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Numerical Modelling of the Position of the New Tunnel and Their Effect on the Existing Tunnel

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Abstract: *The tunnels offer a workable method for creating transportation and utility infrastructure in metropolitan regions. Sometimes we need more than one tunnel in the same place. However, building of the new tunnels inevitably causes settlements and ground displacements, threatening nearby constructions or the old tunnels. In this paper aims to investigate to control the settlement of the soil after the excavation, and the effects of new tunnel on the old tunnel. The study illustrates the importance of the positions of the new tunnels and their effects on the old one. Results show that, the building of a new tunnel below an existing one is the worst location. We note that in order to preserve and protect an existing tunnel, we build new tunnels to the left or right of the existing tunnel, while maintaining a safe distance between the two tunnels.*

Keywords: *Tunnel positions, Settlements, Stability tunnel, finite elements method.*

1. Introduction

As more people move to big cities, urbanization has expanded rapidly in recent years. As a result of this endeavor, metropolitan regions now have a higher population density [1–4]. The most sought sort of solution for the more rapid system of transportation services is the building of tunnels [5]. Numerous research have been carried out, by many of researchers to comprehend the stability of tunnels built in rock and soil [6-7]. At this time, there are several ways to forecast surface settling brought on by tunnel construction, including as, the airy stress function approach [8-12], the stochastic medium theory [13-15], the empirical formula method [16-19], the elastic strain method [20-23], and the numerical modelling method [24-25]. Numerous parameters and many loading types are typically analyzed for tunneling difficulties using the numerical method [26-30]. For tunnelling, the procedures and technologies depend on groundwater levels, the application for which the tunnel is being used, the location, geotechnics, geology, length, form, and diameter of the tunnel, among other criteria.

Conceptually, the tunneling process may be separated into three parts. Planning (feasibility study), is the first step: which outlines and provides a basic design for the tunnel while identifying the project's constraints and dangers; the engineering, is the second step, which focuses on producing exact, constructible designs; the last part is, the building, execution, and ultimate update of the tunnel's preconstruction design, as well as the maintenance plan, [31]. There are several tunneling construction techniques [32-33], some of which include: Drill and Blast Method (New Austrian Tunnelling Method); Cover Method (Bottom Up; Top Down); Jacked Box Method; and Tunnel Boring Machine Method (Slurry TBM, Earth Pressure Balance, Variable Density Tunnel Boring Machine).

Most past research has used the two tunnels for simulated the effect of the surface settlement, they did not used the effect of the new tunnel on the ancient one to analyze the settlement. In this paper we try to study the influence of the new tunnel on the old tunnel, with two-dimensional finite element method by the OptumG2 software.

2. Numerical Analysis

In this study, we compared various position of new tunnel to understand the behavior of these positions and theirs influences on the old tunnel. These tunnels positions were analyzed using the 2D plane strain analysis with the Mohr-Coulomb criteria. The finite element software is called (OPTUMG2). The geometry of the model, and the base of the boundary condition is fixed as shown in figure 1. The width and height of the total modeling domain are 70 m and 50 m, respectively. The tunnels have been studied with a diameter of 8 m, and the lining concrete thickness was 0.25 m. All parameters of this modeling are exposed in Table 1.

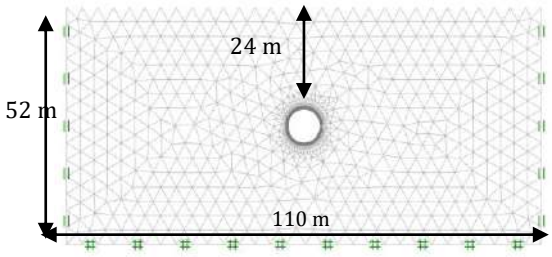

Fig -1:The geometry, Mesh and Boundary condition of the tunnel

Table 1: Soil and concert lining properties

Concrete Lining	***Value (Unite)***
Section area A	2500 (cm^2/m)
Weight W	625 (kg/m/m)
Thickness	25 (cm)
Young's module E	$2.54 * 10^4$(MPa)
Yield strength	28
Moment of inertia I	$1.302 * 10^5$ (cm^4/m)
Plastic section modules	$1.563 * 10^4$ (cm^3/m)
Soil Properties	***Value (Unite)***
Saturated density γ_{sat}	20.5 (KN/m^3)
Young's module E	43.4 (MPa)
Cohesion c	39.5 (KPa)
Poisson's ratio ϑ	0.26
Friction angle φ	29.5 (°)

3. Resultants and Discussion

In this part of modelling, we want to examine the displacements at the ground surface level with Y = 50 m just with the old tunnel, without the new tunnel. Figure 2, illustrate the tunnel's final displacements following the excavation of the old (first) tunnel, the maximum surface settlement value is 6.8 cm.

