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A REVIEW PAPER ON NUMERICAL MODELLING OF BUILDING RESPONSE TO UNDERGROUND TUNNELING

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Abstract - Numerous attempts have been done to predict and subsequently control the tunneling- induced ground movements due to the fact that the number of tunnels in urban areas is increasing. However, existing methods are faced with some limitations and cannot take into account of all the influential parameters in creating surface settlements. As a result, in many cases, the existing methods are not accurate enough, whereas prediction of the exact amount of the maximum surface settlement and the shape of settlement troughs is important to estimate the potential risk of building damage induced by tunneling. Empirically derived relationships have been mainly developed based on field observations obtained from hand mines or tunnels excavated using open faced shields. Therefore, these methods mainly consider more of geological conditions than tunneling operational parameters. Although these methods provide satisfactory results in determining settlement troughs, they tend to be misleading in estimating maximum surface settlement. Analytical methods assume ground as an initially isotropic, incompressible and homogeneous mass. These methods have been only developed for circular tunnels and therefore are inapplicable for noncircular tunnels under invariant geological conditions. Finite element simulation usually obtains the settlement troughs shallower and wider than the field observations (Lee and Rowe, 1989; Gunn, 1993; Dasari et al., 1996; Addenbrooke et al., 1997). This limitation can be partly improved by using advanced soil constitutive models. However, the time and the cost for a full three dimensional analysis with advanced nonlinear soil constitutive models is substantial. In the case of building damage assessment due to settlement of soil layers, the existing methods assume the buildings infinitely flexible ground displacement. Therefore, these methods require separate numerical analyses to determine the influence of building stiffness on ground displacements. Moreover, existing methods mostly determine building damages in two-dimensional condition, while building damage due to tunneling is exposed to three dimensional ground movements. There is no doubt that the ground movements and building damage analysis would be more realistic if the measured data is used. According to the capabilities of FEM to find a pattern among the input and output data, this method has the potential to be appropriate approach to predict ground movements induced by tunneling and building damages induced by ground movements due to tunneling, while its limitation is eliminated.

Key Words: Tunnel Boring Machine (TBM), Earth Pressure Balanced(EPB), Surface settlement prediction and monitoring instruments, Building settlement marker (BSM), Ground settlement marker(GSM),etc.

1. INTRODUCTION

To cater the need of transportation in cities, construction of roads and railways has already been built. But due to higher growth of cities and their increasing population, these modes of transportation are not sufficient now a day. So a new concept has arises and that is Metro railways. But in cities like Mumbai and Delhi, people even don't have sufficient space for building houses and residential complexes. Construction of Elevated Metros requires large space which is not available so underground metro is one of the best solutions. In some of the cities work has already been started. Construction of underground metro tunnels is not an easy task. People have to face various problems while constructing it. There is need to identify the problems and find the solution on it. We can identify number of problems faced by Engineers in metro tunnel construction. One of the problems is settlement of the overlying tunnel has to be reduced.

2. ENGINEERING SITUATION

Settlement of the overlying tunnel happens in Shenzen Metro construction, China. The new tunnels and the existing tunnels are located at the curves of 350-m radius, and the intersection angle between the new tunnels and the existing tunnels in plane is 20°–23°. The vertical distance between two tunnel lines is 2132 mm and ground is made of gravelly clay. Settlement of overlying tunnel is a complex problem. They have reduced this settlement by using grouting in various phases. The grout proportion used was different for different phases.

The east-west Metro of Kolkata must have had a curse of some black magician that heartbreaking incident are happening constantly. It took five years to brake the Gautama the engrossment problem the entire stretch from the Allah to her god realigned via is run it because Bovada did not give land to build the central metro station it took 750 crores extra and extensive planning and several other permission from the army to realign the metro[B_3].

Everything was moving right the heartbreaking incident happened more than 18 residential building affected and not less than 254 resistant has been evacuated from the area two buildings named 13 & 14 as shown in **Fig. No.1** dewlap attorney lane have completely collapsed into dust many more have titled and might collapse anytime the situation become so worse that residents couldn't even take their documents with them while evacuating[B_3].

