, each of which can dig 11 metres per day.

Abdullah et al [11] examined how variables including explosion size, pipe burial depth, soil composition, and blast pressure characteristics interact to determine the extent of damage to a buried pipeline. The dynamic interaction between the ground and the structure, the resulting damage to the structure, the nonlinear response of the ground media, the three-dimensional effects, and the fluid-structure interaction all attest to the complexity of the issue.

Erguler et. al. [12] Using FLAC2D, options for the future Semmering Base Tunnel in Austria were investigated to determine a support and construction strategy that would end up in tunnel displacements in accordance with the fault system. The geological properties of the Graßberg-Schlagl fault system, through which this tunnel was constructed, were evaluated using triaxial compression experiments on core samples. To evaluate the applicability of a nonlinear analysis, The results of a triaxial compression test on a single specimen were back-calculated using the ZSoil finite element software and the M-C and Hardening Soil (HS) - Small Strain constitutive laws.

Guo et al. [13] applied the particle swarm optimization algorithm (PSO) and the Gaussian factor to enhance the pigeon heuristic optimization method (PIO) for optimizing the elastic parameter in the pre-stack amplitude variation with offset (AVO) algorithm.

Khan et al. [14] proposed an innovative approach utilizing the disturbance-inspired equilibrium optimizer (DIEO) to address the challenges associated with groundwater numerical models and the sustainable management of water resources. Their method involves an inversion technique for hydrogeological parameters. The methodology underwent testing across three distinct scenarios. The findings indicate that the system has the ability to rapidly and accurately identify hydrogeological characteristics.

Lawrence et al. [15] proposed a methodology for conducting a retrospective analysis of the earth's stress field, which considers the contextual factors of hydraulic fracturing. This approach involves the integration of an artificial neural network and a genetic algorithm. The concept underlying this idea is rooted in the radial basis function (RBF) neural network. The proposed approach reduces the computational burden by integrating an artificial neural network with an efficiency tool and generating training data from field measurements.

Zhu et al. [16] proposed a neural network approach known as GMDH (Group Modelling and Data Handling) to address the significant challenge of insufficient ground stress sample data. This method utilizes a combination of nonlinear features from the gravity and tectonic stress fields, and employs nonlinear expressions to fit the boundary load. As a result, it is capable of constructing a boundary condition model suitable for intricate geological settings. The efficacy of the technique was demonstrated through the construction of a two-dimensional geological representation of a given region.

Conclusion

The studies underscore the multidisciplinary nature of tunnel design and analysis, where considerations span geotechnical factors, construction methodologies, structural integrity, and optimization techniques. The findings highlight the importance of accurately assessing groundwater conditions, optimizing construction methods, mitigating damage risks, and employing advanced modeling and optimization tools. The integration of such approaches and techniques will contribute to the development of more efficient, safe, and sustainable tunneling practices. By leveraging the knowledge gained from these studies and embracing emerging trends, the field of tunnel engineering will continue to evolve, leading to enhanced infrastructure development and improved underground transportation systems.

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