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Geotechnical Aspects of Underground Construction in Soft Ground – Yoo, Park, Kim & Ban (Eds)
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Construction of underpassing a crowded junction with shallow soil depth (case study, Tehran)

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ABSTRACT: Valiasr junction is a heavy urban area in the middle of Tehran. Several bus and metro stations are located around it. After construction of underpassing, pedestrians can access the north, sought, east and west of the junction without any traffic problem on the surface. On the other hand, a metro line is located in the depth of 9 m from the surface. Furthermore, intersections are planned in the underpassing. Simulation of construction of the tunnel intersections with soil overburden of about 3m is the main goal in this paper. Main section is simulated by 2D soil-structure interaction analysis using finite element method (FEM). Furthermore, combination of 2D soil-structure interaction analysis and 3D FEM analysis are used for modeling of intersections. The results are achieved through the comparison of deformations (surface settlement and crown displacements) and mobilized forces in the lining elements. The results revealed the efficiency of the sequential tunneling method (SEM) accompanied by forepoling technique for safe construction of underpassing with low soil overburden. Therefore, combination of forepoling and NATM tunneling stages was chosen as the design method for construction of the Valiasr underpassing.

1 INTRODUCTION

In recent years, by growing demand for transportation in metropolises, the application of tunnels has become increasingly common, particularly to provide sufficient space to solving traffic problems. Therefore, Tunnels have important or perhaps key role in the redevelopment of urban areas. On the other hand, tunnel construction in urban area also have problems that the main concerns of tunnel construction in populous regions are the excavation instability and uniform or non-uniform ground settlement which may lead to distress beneath surface structures' foundation and appear cracks or inclination in adjacent buildings and above ground facilities. The New Austrian is a method in which, after tunneling, shotcrete is applied to the surface of the tunnel and the surrounding rock or soil becomes integrated into the support structure. Some researchers have applied 2D and 3D numerical models for the analysis of NATM tunnels under static conditions (e.g. Shin and Potts 2010; Desari et al. 1996; Fakhimi et al. 2005; Swoboda 1979; Hosseini et al. 2014).

Underpassing Valiasr junction project is located at the intersection of Valiasr and Enqelab square (a heavy urban area in the middle of Tehran). Several bus and metro stations are located around it. Moreover Tehran City Theater is located near the Valiasr junction. After construction of underpassing, pedestrians can access the north, sought, east and west of the junction without any traffic problem on the surface. On the other hand, a metro line is located in the depth of 9m from the surface. Figure 1 shows a view of valiasr junction entrance. Also, figures 2 show the plans of underpassing Valiasr junction on the Tehran map.

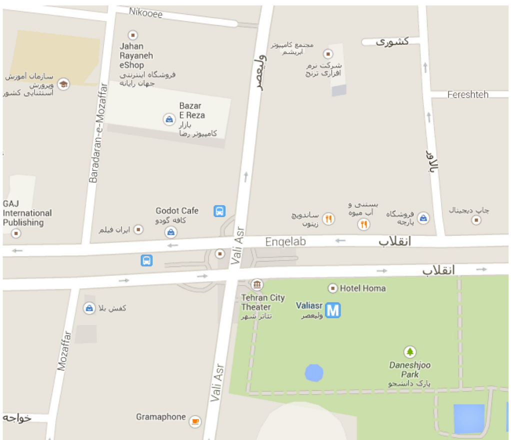
Due to the importance of construction of tunnel intersections in shallow depths, the main focus of this research is the analysis and design of intersections of underpassing Valiasr junction. 3D overview of the underpassing Valiasr junction is shown in Figure 3.

As can be seen in the previous figure, several intersections are considered in the Valiasr underpassing.

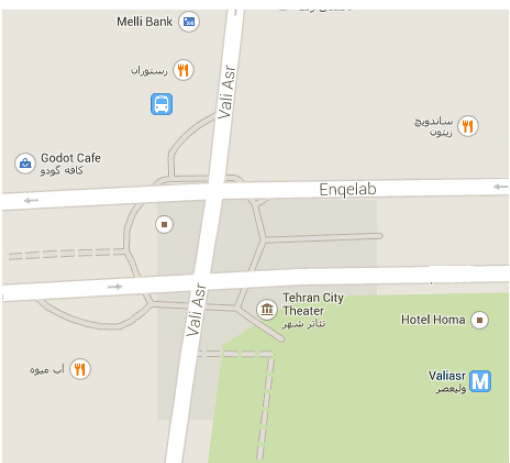
2 CONSTRUCTION METHOD

The excavation and support of main tunnel of underpassing Valiasr junction will be carried out using the New Austrian Tunneling Method (NATM), combining a horizontal and a vertical operation sequence. In this method partial driving and sufficient face support with

Figure 1. View of Valiasr junction entrance.



