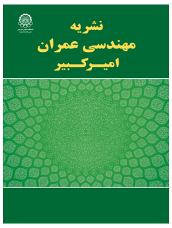

Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 53(5) (2021) 431-434
DOI:10.22060/ceej.2020.17201.6493

Effects of Urban Tunnel Excavation in Tehran in Response to Existing Static and Dynamic Structures in Terms of Soil and Structure Interaction

M. Faraj Mohammadieh[1,*], F. Behnamfar[2], S. J. Mohammadi[1,3]

[1] Earthquake Engineering Department, Razi Technical School of Ardabil, Ardabil, Iran.
[2] Civil Engineering Department, Isfahan University of Technology, Isfahan, Iran.
[3] Structural Engineering Department, Zanjan University, Zanjan, Iran.

ABSTRACT: Excavation of tunnels can cause the earth to move, which is significant in the static and dynamic response of structures. In this study, the effect of tunnel excavation in Tehran city on the dynamic and static response of structures in three sections has been investigated. In the first part, PLAXIS software calculates the following two-step session before and after excavating. The second part of PLAXIS also performs dynamic analysis for both stages and the following acceleration response is calculated. The purpose of the second part is to investigate the impact of excavating on acceleration response and its use in SAP 2000 software as input for structural analysis. In the third part, the structure is modeled in SAP 2000 software and the results of the first part of the displacements of footing are applied and by using accelerating response, the structure`s nonlinear dynamic analysis is performed in two stages (PLAXIS output). The results of the analysis showed that the tunnel excavation has increased the subsidence of the foundation subsurface and the highest subsidence is in the 6th model (operation stage), which is 1.2 times the average of the previous one. The excavation has increased and the impact of the supporting structures during the execution phase compared to the operation stage where the concrete side walls are executed has been effective in reducing the subsidence by 4% and maximizing the acceleration below 1.5 times and also in the structures the displacement increased by 1.25 times compared to the pre-excavation phase response.

Review History:

Received: Oct. 12, 2019
Revised: Dec. 06, 2019
Accepted: Jan. 19, 2020
Available Online: Feb. 02, 2020

Keywords:

Urban Tunnel
Excavation
Supporting Structures
Dynamic Analysis
Subsidence

1- Introduction

Due to the increasing population, the need to build underground structures and drilling urban transport tunnels has become inevitable to provide infrastructure [1]. In general, drilling of tunnels and other underground structures results in the removal of piles of soil and rock at the site besides significant changes in environmental stress conditions, and dynamic and static response of adjacent structures. Tunneling causes a change in the dynamic and static response of existing buildings. Therefore, investigation and estimation of tunneling drilling effects on adjacent structures are of particular importance. It is necessary for tunnel design and construction engineers to estimate the extent of drilling response to structures and determine whether or not these structures will be affected by drilling [2, 3]. The activities carried out in this area are related to Dimok research, which has done a lot of studies on tunneling in urban environments and its contributing factors [4]. In 1993, Wang presented equations to determine the forces generated by tunnel cover during an earthquake [5]. Hashash (2001), has proposed an applied method for seismic analysis and design of tunnels and underground structures by completing Wang's equation to soil and structure interaction [6]. Marinella *et al.*, 2019 performed reinforcement on a case tunnel with a concrete cover that reinforced in two layers of 30 and 40 mm. The first layer having no significant impact on the load, but the second layer being effective in reinforcement [7]. Martino Gatia *et al.* (2019) used a case tunnel with reinforced rouo-plastic mortar and a layer of galvanized steel, which was used in the retrofitting of created cracks [8]. In this research, to evaluate the impact of urban tunnel drilling on the dynamic and static response of existing structures, some main analyses were performed in three parts using two PLAXIS and SAP 2000 software. PLAXIS software was used for nonlinear dynamic soil analysis due to its inability to perform nonlinear dynamic structural analysis using SAP 2000 for nonlinear dynamic analysis which was a step-by-step task.

