

INVESTIGATING OF EFFECTIVE PARAMETERS ON STRESS BEHAVIOR OF PRESSURE DEEP TWIN TUNNELS UNDER PRESSURE

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ABSTRACT

The twin tunnels under the pressure have been analyzed in this study. Full-plane boundary element method (BEM) has been used for modeling. Focus of meshing on the boundary of twin tunnels distinguishes distinct features of the mentioned method with other numerical methods. In this regard, in addition to providing generalities of elastostatic formulation of the method and the required verification, the numerical study of the two tunnel has been done on stress and displacement components. The results showed that if the distance between two tunnel was more than $30R$ (R radius of tunnel), the vertical stress on the wall of one of the twin tunnels was converged towards an alone tunnel.

Keywords: *BEM , deep twin tunnels, stress behaviors, effective radius.*

INTRODUCTION

Today tunnel construction is very important. The presence of conditions such as high traffic volume has increased the use of parallel tunnels. Digging two tunnels next to each other with less than a distance makes them influence on each other, and endangers the stability of tunnels. When the two tunnels are dug next to each other, they will interact with each other due to vicinity, and cause deformations. Thus, it is necessary to examine the effective of the second tunnel on the first tunnel. The increasing development of computer science and computer use for analysis due to the ease and high speed has created numerical methods in engineering. BEM and finite element method (FEM) can be mentioned one of the numerical methods. Several laboratory and numerical studies have been done on the effect of the two tunnels on each other. A study was done by Kim et al [1] based on laboratory studies in 1996. He concluded that the effect of tunnels on each other in two parallel tunnels leads to tunnel crown move downward. Liu et al [2] carried out three-dimensional analysis on parallel tunnels. Chen et al [3] has also studied the distance pillar on parallel tunnel's behavior in 2009. Following Loganathan & Poulos [4] have offered analytical responses to determine the displacement of soft ground due to digging tunnel. A study conducted by Gioda and Locatelli [5] in 1999 on the effective of digging tunnel in sandy land with the help of field measurements. In 2003, displacement ground for an environment with two tunnels was investigated using centrifuge test [6]. For tunnels modeling in various geometric states, material properties were performed using FEM by Koutasbeleulis & Giriffith [7]. Lee and Rowe [8] investigated around the tunnel in clay soils using FEM deformation.

Beginning of BEM formation is nearly four decades. However, significant progresses have happened in the development of boundary element method. Discrete process of the boundary was used for the first time by Fredholm [9] in 1903 for potential flow equations. Since 1980 BEM was used to solve the soil problems, so that some researchers investigated discrete method of boundary in unbounded space [10 and 11]. In 2011, Duenser et al [12] simulated the underground structures using boundary element method, and analyzed their behavior , Also in 2006 so far Panji et al [13,14,15 and 16] have studied basic solutions of the full & half page using numerical method, and have utilized it to analyze

foundation and tunnel. The aim of the research is to examine the most minimum distance between two tunnels that do not effective on each other and is a state similar to absence of the second hole.

FULL-PLANE BEM

One of the most important features of BEM modeling of semi-infinite environments is without considering approximation. In numerical methods such as FEM to model the infinite and semi-infinite environments, it is required to analyze the scope with regarding an approximation from the environment. This will reduce the accuracy of these methods. Also in the case of extensive environment, the volume of calculations is increased, and finally the results are achieved slowly.

In boundary element method only with discrete boundary loading in infinite and semi-infinite environments, the whole environment is participated in the analysis, that in addition to higher speed it will have also higher accuracy. Tunnels in infinite space, loading on the surface of soil, wide strip surface or deep foundations with considering soil-structure interaction effect can be mentioned of a variety of infinite and semi-infinite environments.

FORMULATION OF BOUNDARY ELEMENTS IN FULL PLANE

By applying the weighted residuals' integral on equation of Navier elastostatic balance regardless of volume forces, we will have [17].

$$\int_{\Omega} \Omega_{kj,j} u_k^* d\Omega = 0 \quad (1)$$

So that in the above equation, u_k^* is weight function in weighted residuals or full-space Kelvin fundamental solution, Ω represents the problem, and $\sigma_{kj,j}$ is the equilibrium equation according to stress components. Solving the fundamental displacement in two-dimensional elasticity utilizing Navier equation and Galerkin method is obtained as follows:

$$u_{lk}^* = \frac{1}{8\pi\mu(1-\nu)} \left[(3-4\nu) \ln \frac{1}{r} \delta_{lk} + r_{,l} r_{,k} \right] \quad (2)$$

u_k^* is full space displacement fundamental solution along 1 under a single force along $r.k = 1.2$ $l = 1.2$ $\therefore$, r is distance of source point to receiver point (boundary or internal), $r_{,l}$ is derivative of r vector compared to along 1 δ_{lk} , l is Kronecker delta, and ν, μ represent the shear modulus and Poisson's coefficient, respectively. Twice part-by-part integration of equation (1), the Green relation is obtained as follows:

$$\int_{\Omega} \sigma_{kj,j}^* u_k d\Omega = - \int_{\Gamma} p_k u_k^* d\Gamma + \int_{\Gamma} u_k p_k^* d\Gamma \quad (3)$$