(a)



(b)

Figure 2. Plan of Valiasr junction.

shotcrete as well as steel lattice girders are required to provide safe tunneling conditions. The initial support system includes lining composed of layers of shotcrete reinforced with two layers of wire mesh and steel lattice girders spaced at 50 or 75 cm. The construction stages are modeled with 5 zones of excavation as shown in Figure 4 and described below:

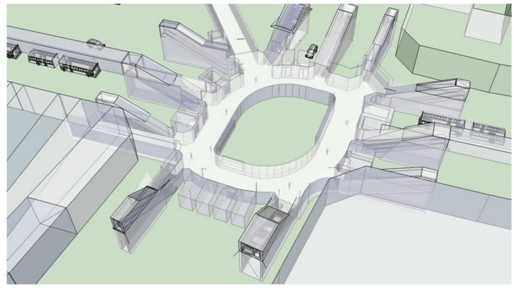


Figure 3. 3D overview of underpassing Valiasr junction.

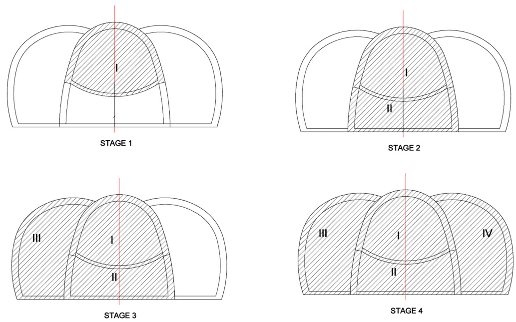


Figure 4. Excavation Stages of underpassing Valiasr junction.

1 – Excavation and support of the top heading of the middle; 2 – Excavation and support of the bench of the middle; 3 – Excavation and support of the left side drift; 4 – Excavation and support of the right side drift

Extreme care is taken during excavation and immediate application of support media prevent unnecessary loosening of media. These tunnels have rounded tunnel shapes to prevent stress concentrations in corners where most failure mechanisms start from; and also utilize thin linings to minimize bending moment. Observation of tunnel behavior during construction is an important part of NATM which is important especially in urban areas. This optimizes working procedures and support requirements. Many countries have adopted this method as the primary method of construction. This method is selected in this project.

The final cross section of main tunnel including initial and final linings is brought in figure 5. It should be noted that due to low soil overburden, forepoles are installed in the top of tunnel after each round of top middle excavation. After completion of main tunnel, some parts of initial lining were removed and opening sections were constructed.

Figure 6 shows construction stages in a view of temporary portal.

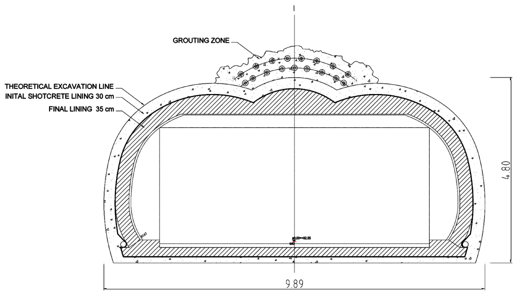


Figure 5. Cross section of main tunnel.

Figure 6. A view of construction stages.

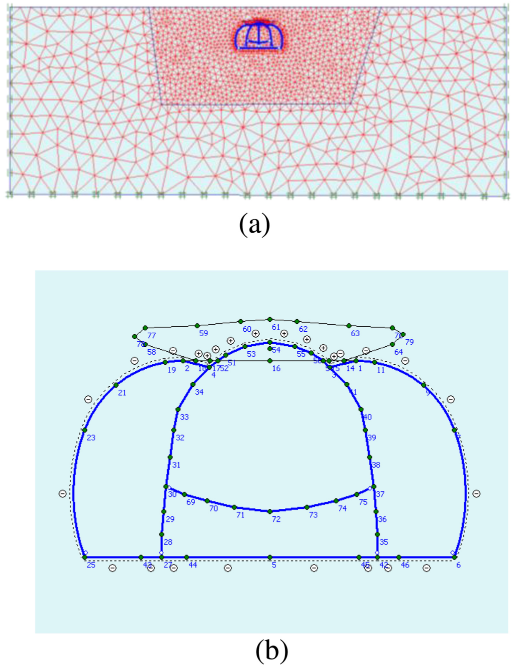


Figure 7. 2D Plaxis model: (a) mesh generation; (b) main cross section of underpassing.