2- Methodology

According to the modeling, to determine the effect of tunnel drilling on existing buildings, an applied tunneling method has been employed. In this way, first, in PLAXIS software, by performing a static analysis the subsidence of the existing building under dead and live load was calculated

*Corresponding author's email: mehdifaraj66@yahoo.com

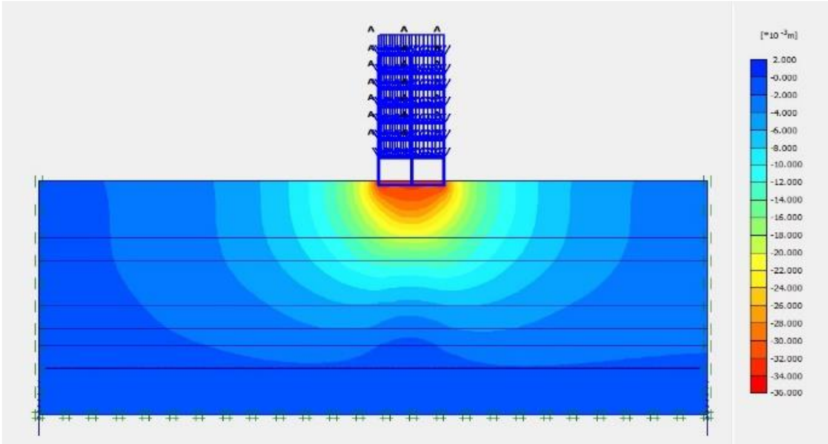

Fig. 1. Structure foundation displacement before excavation

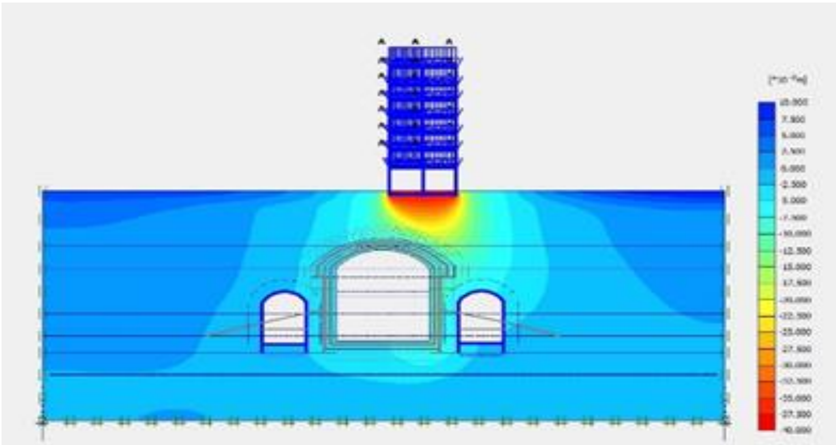

Fig. 2. Post-drilling step (model six)

in two steps before and after tunnel excavation. In the later stage of drilling, the calculation of the subsidence due to drilling was investigated in two parts. In the first part, which consisted of 6 operating phases, in all phases, the building assembly was calculated. In the first and second phases, the building was activated and in the third phase, excavation and pile execution and concreting around drilling were done. In the fourth phase, drilling was carried out up to -22 m and the tunnel retaining structure was activated, and concreting around drilling is done. In the fifth phase, drilling was carried out to a height of -28 m and the tunnel retaining structure was activated, and concreting around drilling was done. In the sixth drilling of side platforms and implementation of the Anchor element and the seventh phase, which is the post-implementation phase (operation phase) guard structures are removed and the subsidence of structure was calculated. In the second part, the PLAXIS software also performs dynamic analysis for both stages using the desired record, and the acceleration response under the existing building was calculated. The purpose of this section is to investigate the effect of tunnel drilling on acceleration response and use in SAP 2000 as input for structural analysis. In the third part, the structure was modeled in APSAP 2000 software and the results of the first part of the displacements were applied to the foundation. Using the acceleration response (PLAXIS output), dynamic nonlinear analysis of structures was performed in two stages.

3- Results and Discussion

3- 1- Calculate the building foundation subsidence

For the pre-drilling phase, using the PLAXIS software, the soil and the existing building frame without drilling were modeled considering soil and structure interactions as shown in Fig. 1. By performing static analysis, the horizontal and vertical sub-basement displacements were calculated under dead and live load.