So that p_k and u_k represent the values of traction and boundary displacement of boundary. p_k^* Is fundamental solution of full space traction and Γ specifies boundary. Using Dirac delta function (one of the Boundary solution methods) boundary integral equation (BIE) is offered after the removal of sentences over the domain as follows:

$$c_{lk}^i u_l^i + \int_{\Gamma} p_{lk}^* u_k d\Gamma = \int_{\Gamma} u_{lk}^* d\Gamma \quad (4)$$

In the above equation $c_{lk}^i = 1 - (\theta_1/2\pi)$ and θ_1 are placement angle of boundary node of i (angle of boundary refraction). Fundamental solution of traction components of p_{lk}^* is achieved as follows:

$$p_{lk}^* = - \frac{1}{4\pi(1-\nu)r} \left[\frac{\partial r}{\partial n} [(1-2\nu)\delta_{lk} + 2r_{,j}r_{,k}] + (1-2\nu)(n_j r_{,k} - n_k r_{,j}) \right] \quad (5)$$

In this relation, n_j is j th-component of normal vector perpendicular to the boundary of Γ and $\partial r/\partial n$ is derivative of position vector of r compared to the normal vector. In the used of fundamental solutions of u_{lk}^* and p_{lk}^* , as well as BIM of 4, boundary unknowns can be obtained for each boundary node of i . It should be noted that stress fundamental solutions to determine the stress at each internal point defined in the problem can be achieved using equilibrium equation and fundamental solutions of full space displacement as follows:

$$\sigma_{ij} = \int_{\Gamma} D_{kij}^* p_k d\Gamma - \int_{\Gamma} S_{kij}^* u_k d\Gamma \quad (6)$$

$$D_{kij}^* = \frac{1}{r} \left\{ (1-2\nu) \left\{ \delta_{ki} r_{,i} + \delta_{ki} r_{,i} - \delta_{ij} r_{,k} \right\} + 2r_{,i} r_{,j} r_{,k} \right\} \frac{1}{4\pi(1-\nu)r} \quad (7)$$

(8)

$$S_{kij}^* = \frac{2\mu}{r^2} \left\{ 2 \frac{\partial r}{\partial n} \left[\frac{(1-2\nu)\delta_{ij} r_k}{+v(\delta_{ik} r_j + \delta_{jk} r_j) - 4r_j r_j r_k} \right] + 2v(n_i r_{,j} r_{,k} + n_i r_{,j} r_{,k}) + (1-2\nu)(2n_k r_{,j} r_{,j} + n_j \delta_{ik} + n_i \delta_{jk}) - (1-4\nu)n_k \delta_{ij} \right\} \cdot \frac{1}{4\pi(1-\nu)}$$

In the above equations D_{kij}^* and S_{kij}^* are fundamental solutions of internal stress and δ_y is the stress tensor.

NUMERICAL MODELING

First, a software was prepared based on full-plane BEM which was presented in the above . This software is able to analyze and examine the subsurface tunnels in a static state. In the Figure 1, a numerical study including geometric parameters and material properties was shown. Also, the discretized boundaries can be seen in this figure.

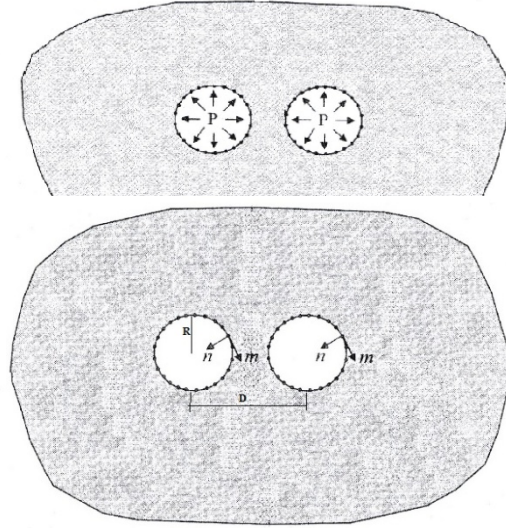


Figure 1: the modeling deep twin tunnel under pressure for present study

ASSUMPTIONS

The assumptions of present study are presented as follows:

1. Radius of the tunnel in this study has been assumed 3m.
2. Poisson's ratio has been considered 0.1.
3. Quadratic element has been used for discretizing the tunnel boundary.
4. pressure value has been assumed 100 MPa.