3 NUMERICAL MODELING

Combination of 2D soil-structure interaction analysis (Plaxis software 2002) and 3D finite element (SAP software 2009) were used for analysis and design of underpassing Valiasr junction including intersection of main tunnel with openings. Soil-lining Interaction forces were estimated from Plaxis and applied to lining in the SAP model. Using aforementioned approach the effects of construction sequences and stiffness of improved soil layer with forepoles above the tunnel is considered in design of tunnel support.

3.1 *2D soil-structure interaction analysis*

The numerical models comprise of 100 m soil in vertical direction and 40 m laterally soil in horizontal direction. Boundary conditions are taken as vertical constraints on the sides of models and full fixity at the base. Figure 7 shows 2D numerical model. The bifurcation structure and the surrounding soil are modeled together simultaneously. Staged excavation and lining sequence has been incorporated in the model based on the conceptual construction procedure following establishment of the initial stress condition. The tunnel initial lining is statically loaded. The loads are computed by the software directly from the soil-structure interaction based on the material properties for the soil layers.

In the construction stages simulation procedure, stages include successive excavation followed by placement of shotcrete. The interface normal stress of initial lining is shown in Figure 8. The obtained stress from 2D numerical modelling is applied to the 3D model. Furtheremore, The vertical and horizontal displacements contours are brought in Figures 9 and 10.

3.1.1 *Soil model*

The proper soil constitutive model is an important issue and matter of discussion in numerical simulations of soil structures which affects the results. In the present study, soil models namely, HS-model (Hardening soil model) used for the numerical simulations of bifurcation.

The soil parameters considered for analysis are listed in Table 1. The high stiffness of unloading paths in soil mass around tunnel section and of low strain affects the results. Hence, prediction of ground settlement strictly is influenced by the material constitutive model.

3.2 *3D SAP model*

3D geometry model of initial lining including main cross section and opening is shown in figure 11.

Soil-initial lining interaction loads obtained from Plaxis were applied to the sap model and mobilized

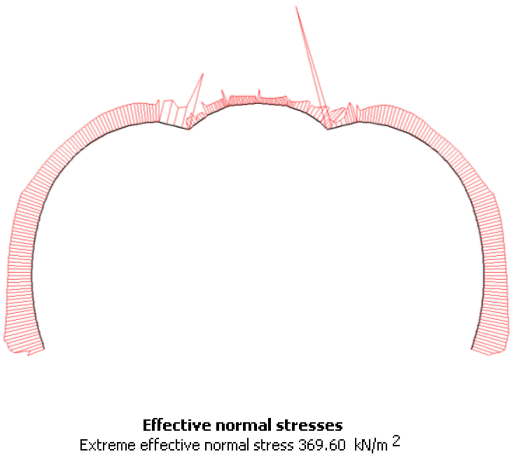
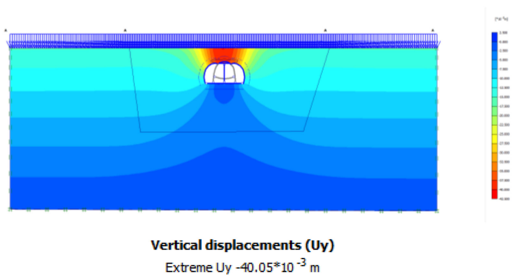


Figure 8. 2D Plaxis model: (a) mesh generation; (b) main cross section of underpassing.



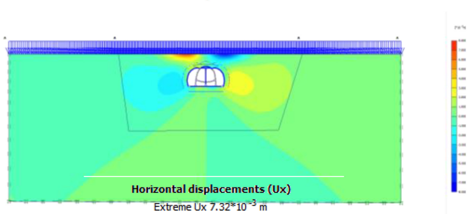


Figure 9. Contours of vertical displacements for 2D Plaxis analysis.

Figure 10. Contours of vertical displacements for 2D Plaxis analysis.

Table 1. The properties of the sub surface.

$\phi_{cu} = 33°$	Internal friction angle (CU)
$c = 0.05\,kg/cm^2$	Cohesion (CU)
$\gamma_m = 1.80\,gr/cm^3$	Natural density
$\nu = 0.2$	Poisson ratio of unloading/reloading
$400\,kg/cm^2$	Secant deformation modulus
0.27	Power of stress level of stiffness
$1200\,kg/cm^2$	Unloading stiffness

forces are calculated. It is worth noting that a same procedure is used for design of final lining. However, seismic and traffic loads are calculated separately and applied to the SAP model in tha latter case.