In the post-drilling step, Fig. 2, the calculation of the subsidence under the foundation due to drilling was investigated in two parts. In the first part, simultaneously with the drilling implementation which consists of 6 operating phases that in all phases the subsidence of the building was calculated.

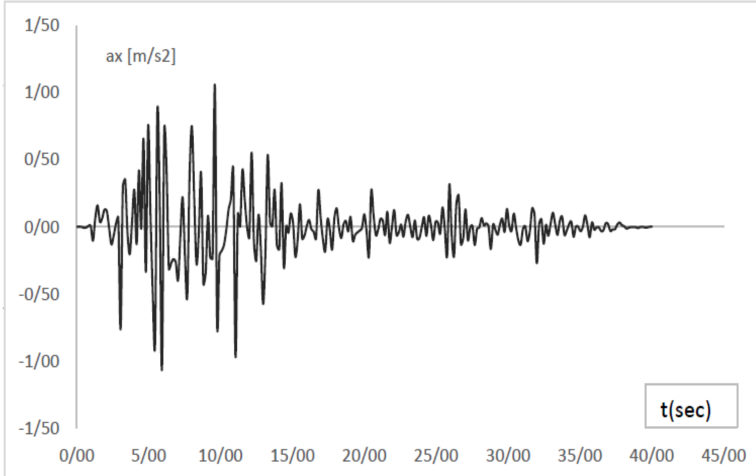

Fig. 3. Acceleration response under foundation before excavation

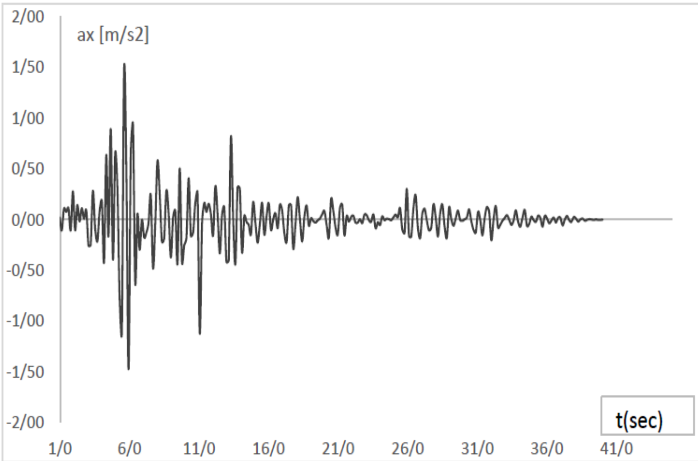

Fig. 4. Acceleration response under foundation after excavation

3- 2- Nonlinear Dynamic Analysis Of Soil

In PLAXIS software, dynamic analysis with Irpinia record and considering soil-structure interaction were performed in two separate stages before and after drilling. Then, the acceleration response under the foundation was calculated. The purpose of this section is to investigate the effect of drilling on acceleration response and use in SAP 2000 as input for structural analysis.

3- 3- Nonlinear Dynamic Analysis Of Structures

In this section, the structure was modeled in SAP2000 software and the results of the static analysis displacements were applied to the foundations of the structure. Using the acceleration response (PLAXIS output), nonlinear dynamic analysis of the structure was performed in two-stage. Finally, the changes of the structural response due to drilling were investigated and the results of the analyses were presented in Fig. 5. Due to the figure, the impact of drilling on the seventh-floor displacement response, the maximum displacement of the structure increased by 1.15 times compared to the pre-drilling phase.

4- Conclusion

In this research, first, to verification the software, used the model of Castaldo *et al.* that they had done the impact of drilling on the Italian Naples station adjacent to the Ferrari building in 2014, all stages of his research were modeled and analyzed. After validation, the present study was conducted in a case tunnel located in Tehran using PLAXIS and SAP 2000 software. PLAXIS software was used for dynamic nonlinear soil analysis. The SAP 2000 software was used for nonlinear dynamic analysis of structures because of its inability to perform nonlinear structural analysis. In the first part, PLAXIS software calculated the subsidence below the foundation in a two-step session before and after drilling. In the second part in PLAXIS software, dynamic analysis was done for both stages and the acceleration response was calculated below the foundation. The second part aimed to investigate the impact of drilling on acceleration response and its use in SAP 2000 software as input for structural analysis. In the third part, the structure was modeled in APSAP 2000 software and the results of the first part of displacements were applied on the

