Iran University of Science and Technology

International Journal of Railway Research

ISSN: 2423-3838

Optimal Selection of Underground Parking Lines Arrangement: A Case Study of Tehran Subway Line 7

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ARTICLE INFO

Article history:

Received: 21.03.2018

Accepted: 12.05.2018

Published: 15.06.2018

Keywords:

Underground parking

Subway parking

Large span tunnel

Plaxis 2D modeling

Geotechnical analysis

A B S T R A C T

Due to the development of urban subway lines in order to extend public transportation and to accommodate the increased number of trains, depot and parking are necessary. This is to provide a space for parking trains in non-operating hours and to carry out maintenance and repair operations on trains. Subway depot is a predetermined space where trains, washing, car parks, and refueling work are performed. This space can be designed either underground or at-grade according to the existing conditions. These depots and parking occupy a large part of urban land. Due to the rapid growth of urbanization and with considering the value and importance of at-grade land for social and economic development, the problems of possession of at-grade spaces and also the lack of suitable urban area in some parts of the cities, the construction of underground depots is an idea against at-grade depots. Therefore, in this study different development modes of underground depot and parking are investigated. For this purpose, the North Parking of Tehran Subway line 7 is selected for the case study. Each development mode includes a two-line tunnel, two separate one-line tunnels, four separate one-line tunnels and a large span tunnel with four lines together compared by analytic hierarchy process (AHP) and the best option was chosen. In order to investigate the feasibility of implementing the best choice, geotechnical analyses are performed by using PLAXIS 2D software.

1. Introduction

Due to the industrial and welfare facilities of large cities, the population in these cities is grown. Construction and facilities are proportionally developed. Therefore, optimal and proper using of the land is very important. Subway depot and parking occupy a large part of space on the ground, which is a worrying factor because of the importance of land in populated cities. Therefore, the matter of depot and parking development for underground tracks is important. This requires investigation and examination of the challenges ahead. Because of the large dimensions of the underground depot and parking and the design and construction challenges when possible, underground development becomes feasibility. Therefore, the current research deals with underground parking design in order to achieve the proper answer for the above questions. In this regard, despite the limited studies in this field, the technical literature is discussed.

Sadaghiani and Dadizadeh [1] developed a new method for construction of large underground spaces. The results show that by using a new construction method, the so called CAPS, the ground surface settlement decreased. Zou et al. [2] studied ground and nearby building noise and vibration due to train movements in a subway depot at Guangzhou, China. They presented some models to predicate the level of noise and vibration that

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[DOI: 10.22068/IJRARE.5.1.19]

can be used for the design and assessment in newly built subway depot. A review of the economics of underground space utilization was studied by Kaliampakos et al [3]. This research mentions that, underground facilities can be considered as one of the infrastructure development priorities. Durmisevic [4] investigated planning and design aspects of a few underground projects. It's found that despite managing to improve the quality of the underground environment, underground spaces have little justification. Research on solving space requirement for cities was also studied by Broere [5]. This paper presents the innovative use of underground space for residential and commercial utilization, storage, etc. Gamayunova and Gumerova [6] studied solutions for urban problems using underground space. They found that by using new construction methods it's possible to use underground spaces for the development of new urban highway, parking, etc.

Unfortunately, the lack of technical literature about underground depots and underground parking line arrangements is obvious. Therefore, this study proposes a different mode of underground subway parking and depot for Tehran subway line 7. In order to select the best possible arrangement of underground subway parking, four modes are considered. These include a two-line tunnel, two separated one- line tunnels, four separated one-line tunnels and a four-line tunnel with a large span. After selecting the proper parking mode arrangement, numerical analyses are performed to examine the feasibility of the selected mode.

2. The Case Study Specifications

Line 7 of Tehran subway includes 25 stations with south-east to north-west directions. Figure 1 shows the schematic plan of Tehran subway line 7. The considered parking in north part of the line is located where population density is high in a residential area under Kouhestan Street with a width of 23 m. The parking is located in the north of Y7 station as presented in Figure 2. Based on transportation studies, in order to supply 2 minutes headway for the trains dispatching, this parking should provide a space for 10 trains with a length of 160m.

3. Different Arrangement Modes Survey

This study considers four common arrangement modes for the parking space including a two-line tunnel, two separate one-line tunnels, four separate one-line tunnels and a large span tunnel with four lines together that are discussed in the following section.

