Trends in Life Sciences
An International Peer-reviewed Journal
www.sciencejournal.in

THREE-DIMENSIONAL SIMULATION OF MECHANIZED EXCAVATION OF TWIN TUNNELS IN SOFT SOIL

Saber Gholizadeh@ and Golam Moradi
Geotechnical branch, Department of Civil engineering, Engineering Faculty, Tabriz University, Iran
@Corresponding author: Golam Moradi - email: gmoradi@tabrizu.ir

ABSTRACT
The upsurge in transportation in large towns has influenced the twin tunnelsconstruction atshallownadirs. In relation to the parallel excavation of mechanized twin tunnels, many cases discussed in the last studies have mainly concentrated on the relationship between two horizontally driven tunnels. But, little work and research have been devoted to the relationships between tunnels that are stacked over each other. The numerical analysis done in this research study has enabled the evaluation of the effect of construction process on tunnels which are two stacked with the help of FLAC3D set difference element software possible. The induced structural forces in every stacked tunnel as well as the displacements in the neighboring ground have been emphasized. The numerical analysis outcome shows that new tunnel construction can greatly influence the existing tunnel. The greatest effects are noted when the excavation of the upper tunnel is done first. The upper tunnel excavation normally results in greater surface settlements than when the excavation of the lower tunnel is done first. In addition, the study indicates that normal forces induced in the upper tunnel are ever less than those created in the lower tunnel. The bending moment and normal displacement induced in the upper tunnel are usually larger than those in the lower tunnel.

KEYWORDS: Stacked tunnels, Segmental tunnel lining three-dimensional modeling, surface settlement, Tunnel support, lining response.

INTRODUCTION

The creation of twin tunnels close to each other has become popular in cities currently. At some points, twin tunnels are stacked over each other to prevent the pile foundations of the current structures on the ground surface (Potts and Higgins, 2004). In relation to the excavation of modern twin tunnels near each other, most of the previous studies have concentrated on the use of physical tests to determine correlation between two horizontally driven tunnels.

However, petite has been executed in relation to the interactions between tunnels stacked over each other (Australian Tunnelling Conference, 1999).
A series of 3D centrifuge model tests were employed to determine the impact of twin tunnel creation in dry sand. A vital effect of the tunnel creation procedure on the ground movement of the surrounding tunnels was highlighted by altering the induced internal forces within the existing piles as well as by settlement curves. According Yamaguchi et al. (1998), the interactions between two tunnels are divided into three stages:
Stage 1- the succeeding shield nears the measuring point as well as its thrust starts to have an impact;
Stage 2- the succeeding shield's tail passes the measuring point as well as the influenceor impact of the falling pressure following excavation can be seen;
Stage 3- the succeeding shield regress and halts to have effect.

Unluckily, only the earth pressures and tunnel bending moments measured in the existing tunnel during the passing of the succeeding shields were studied in this work. The superposition technique introduced by Suwansawat and Einstein (2007), to handle cases of stacked tunnels and two horizontal tunnels that are parallel driven, assumes the influence of the ground unloading or existing tunnel because of the preceding tunnel excavation. Thus, the settlement curves fail to represent the final displacement appropriately (Divall and Goodey, 2012). Channabasavaraj and Vishwanath (2012) presented the numerical analyses of 2D, which revealed the effect of the new tunnel position on the existing tunnel behavior. They proved that when the upper tunnel is constructed first, there will be greater structural forces plus settlement than those due to constructing the lower tunnel first. Li and associates (2012) presented 3D numerical simulation series on the interactions between 2-shield tunnels, where the Mohr-Coulomb Constitutive model was used to model the ground behavior. The main focus was on the impact of the relative position of the 2-parallel tunnels. A situation of stacked tunnels where the upper tunnel was driven first was presented. Unluckily, the joints existence within the segmental lining, as well as the construction loads during shield tunneling was never simulated in the numerical model (Lunardi, 2008). Zhang and Huang (2014) conducted a basic theoretical analysis as well as 3D finite element numerical simulations to determine the effect of multiline overlay tunneling on the extant tunnels. The dig of the new twin stacked tunnels was done below and above the existing horizontal tunnels and the deformation evaluation of the existing underpass tunnels done. Currently, a complete 3D simulation for modern twin stacked tunnel excavation in soft ground especially that can allow the consideration of both structural lining forces and ground displacement does not exist (Blunt and Jiang, 2003). The main objective of the study was to offer such a simulation, using the Cap-Yield Soil, a strain hardening Constitutive model.

MATERIALS AND METHODS

Procedure

The excavation of the twin stacked tunnel was modeled as below:

Case 1:

i). the upper tunnel being excavated first.

ii. The lower tunnel being excavated at a lagged distance of LF=10D behind the initial tunnel face

Case 2:

i). the lower tunnel being excavated first.

ii. The upper tunnel being excavated at a lagged distance of LF=10D behind the initial tunnel face

Case 3:

Concurrent excavation of the lower and upper tunnels, that is a LF=0D (Lagged distance) adopted.