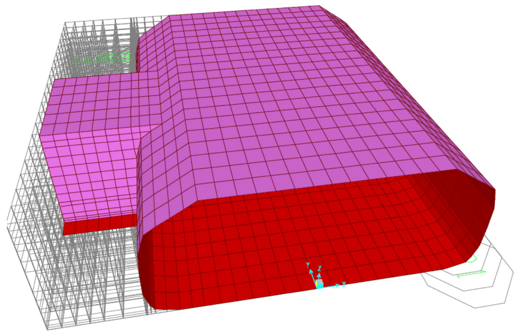


Figure 11. 3D SAP model.

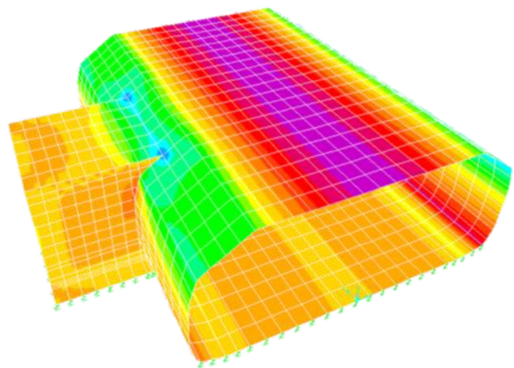


Figure 12. Diagram of bending moment in transverse direction with maximum of 200 kN.m.

Table 2. Summaries of maximum mobilized forces in the initial lining.

P (kN)	M (kN-m)
Positive bending moment	tranverse direction
300	220
Negative bending moment	tranverse direction
300	−190
Positive bending moment	Longitudinal direction
24	45
Negative bending moment	Longitudinal direction
360	−75
Openings	
450	−140

4 RESULTS

The results of mobilized structural forces are discussed in this section. Figure 12 shows the bending moment of the initial lining in transverse direction.

The results of mobilized forces for design of initial lining are summarized in Table 2. The required reinforcement for lattice girders and wall and roof of openings were estimated using values in the Table 2.

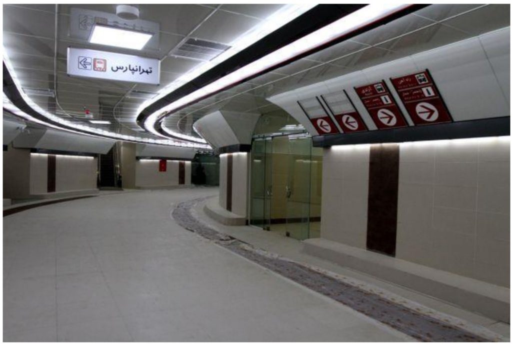


Figure 13. A view of underpassing Valiasr junction after construction.

5 CONCLUSION

Due to numbers of openings in the underpassing valiasr projects and importance of intersection with 3D nature in transffering soil loads, a specified approach was selected for design of initial lining of this project. Combination of 2D soil-structure interaction analysis (Plaxis software) and 3D finite element (SAP software) were used for analysis and design of underpassing Valiasr junction including intersection of main tunnel with openings. Soil-lining Interaction forces were estimated from Plaxis and applied to lining in the SAP model. Using this approach the effects of construction sequences and stiffness of improved soil layer with forepoles above the tunnel can be considered in design of tunnel support. The project was constructed based on results of aforementioned approach without observation of any failure or gross deformations on the surface. Therefore combination of forepoling and NATM tunnelling stages is suggested for the design of underground structure with low soil overburden Figure 12 shows a view of underpassing Valiasr junction after construction.

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REFERENCES

Brinkgreve, R.B.J. et al., 2002, PLAXIS 2D- Version 8 User Manual, A.A. Balkema Publishers.

Desari G. R. Rawlings, C. G. & Bolton, M.D. 1996. Numerical modeling of NATM tunnel construction in London clay. In geotechnical aspects of underground construction in soft ground, Rotterdam, 491–496.

Fakhimi, A., Salehi, D. & Mojtabai, N. 2005. Numerical back analysis for estimation of soil parameters in the Resalat tunnel project, Tunnelling Underground Space Technol. 19: 435–44.

Hossein, M, Golshani, Aliakbar & Majidian, Sina 2014. Numerical modeling for construction of large span bifurcations of the Niayesh tunnel, Iran. Electrical journal of geotechnical engineering. 19/G: 1457–1470.

SAP 2000 Ver 14. Computers and Structures Inc. 2009.

Shin, J.H., Potts, D.M. 2010. Time-based two dimensional modeling of NATM tunneling. Can. Geotech Journal. 39, 710–724.

Swoboda, G. 1979. Finite element of New Austrian Tunnelling Method (NATM). In Proceedings of the International Conference on Numerical Methods in Geomechanics, Aachen, Rotterdom 581–586.