Fig. No.1 Homes emptied after cracks in Kolkata's Bowbazar (Google Source)

Fig.No.2 House Collapse during metro tunneling in Bow Bazaar, Kolkata (Google Source)

When most of the east-west Metro is structurally ready the last section left to be bridged was the 2.45Kms section from shielded to Esplanade following this on January 25th this final stretch of tunneling began to tunnel boring machines named chandi or v- world applied when chandi was boring the westbound or Hara more than bound tunnel moive board the salt lake Mountain the TBMs began from this point following this and managed erode at Wellington crossing near Maulana Azad College the TBMs Bent left and following NEENO Chandra street they went ahead this point was the most critical part of the tunneling from Boubacar mode the DBMS had to turn right to follow the Bibi Ganguly Street up to see Allah while constructing underground metro TBMs often follow main roads even in this case you have been seen the TBEs were following his and managed erode an image on the street but here it wasn't possible Nimmo Chandra street intersects Bibi Ganguly Street approximately at 90-degree angle, metro rails cannot negotiate such sharp bends so to increase the radius of curvature of the tunnel the TBMs had no choice other than burrowing under residential building according to KMRC 6 building along the entire stretch have been identified to be in extremely dangerous condition as shown in **Fig.No. 2** most of the building present here dates back to colonial rules in British India when most of them are more than 100 years old some are even 200 years old[B_3].

3. OBJECTIVES

The present review covers the following significant objectives with reference to process of construction of underground tunnels & various problems associated with it.

1) To study ground settlement occurred in various places & various problems associated with it.
2) Literature survey of various studies carried on settlement caused to the structure by underground tunneling.
3) Collect information of building response to underground tunneling using different methods.
4) Learning the ways and methods to predict assessment of impact on structures.
5) To study solutions for prediction of building damage due to ground movement induced by tunneling using FEM based Numerical modelling & proposed measures to eliminate the construction risks.

4. LITERATURE REVIEW

As the topic of this project is modern and very high end not much of the literature is available on it. Some of the research has been performed on it and the. The following are the few mentioned main objective of given literature.

Reviews of previous studies

Victor H. Franco, et.al. (2019)[13]

Author investigate a rational and efficient probabilistic framework to address the uncertainties of geotechnical properties and the stratigraphic profile in a tunneling-induced building damage assessment. The probabilistic approach was based on the application of a hybrid point estimation method that employs a reduced number of computations without losing accuracy.

The framework also relies on sensitivity analyses using tornado diagrams. Analyses of ground movements and building displacements were considered prior to the building damage assessment. The proposed approach was applied to the recently constructed extension of Line 5 of the Sao Paulo Metro. Two- dimensional (2D) and three-dimensional (3D) numerical analyses were carried out using a commercial finite element code by considering the Mohr-Coulomb and linear elastic constitutive models. Three probabilistic scenarios based on the lower, mean, and upper bound values of the coefficient of variation of input variables were considered. The results obtained using the proposed framework allowed estimating the probabilistic scenario that better provides an ideal coefficient of variation to adopt for input variables. The ground elastic properties and upper layer thickness had the greatest influence on ground movements and building displacements. Finally, the building damage analysis showed good agreement with the settlement data measured in the field.

Dalong Jin, et.al. (2018) [3]

Author studied on shield tunneling underneath will inevitably cause settlement of the existing tunnel and may even threaten the safety of running trains. He proposed an analysis of extensive monitoring data from massive undercrossing construction cases in the Shenzhen metro area, the deformation characteristics of existing tunnels and the ground caused by the construction of a new shield tunnel underneath were analyzed. The additional longitudinal stress of the existing tunnel, which was the main reason for water seepage and structural damage of the tunnel lining, was studied. The difference between the settlement of greenfield and the existing tunnel was analyzed. Several key influence factors of existing tunnel settlement, such as the spatial position, support pressure and tunnel stiffness, were discussed and an empirical equation for estimating the settlement of existing tunnels induced by the excavation of a new shield tunnel was proposed. The settlement profiles obtained using the new prediction equation were compared with the real monitoring records, and good agreement was observed. The new equation derived from the cases studied in this paper can provide a reference for predicting and controlling the deformation of existing tunnels induced by shield tunneling.