These two LF=10D case, which is common in practical situation, imply that new tunnel is normally excavated when the steady state of ground displacement and the lining structure due to the existing tunnel dig have been reached. To highlight the impact of the excavation process of a fresh tunnel on the existing tunnel, the study adopted a center-to-center distance (B) of 1.25D (11.75 m) in the vertical direction.

A full twin stacked tunnels model, considering a 160m-width, 71.5 m height was adopted. The model's mesh length was 120 m. The length of the excavation step was 1.5 m, a distance that matches up the lining ring width. The nodes were fixed horizontally on all sides of the model in the y-z and x-z planes that is y=120, y=0, x=80, x=-80. On the other side, the model base nodes (z=-51.75) were fixed vertically (in the Z direction). Fig 1 below shows a perspective view of half of the created numerical model, which consists of approximately 800,000 zones and 920,000 grid points.

RESULTS AND DISCUSSION

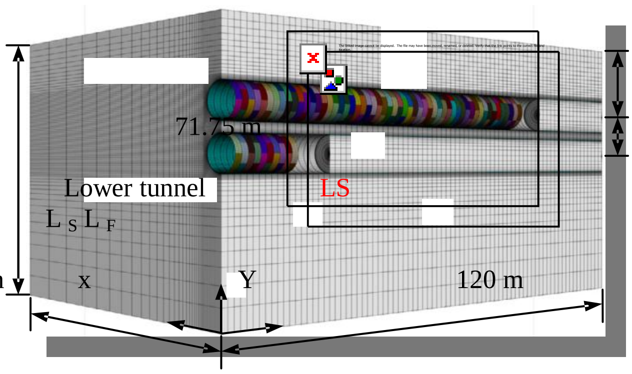
This part presents the deviations within the forces of structural lining induced in the ground displacements and tunnels during new tunnel development. The differences in structural forces of the new and existing tunnel, as well as in the ground tunnel have been indicated to take place at the part equivalent to the 30th ring. This section is hence forth described as measuring ring or measuring section in both tunnels counting from the boundary of the model (y=0 m). The effect of the boundary condition on the behavior of the tunnel is negligible at this part.

Surface Developments

Upper tunnel
11.75 m

.
Z

measured section



Y_{UL}

Case: **Fig. 1 Perspective view of half of the created numerical model presented into FLAC3D**

TLS
Trends in Life Sciences
An International Peer-reviewed Journal
www.sciencejournal.in
DAMA INTERNATIONAL

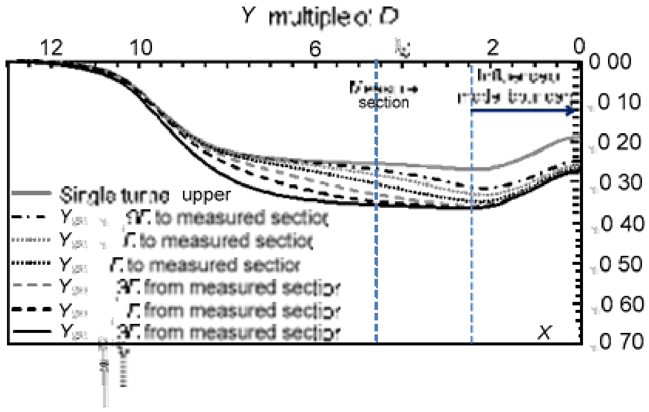


Fig 2. (Douglas et al. 2010).

Table 1.

Parameter	Single upper tunnel	Distance, Y_{UL}(m).						Final lower tunnel R	B/A (%)
		-1.9D	-1D	0	1.3D	2.6D	5.3D		
Max.pos.bendingmoment(kN·m/m)	69.2	78.3	84.3	48.9	73.7	89.1	92.9	40.5	43.6
R_{M+}(%)	100	113.2	121.8	70.7	106.5	128.8	134.2	58.5	
Max. Normal force (kN/M)	1466	1527	1622	1597	1107	1016	1017	2203	216.6
R_X (%)	100	104.2	110.6	108.9	75.5	69.3	69.4	150.3	
Min. neg. bending Moment (kN.m/m)	-95.1	- 109.8	- 113.2	-48.1	- 125.5	-117.6	- 113.8	-48.1	42.3
R_{M-} (%)	100	115.5	119.0	50.6	132.0	123.7	119.7	50.6	
Maximum longitudinal force (kN/m	1669	1965	2212	1565	1896	1604	1690	1033	61.1
R_{LN}(%)	100	117.7	132.5	93.8	113.6	96.1	101.3	61.9	
Min. normaldisplacement (mm	-2.59	-3.17	-3.85	-7.82	- 14.54	-15.27	-15-76	-069	4.4
R_{dip-} (%)	100	122.4	148.6	301.9	561.4	589.6	608.5	26.6	
Maximum normal displacement	5.24	6.37	7.88	10.27	13.17	--------	16.72	1.36	8.1
R_{dip+}	100	121.6	150.4	196.0	251.3	301.3	319.1	26.0	
Maximum settlement (%D)	-0.26	-0.27	-0.28	-0.30	-0.33	-0.36	-0.36	-	
R_{set} (%)	100	105.0	109.5	118.2	128.9	139.3	140.1	-	