VERIFICATION

In this state, first a tunnel has been investigated under the pressure of 100 MPa in a static state Figure2. Then, by creating a second tunnel parallel to the first tunnel, stress disorganization and stress change can be seen around the first tunnel. In this study, it has been tried to make zero the effective of second tunnel on the first one by increasing distance. According to the results obtained from this program that have been shown in Figure 2, it can be seen that the effective of chart with distance more than 30R has become zero.

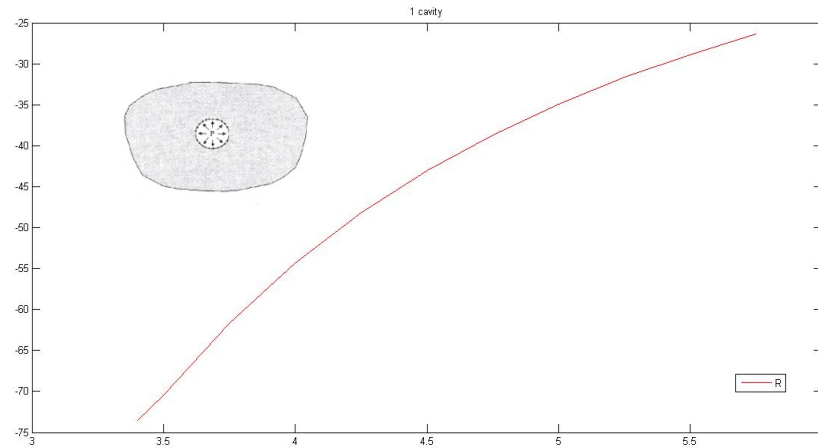


Figure 3: First tunnel without the second tunnel

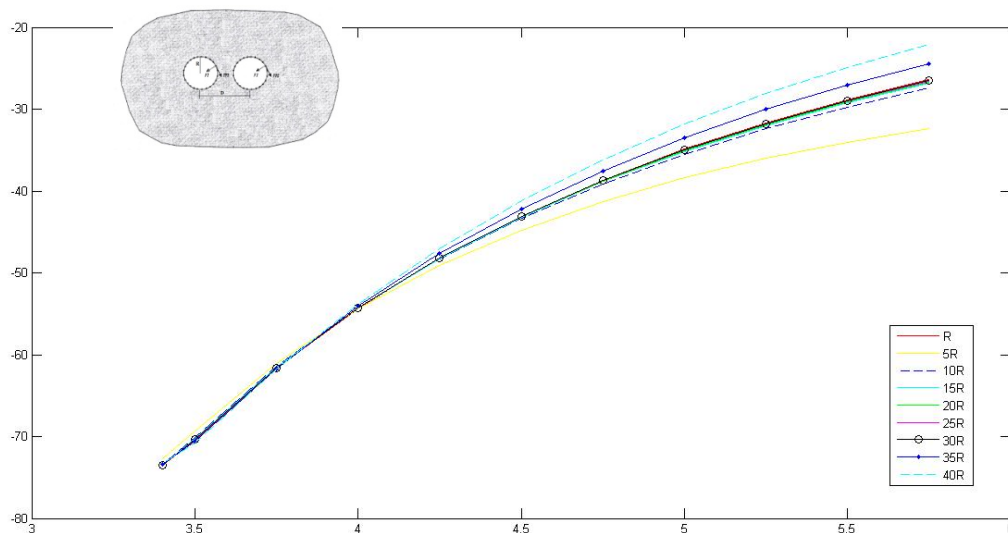


Figure 4: Diagram of twin tunnels

VERIFICATION EXAMINATION

Today authenticity of a subject in engineering is done in two ways. The first method is examination of the current method with previous researchers' studies that in addition it should not violated them, should have more accuracy than them. The later method mentions an engineering reason to prove the subject. According to Figure 4, it can be seen that increasing the distance between the two tunnels from other reduces the effective of the second tunnel on first tunnel. This is a logical reason and confirms the authenticity of the software.

CONCLUSION

According to conducted analysis using the prepared algorithm, the importance of the presence of two parallel tunnels on stress responses and their displacement was analyzed. The results showed that the effective radius on each other is removed and the responses of each of the tunnels converge towards

the single hole tunnel by increasing distance of one of the tunnels to the other tunnel as much as 30 times the tunnel radius.

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