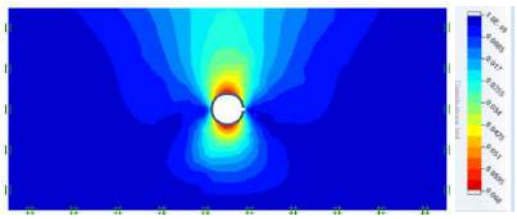

Fig -2:The total displacement of the first tunnel

As we see, the total vertical displacements are concentrated at the bottom and top of the first tunnel as shown in figure 2, this figure illustrated the outlines of total displacement, these deformation are symmetrical with vertical axis of the tunnel.

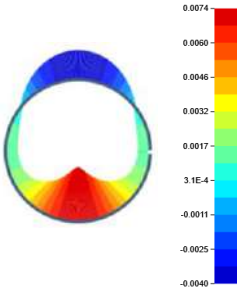

Fig -3: Vertical displacements of the concrete lining (m)

To more clearly discern the deformation near the tunnel's edge (see figure 3). The emergence of surface settlement may be an indication of the failure zone that surrounds the tunnel. Due to soil pressure, the tunnel lining deforms. As we see in the figure 3, there are different vertical displacements exist. Underneath the tunnel, there is the most displacement (7.4 mm), and there is the least displacement at the top of the tunnel (- 4 mm).

3.1. Adding a new tunnel to the left and to the right, near to the existing tunnel

In this part of modelling we add the new tunnel on the left (figure 4 (a)), and other modelling to other new tunnel on the right (figure 4 (b)), the distances of these new tunnels to the old one are 12 m to the left, and 12 m to the right. Figure 4 (c), (d) illustrates that the total displacements of this model. The displacement of these two models are the same the only difference is in location of their displacements. We notice that the settlement of the soil (in top of the tunnel), is more developed that the bottom of the tunnels. The total displacements of the left and right models are the same 7.72 cm, these displacements are bigger than the displacement of one tunnel (old tunnel). When we compared these models with one tunnel (old tunnel only), we find that the new tunnel represented the developments of large displacement.

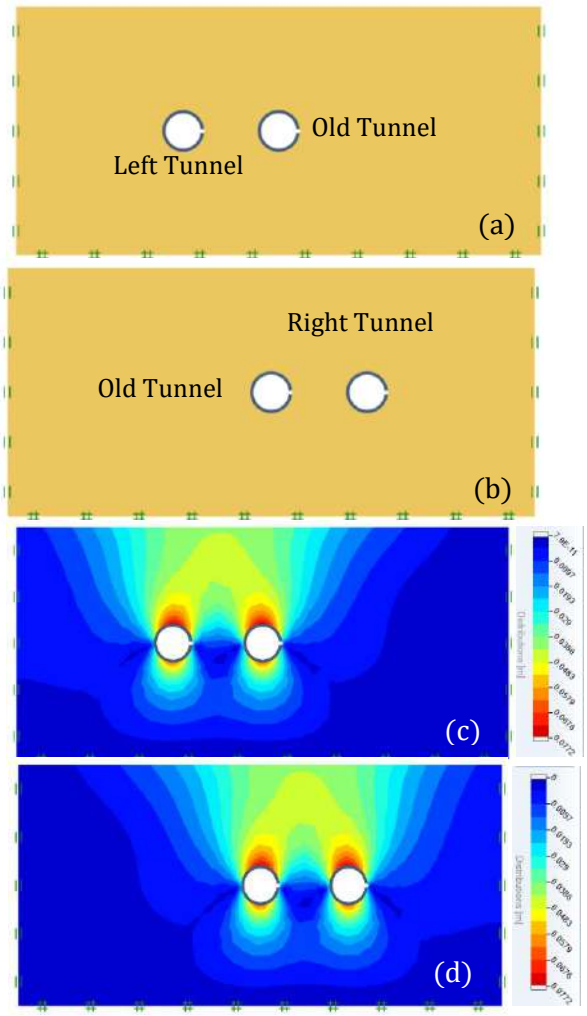

Fig -4: The existing tunnel with left (a), right (b) tunnel and the total displacements (c), (d)