Trends in Life Sciences
An International Peer-reviewed Journal
www.sciencejournal.in

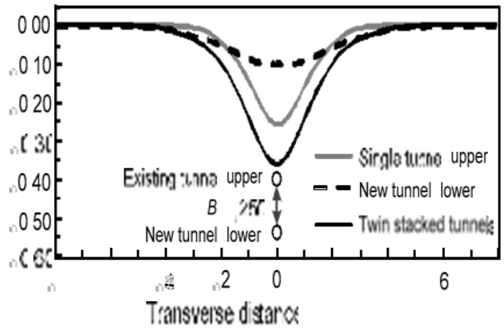


Fig 3. The settlement trough within the stacked tunnels transverse section (Ports, 2011)

CONCLUSION

In the study, a 3D model of the mechanized twin stacked tunneling was developed. The new tunnel excavation was indicated to have a significant effect on the displacements of the ground surface surrounding the twin stacked tunnels and the characteristics of the linings developed in the existing tunnel. The structural thrusts induced in the existing channel vary during the new tunnel advancement. The extreme interaction amid the 2 tunnels happens when the new tunnelarmor passes over the measuredpart. The greatest effects were seen in case 1, where the upper tunnel is firstly excavated. In terms of 3D numerical analysis, it can be concluded that (i). The upper tunnel is influenced to a larger extent by the procedure of the excavation. (ii).The tunneling procedure and tunnel depth greatly affect the lateral displacement. (iii). The procedure of tunneling impacts on the variations in the surface settlement that develops when each tunnel is excavated.

REFERENCES

Australian Tunnelling Conference. (1999). 10th Australian Tunnelling Conference: The race for space. Australian Tunnelling Conference, Melbourne, Victoria: *Australasian Institute of Mining and Metallurgy*.

Blunt L. and Jiang X. (2003). Advanced techniques for assessment surface topography: Development of a Basis for 3D Surface Texture Standards "Surfstand". London; Sterling, VA: *Kogan Page Science*.

Bolton M. D. (1991). A guide to soil mechanics. Cambridge, UK: *M.D. & K. Bolton*.

Channabasavaraj W. and Vishwanath B. (2012). Influence of relative position of the tunnels — numerical analysis on interaction between twin tunnels. Indian Geotechnical Conference, Delhi, India.

Divall S. and Goodey R. J. (2012). Apparatus for centrifuge modelling of twin-tunnel construction. *Int. J.* Physical *Modelling Geotechnics.* 12(3): 102-111.

Lunardi P. (2008). Design and Construction of Tunnels. Analysis of controlled deformation in rocks and soils (ADECO-RS). Berlin Heidelberg, Germany: *Springer-Verlag*.

National Highway Institute (U.S.), Parsons, Brinckerhoff, Quade and Douglas. (2010). Technical Manual for Design and Construction of Road Tunnels — Civil Elements. Washington, D.C: *American Association of State Highway and Transportation Officials*.

Pati U. C. (2012). 3-D Surface Geometry and Reconstruction. Developing Concepts and Applications. Hershey, PA: *Info. Sci. Reference*.

Potts D. M. and Higgins K. G. (2004). Advances in Geotechnical Engineering: The Skempton Conference. Volume 1. London: *Thomas Telford*.

Potts D. M. and Zdravkovic L. (2001). Finite Element Analysis in Geotechnical Engineering: Application. London: *Thomas Telford*.

Suwansawat S. and Einstein H. (2007). Describing Settlement Troughs over Twin Tunnels Using a Superposition Technique. *J. Geotech. Geoenviron. Eng*. **133**(4): 445-468.

Yamaguchi I., Yamazaki I. and Kiritani Y. (1998). Study of ground-tunnel interactions of four shield tunnels driven in close proximity, in relation to design and construction of parallel shield tunnels. *Tunn Undergr Sp Tech*. 13(3): 289–304.

Zhang Z. G. and Huang M. S. (2014). Geotechnical influence on existing subway tunnels induced by multiline tunneling in Shanghai soft soil. *Comput Geotech*. 56: 121–132.