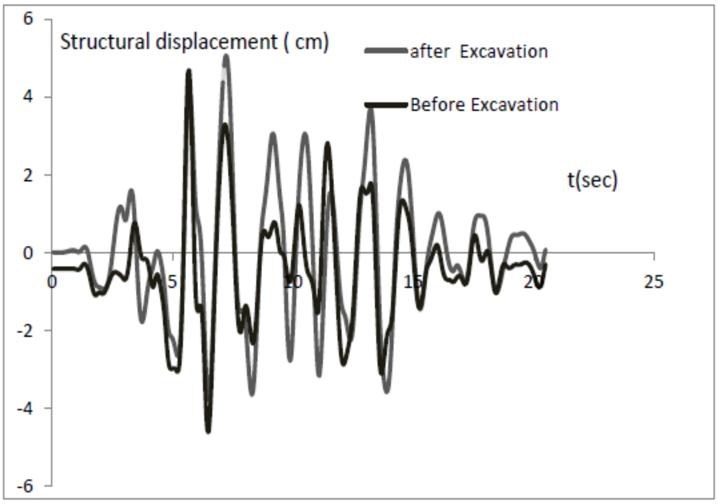

Fig. 5. Comparison of structural change

foundation. Then, using the acceleration response (PLAXIS output), the nonlinear dynamic analysis of the structure was performed in two stages. The main purpose of this study was to investigate the effect of tunnel drilling on the static and dynamic response of adjacent structures in which the rate of subsidence changes under the foundation and the role of guard structures as well as the rate of acceleration changes and displacement of existing structures due to drilling the tunnel has been calculated. The results of the analysis showed that due to tunnel drilling, the subsidence under the foundation was increased and the highest subsidence due to excavation was in model 6 (operation stage) which average of 1.2 times was increased towards the pre-drilling stage and the impact of guard structures at the implementation stage compared to the operation stage where the side concrete walls are made effective in reducing the 4% subsidence and the maximum acceleration below the foundation 1.5 times increased, and in the structure, the displacement 1.25 times was higher than the pre-drilling response. The usage of this research can be useful in identifying structural vulnerabilities before and after construction.

References

[1] Castaldo, P., et al. (2014). “Structural safety of existing buildings near deep excavations.” International Journal of Structural Engineering 5(2): 163-187.

[2] Long, M. (2001). “Database for retaining wall and ground movements due to deep excavations.” Journal of Geotechnical and Geoenvironmental Engineering 127(3): 203-224.

[3] Moormann, C. (2004). “Analysis of wall and ground movements due to deep excavations in soft soil based on a new worldwide database.” Soils and foundations 44(1): 87-98.

[4] Doğangün, A., et al. (2007). “A study on seismic behavior of minarets considering soil-structure interaction."

[5] Wang, J. (1993). “Seismic design of tunnels: a state-of-the-art approach, monograph, monograph 7.” Parsons, Brinckerhoff, Quade and Douglas Inc, New York.

[6] Hashash, Y. M., et al. (2001). “Seismic design and analysis of underground structures.” Tunneling and underground space technology 16(4): 247-293

[7] Cottonaro, R. D., et al. (2019). “Retrofitting of existing tunnels with concrete lining: a preliminary experimental investigation.” Retrofitting of existing tunnels with concrete lining: a preliminary experimental investigation: 95-104.

[8] Lunardi, G., et al. (2019). “Refurbish and static reinforcement of tunnels: innovative construction methods and materials.” Refurbish and static reinforcement of tunnels: innovative construction methods and materials.: 12-20.

HOW TO CITE THIS ARTICLE

M. Faraj Mohammadieh, F. Behnamfar, S. J. Mohammadi, Effects of Urban Tunnel Excavation in Tehran in Response to Existing Static and Dynamic Structures in Terms of Soil and Structure Interaction Amirkabir J. Civil Eng., 53 (5) (2021) 431-434

DOI: 10.22060/ceej.2020.17201.6493