Figure 5, displays the total vertical displacements for the three types of tunnels. We note that the vertical displacements of one tunnel (old tunnel) are small compared to the vertical displacement of the present of the new tunnel is the left and right, the maximum settlement of one tunnel is 2.5 cm. when we add the second tunnel in the left or right, the settlements will bigger, (4.3 cm), these settlements around the old tunnel.

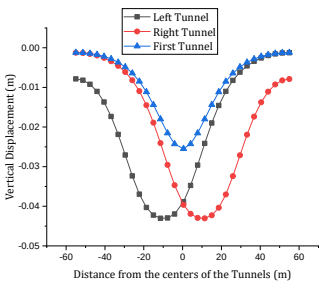

Fig -5: Vertical displacement of the first tunnel with the near left and right tunnel

3.2. Adding a new tunnel to the left and to the right, far the existing tunnel

Figure 6 (a) and (b) illustrate, two new tunnels, the first one is far by 32 m in the left of the old tunnel, with same distance (32 m) we add other tunnel to the right of old one. In this part of modelling, we illustrates that the total settlement of these models are the same, and these displacements are larger of the past modelling (near tunnels), because the distance between the tunnels. The displacement of the soil, is bigger at the top of the tunnels. The total displacements of the left and right models are the same 7.27 cm, these displacements are bigger than the displacement of one tunnel (old tunnel), but smaller when compared with the near tunnels.

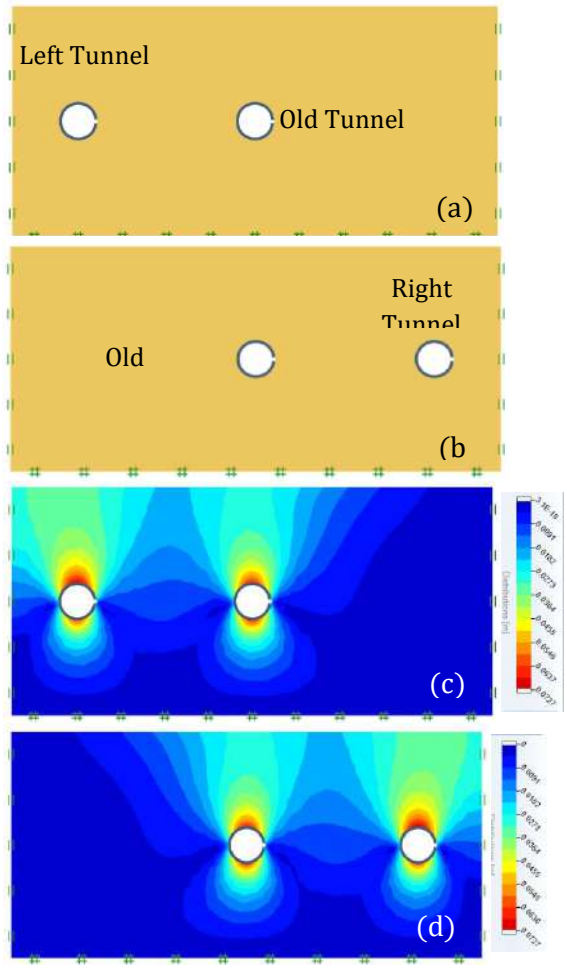

Fig -6: The existing tunnel with left (a), right (b) tunnel and the total displacements (c), (d)

Figure 7 shows the settlements of the soil in the tunnels centers at the bottom of the tunnels, and all of the vertical displacements values are the same results (4.3 cm) in the left and right sides of the old tunnel, because we add of the new tunnel at left and right as we see in

figure 7. When we take the old tunnel only, the value of the vertical displacement is 2.5 cm, it is small with the new tunnels.