3.1. A two-line tunnel

In this case, along with the Y7 station, about 820 meters in length must be excavated that can accommodate five trains with a length of 160 m in each line. The cost of this mode is lower than that of an at-grade parking. This mode is currently located at the northern end of Tehran Subway Line 1 at Mirdamad station with a length of 440 meters and a capacity of four trains, Figure 3. The main problem with this method is that when a large number of trains

Figure 1. Plan view of Tehran subway line 7

Figure 2. The location of parking under Kouhestan Street

(more than 6 trains) stay in the depot, due to the large length of trains (160 meters), maneuvering operations become difficult and there is no possibility to locate the viewing hole. In this case, the useful width of the tunnel is 4.10 meters.

Figure 3. Mirdamad parking in Tehran subway line 1.

3.2. Two separate one-line tunnels

In this mode that is presented in Figure 4, two separate tunnels with one-line track for each are parallel located. The length of each tunnel is 830 m that can accommodate 5 trains in per tunnel. The main problem is the maneuvering operation and also in this mode, there is no possibility to place the viewing hole. The useful width of the tunnel is 17 meters in this case.

3.3. Four separated one-line tunnels

This mode includes four parallel tunnels that. Three tunnels have a length of 490 m (to park 9 trains) and one tunnel has a length of 165 m that can fit one parked train. Figure 5, presents an existing parking that resembles this mode. Considering the 23 m width of Kouhestan Street and the vicinity of buildings to the tunnel in this area, this configuration is not operational for the said location. Since according to regulations the minimum required width for this mode is 30 meters.

Figure 4. An existing sample of two separate one-line tunnels

Figure 5. An underground parking with four separate lines

[DOI: 10.22068/IJRARE.5.1.19]

3.4. A large span tunnel with four separate lines

In this mode by the construction of one large span tunnel, all four lines of parking are accommodated. Three of such lines accommodate nine trains and one track can be used for daily inspection of parked trains. The advantages of this method are providing daily inspection for the trains and also facilitating easy maneuvering operations for trains. The useful width in this mode is 19.4 meters that can match with the width of Kouhestan Street.

4. Analytic Hierarchy Process (AHP) of Different Arrangement Modes

One of the most efficient decision-making techniques for the subject of interest for this case is the Analytical Hierarchy Process (AHP). This study uses this technique to select the best parking arrangement as discussed in the previous sections of this article.

4.1. Selection of the main indicators

It is already explained that four different arrangement modes were considered for the configuration of the depot and parking spaces for the trains. Amongst them, the third mode that included four separate one-line tunnels had to be eliminated. This elimination was due to the width of the Kouhestan Street and its intimacy to the residential units. To compare the remaining three modes, the following indicators based on the technical literature review are used including the possibility for the daily inspection and cleaning up the trains, operation desirability, and construction cost. A questionnaire for comparing the indicators was prepared. This questionnaire was presnted to 15 subway experts from different departments of operations, consultantants and execution companies.

4.2. AHP results

The collected data was used to carry out the AHP analysis. The assessment for each of these indicators is calculated and is presented in Table 1. Based on the relative weight of each criterion, the weight of each criterion is calculated and is presented in the Table 2. In the following, the various parking arrangement modes are valued for each one of the indicators. In order to rank the decision options, at this stage, the relative weight of each element needs to be multiplied by the weight of the higher elements in order to obtain the final weight. By doing this for each mode, the amount of the final weight is obtained. In Table 3, the parking arrangement modes are compared based on the AHP analysis and the best mode with the highest score is chosen. As result that is presented in Table 3, the large span tunnel with four lines shows the highest score among other modes.

5. Geotechnical Analysis

As discussed above, the North parking need to provide a space for 10 trains' services. In order to park 10 trains the space requirements are 600 meters in length and 19.4 meters in width. The plan view for this depot was presented in Figure 2. It should be noted that based on the results from the AHP analysis in the previous sections of this research, a large span tunnel with four-line mode is selected for the north parking. The implementation method for this parking is considered as underground.

Table 1. The selected indicators value relative to each other

Criteria	Possibility for daily inspection and cleaning up the trains	Operation desirability	Construction cost
Possibility for daily inspection and cleaning up the trains	1	2	3
Operation desirability	0.5	1	2
Construction cost	0.33	0.5	1

[DOI: 10.22068/IJRARE.5.1.19]

Table 2. Weight of indicators

Indicator	Possibility for daily inspection and cleaning up the trains	Operation desirability	Construction cost
Indicator weight	0.5390	0.2973	0.1638

Table 3. Comparing different modes of parking arrangement based on the selected indictors

-		A two-line tunnel	Two separate one-line tunnels	A large span tunnel with four lines
Possibility for daily inspection and cleaning up the trains	54%	12%	23%	65%
Operation desirability	30%	14%	14%	71%
Construction cost	16%	37%	32%	30%

The high depth requirement at the location of this depot and interference with the street level regular traffic is the justification for placing this depot under the ground.