V.B. Maji, A. Adugna, (2016)[12]

Author studied tunneling through cities underlain by soft soil, is commonly associated with soil movement around the tunnels and subsequently surface settlement. The predication of ground movement during a tunnelling project and optimum support pressure could be based on analytical, empirical or the numerical methods. The commonly used Earth Pressure Balance (EPB) tunneling machines, make use of the excavated soil in a pressurized head chamber to exert a support pressure to the tunnel face during excavation. This face pressure was a critical paramater in EPB tunnelling because the varying pressure could lead to the total failure and collapse of the face. The main focus of the author was to evaluate the critical supporting face pressure and grout pressure by observation of the vertical deformation and horizontal displacement of soil body during tunneling. The face pressure and grout pressures were varied to see how they might influence the magnitude of surface settlements/heave. A numerical model using PLAXIS-3D Tunnel software package was developed to analyze the soil movement around the tunnel which can involves different geotechnical conditions. The ground surrounding the tunnel was found to be very sensitive to the face pressure and grout pressure in terms of surface settlement and the possibility of collapse in the body of soil.

K. Premalatha, K. Raja (2015)[8]

The author studied on the estimation of ground movements induced by tunneling (both vertical displacements and horizontal displacements) and the imposition of these soil movements on the pile and computation of the consequent pile responses. Tunneling induced behavior of piles was estimated using PLAXIS software. Author found out that ground movements in the field are greater than those estimated using both empirical and analytical methods. This variation was may be due to negligence of soil type and its properties in the analysis.

A. Mirhabibi, A. Soroush (2012)[1]

Author investigate the reciprocal effects of tunnelling-induced ground settlement and surface buildings were among the main concerns in urban underground projects. Interactions between buildings and tunnels could had major effects on the settlement trough. Therefore the factors involved in this interaction need to be assessed prior to construction. The interaction of twin tunnels construction and buildings has been less studied compared to single tunnels. The authors present the results of a study on field data of the Shiraz metro line1 and conduct two dimensional numerical parametric simulations. The effects of different factors such as tunnels' depth and their center to center distance, and buildings stiffness, their weight, width and locations on the surface are assessed. Based on the results of the numerical simulations, the influence of each factor on the settlement trough is assessed and a new parameter named 'relative bending stiffness' was introduced to incorporate these factors. Two design graphs were developed for fast evaluation of the buildings effects on surface settlements in preliminary design phases. These graphs relate the maximum building settlement caused by tunneling to the corresponding green-field settlement.

5. CONCLUSIONS

We have gone through above mentioned international, National research papers and from these papers we understand different techniques using different software. We are trying to measure the settlement caused to the structure with the help of FEM Based numerical modeling.

6. SIGNIFICANCE OF RESEARCH

Large numbers of tunnels are excavated in many big cities around the world. A major concern of engineers during excavation of tunnels in the populated areas is to know that the surface and underground structures and services are sufficiently safe from ground movements induced by tunnel excavation. Hence, a reliable method to predict surface settlements and consequently the risk of the damage to adjacent building is necessary. The importance of the study on ground movements induced by tunneling is associated with the safety and economic aspects of underground projects. The significant of research are as follows: I. This study demonstrates the relationships among the surface settlement induced by tunneling and influential parameters. Therefore, the outcomes of the study contribute better understanding towards the behavior of the ground surface settlements related to tunneling. II. The presented research considers the effects of the existing structures on the surface settlement, due to the fact that actual data are used. Therefore, the method developed from this research provides more realistic and accurate prediction. III. In the model developed in this research, the ground movements induced by tunneling are simulated three-dimensionally, to the analysis of ground movements using advanced finite element tools that usually need much time to create and run a model, the presented model is practically useful to simulate ground movements threedimensionally in detail within a short time. IV. The existing methods for assessing building damage provide a simple means of estimating the near surface displacements due to tunneling under prediction condition, whereas a separate three dimensional analysis is required to investigate the effects of the building stiffness on the twist deformation. In contrast, the proposed model is able to estimate tunneling-induced building damage, in a straightforward manner. This is a useful model to quantify the building damage using all the influential parameters in actual condition with reasonable accuracy.

7. SCOPE OF WORK

This project utilized the geometrical parameters and stiffness ratio of buildings, settlement trough parameters and relative location of buildings and tunnel to estimate building damage induced by tunneling. The influences of non-linear building behavior were not considered in simulations. Furthermore, the range of applicability and accuracy of the presented model to predict potential risk of building damage induced by tunneling is limited by the data used in the model. However, the model presented can be used to predict building damage induced by all the existing tunneling methods and even braced excavations, while the parameters of the settlement trough and adjacent buildings are available.

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