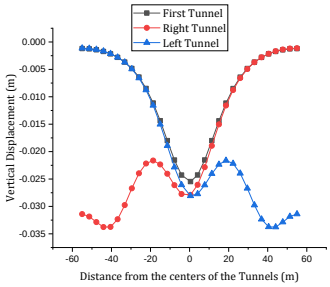

Fig -7: Vertical displacement of the first tunnel with the far left and right tunnel

3.3. Adding a new tunnel to the top and to the bottom, of the existing tunnel

In the last section of this numerical modelling, we will analyze the effect of top and bottom new tunnels, in the similar method we treated the right and left tunnels. Figure 8 (a), (b) shows, two new tunnels in the top and other in the bottom of the existing tunnel, these two new tunnels are far by 7 m, in the top, and in the bottom of the first tunnel. Figure 8 (c), and (d) illustrates that the total settlement of these models are not the same, and the biggest displacements with value of 8.83cm when the new tunnel at the bottom. The settlement of the model when the new tunnel on the top is 7.2 cm.

In term of displacements vertically, the figure 9 shows the difference between the displacements of these three cases of tunnels, the old one only, the top and bottom new tunnel with the first tunnel (old tunnel). Figure 9 illustrates the maximal vertical displacement of the lower tunnel with value of 4.8 cm that because the effect of the new tunnel one the bottom of the old one, the smaller displacement is the old tunnel only with 2.5 cm.

To more clearly see how the dirt affects the concrete lining, Figure 10 shows that the ground movements caused by the new tunnel at the bottom of the old one. The normal forces, around the concrete lining of the two tunnels due to the displacements and pressure of the soil. As we see the figure 10, the most large and important normal force is concentered at the bottom of the lower new tunnel.

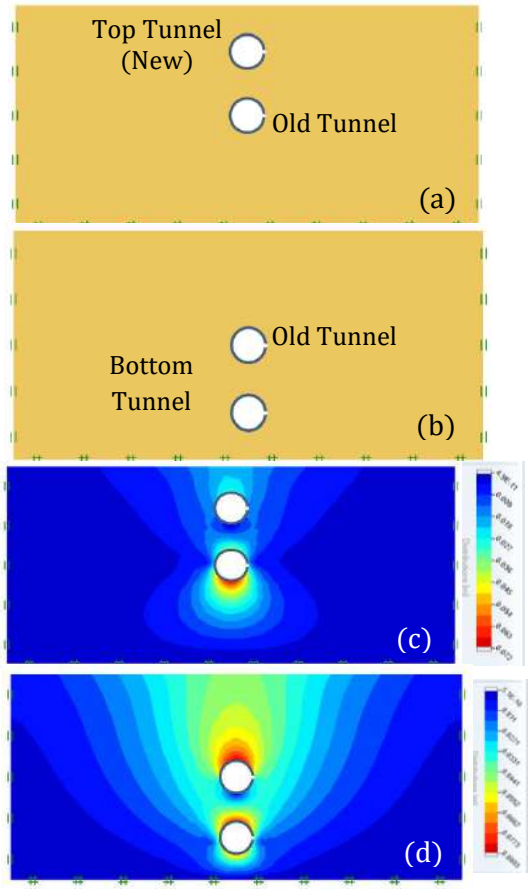

Fig -8: The existing tunnel with top (a), bottom (b) tunnel and the total displacements (c), (d)

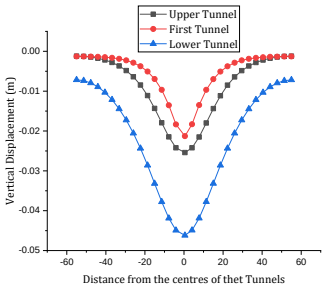

Fig -9: Vertical displacement of the first tunnel with the Upper and Lower tunnel

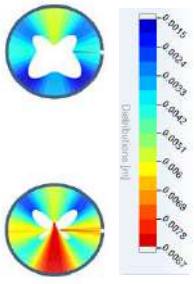

Fig -10: Normal force (kN/m)of the lower tunnel on the existing tunnel

4. Conclusion

Due to the excavation of rock mass, to create the new tunnel with the old tunnel these underground buildings are impacted by settlements, and displacements with two-dimensional finite element method by the OptumG2 software. This aim goal of this study, is to assessment the old tunnel when we add the other tunnel, and the effect of the position of the new one, on the old tunnel. The numerical study clearly show that, the maximum and the larger displacements and settlements are presented when we add new tunnel at the bottom of the old tunnel. We also observe when the new tunnels are created far to the left and right the old tunnel, it is so stable to the near new tunnels (left and right). The normal forces is large in the bottom of the concrete lining at the new tunnel.

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References

[1] M. Wasif Naqvi, M. F. Akhtar, Mohammad Zaid, M. R. Sadique. Effect of Superstructure on the Stability of Underground Tunnels. Transportation Infrastructure Geotechnology (2021) 8:142–161. https://doi.org/10.1007/s40515-020-00119-6.

[2] H. A. TALEB, Ch. Fayssal, Ou. AZZOUZI, H. Ch. LEDJDEL, Two Dimensional Numerical Analysis of Tunnel by the Finite Element Method: Evaluation Case of "Djelfa, Algeria". International Journal of Advanced Studies in Computer Science & Engineering Ijascse Volume 11 ISSUE 6, 2022.

[3] I. GUEMIDI, H. A. TALEB, B. ELBAHI, M. k. M. AHMED. A Numerical Study Using a Two-Dimensional Finite Elements Method to Analyze the Stability of Seven Tunnel Transversal Sections. International Journal of Advanced Studies in Computer Science & Engineering Ijascse Volume 11 Issue 8, 2022.

[4] H. A. TALEB, I. GUEMIDI, A Numerical Study of the Various Tunnel Transversal Sections (Four Tunnel Shapes) Using the Finite Element Method. 5TH International Conference ON LIFE AND ENGINEERING Sciences, Antalya, TURKEY ICOLES, 19-22, May, 2022.

[5] Meguid MA, Saada O, Nunes MA, Mattar J (2008) Physical modeling of tunnels in soft ground: a review. Tunn Undergr Space Technol 23:185–198

[6] Carranza-Torres C, Fairhurst C (1999) Theelasto-plastic response of underground excavations in rock masses that satisfy the Hoek-Brown failure criterion. Int J Rock Mech Min Sci 36:777–809. https://doi.org/10.1016/S01489062(99)00047-.

[7] Ouchi A, Pakalnis R, AGM-CIM TB (2004) Update of span design curve for weak rock masses. In: Proceedings of the 99th annual AGM-CIM conference. Edmonton, AB.

[8] A. M. M. Wood, "/e circular tunnel in elastic ground," Géotechnique, vol. 25, no. 1, pp. 115–127, 1975.

[9] A. Bobet, "Analytical solutions for shallow tunnels in saturated ground," Journal of Engineering Mechanics, vol. 127, no. 12, pp. 1258–1266, 2001.

[10] K. H. Park, "Elastic solution for tunneling-induced ground movements in clays," International Journal of Geomechanics, vol. 4, no. 4, pp. 310–318, 2004.

[11] K.-H. Park, "Analytical solution for tunnelling-induced ground movement in clays," Tunnelling and Underground Space Technology, vol. 20, no. 3, pp. 249–261, 2005.

[12] A. M. Puzrin, J. B. Burland, and J. R. Standing, "Simple approach to predicting ground displacements caused by tunnelling in undrained anisotropic elastic soil," Géotechnique, vol. 62,no. 4, pp. 341–352, 2012.

[13] J. Litwiniszyn, "the theories and model research of movements of ground masses," in Proceedings of the European Congress Ground Movement, pp. 203–209, Leeds, UK, April1957.

[14] K. Wu, Z. S. Shao, S. Qin, and B. X. Li, "Determination of deformation mechanism and countermeasures in silty clay tunnel, "Journal of Performance of Constructed Facilities, 2019.

[15] X. L. Yangand J. M. Wang, "Ground movement prediction for tunnels using simplified procedure," Tunnelling and Underground Space Technology, vol.26, no.3, pp. 462–471,2011.

[16] R. B. Peck, "Deep excavations and tunnelling in soft ground," in Proceedings of the Seventh International Conference on Soil Mechanics and Foundation Engineering, pp.225–290,Mexico City, Mexico, August 1969.

[17] P. B. Attewell and J. P. Woodman, "Predicting the dynamics of ground settlement and its derivatives caused by tunneling in soil," International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts, vol.15, no. 8, pp.13–22, 1982.

[18] R. J. Mair, R. N. Taylor, and A. Bracegirdle, "Subsurface settlement profiles above tunnels in clays," Géotechnique, vol. 45, no. 2, pp. 361-362, 1995.

[19] M. Lei, J. Liu, Y. Lin, C. Shi, and C. Liu, "Deformation characteristics and influence factors of a shallow tunnel excavated in soft clay with high plasticity," Advances in CivilEngineering, vol. 2019, Article ID 7483628, 14 pages, 2019.

[20] C. Sagaseta, "Analysis of undraind soil deformation due to ground loss," Géotechnique, vol. 37, no. 3, pp. 301–320, 1987.

[21] A. Verruijt and J. R. Booker, "Surface settlements due to deformation of a tunnel in an elastic half plane," Géotechnique, vol. 46, no. 4, pp. 753–756, 1996.

[22] N. Loganathan and H. G. Poulos, "Analytical prediction for tunneling-induced ground movements in clays," Journal of Geotechnical and Geoenvironmental Engineering, vol. 124, no. 9, pp. 846–856, 1998.

[23] B. Zeng, D. Huang, and J. He, "Analysis of double-O-tube shield tunnelling-induced soil deformation due to ground loss," Géotechnique Letters, vol. 6, no. 1, pp. 7–15, 2016.

[24] Y. Cheng, Z. Song, J. Jin, and T. Yang, "Attenuation characteristics of stress wave peak in sandstone subjected to different axial stresses," Advances in Materials Science and Engineering, vol. 2019, Article ID 6320601, 11 pages, 2019.

[25] G. Swoboda and A. Abu-Krisha, "/ree-dimensional numerical modelling for TBM tunnelling in consolidated clay," Tunnelling and Underground Space Technology, vol.14, no. 3, pp. 327–333, 1999.

[26] Irfan Ahmad Shah, and Mohammad Zaid. Behavior of Underground Tunnel under Strong Ground Motion. Proceedings of Indian Geotechnical conference 2020. December 17-19, 2020, Andhra University, Visakhapatnam. Theme 13,pp. 229-239.

[27] Zaid, M., Irfan, S., Farooqi, M.A. (2019). Effect of Cover Depth in Unlined Himalayan Tunnel: A Finite Element Approach. In the proceeding of 8th Indian Rock conference, Indian International Centre, New Delhi, India, 03-04 March 2019, ISBN No. 81-86501-27-1. pp 448-454.

[28] Shahin, H. M., Nakai, T., Zhang, F., Kikumoto, M., & Nakahara, E. (2011). Behavior of ground and response of existing foundation due to tunneling. Soils and foundations, 51(3), pp. 395-409.

[29] Pakbaz, M. C., &Yareevand, A. (2005). 2-D analysis of circular tunnel against earthquake loading. Tunnelling and Underground Space Technology, 20(5), 411-417.

[30] Mroueh, H., &Shahrour, I. (2003). A full 3-D finite element analysis of tunneling adjacent structures interaction. Computers and Geotechnics, 30(3), 245-253.

[31] C. di Prisco, L. Flessati, D. Peila, E.M. Pizzarotti. Book "Handbook on Tunnels and Underground Works" Chapter "Risk management in tunnelling". 1st Edition, 2022, CRC Press, ISBN 9781003256175.

[32] M. Faraz Athar, Mohammad Zaid, Md. Rehan Sadique, (2019) "Stability of Different shapes of Tunnels in Weathering Stages of Basalt", In Proceedings: National Conference on Advances in Structural Technologies (CoAST-2019), NIT Silchar, Silchar, India. http://www.nits.ac.in/conferences/CoAST_2019/CoAST_2019.html.

[33] Zainul Abedin Khana, Md Shahab Khana, M. R. Sadiquea, ManojitSamantab, Mohd. MasroorAlama. Response of Twin Transportation Tunnel in Earthquake Loading: A Review.2021. IOP Publishing. Ser.: Earth Environ. Sci. 796 012044. doi:10.1088/1755-1315/796/1/012044.

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