5.1. Soil layering specifications

According to subway line 7 geology reports, north part of the route that is located on top of the underground parking, as shown in Figure 2, contains different layers of soils that are presented in Figure 6. From such data, it is clear that most soil regions in this area consist of ET-2 type of soil. The geotechnical specification of ET-2 soil type is provided in Table 4.

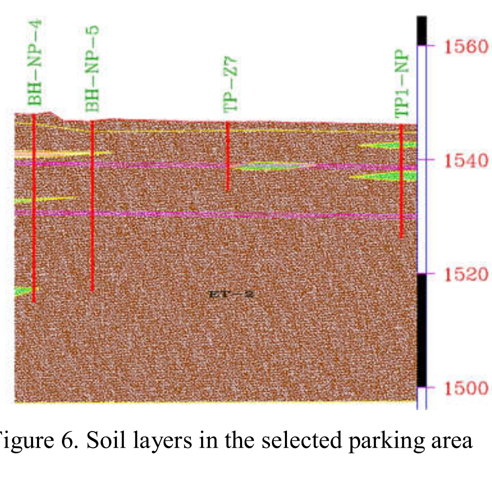


Figure 6. Soil layers in the selected parking area

5.2. Structural system and geotechnical analysis

Based on the route longitudinal profile in the north parking location, the rails are located at a depth of about 22 meters from the Kouhestan Street surface. As a result, the execution method for this depot needs to be an underground. Then the ribbed pile method adopted for the parking structural system modeling, Figure 7. This is due to the lower execution cost, the possibility for construction of large-span structures, the higher execution speed and the continuation of the traffic flow rather than other methods.

Table 4. Specifications of soil type ET-2

Density, $\gamma(\mathrm{kg/cm^3})$	1.90
Poison's ratio, ν	0.3
Elasticity modulus, E $(\mathrm{kg/cm^2})$	800
Friction angle, ϕ (degree)	34
Cohesion, C $(\mathrm{kg/cm^2})$	0.25

Also, according to the literature review in ribbed pile method the ground surface settlement is lower than other underground methods. In this study the so called PLAXIS 2D code is used to perform geotechnical analysis by the adopted Mohr-Coulomb theory. Seismic variables that are used are the same as in

[DOI: 10.22068/IJRARE.5.1.19]

Hashash et al. [7] that was found for seismic design of the underground structure. It should be noted that the surface load of 2.4tonne and 5tonne are considered for the live and the dead surcharges, respectively.

It is clear that in urban areas the land settlement issue is very important due to the existence of urban facilities, residential buildings, and underground structures. In the current study the Rankin criterion is used to control the land settlement. As shown in Figure 8, the maximum settlement of less than 3 cm occurs in the building area and under the street

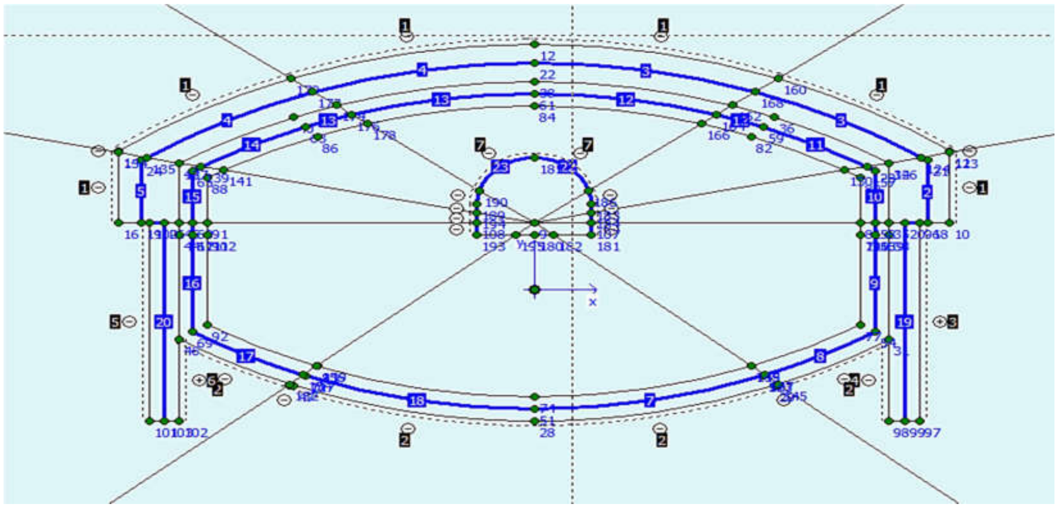
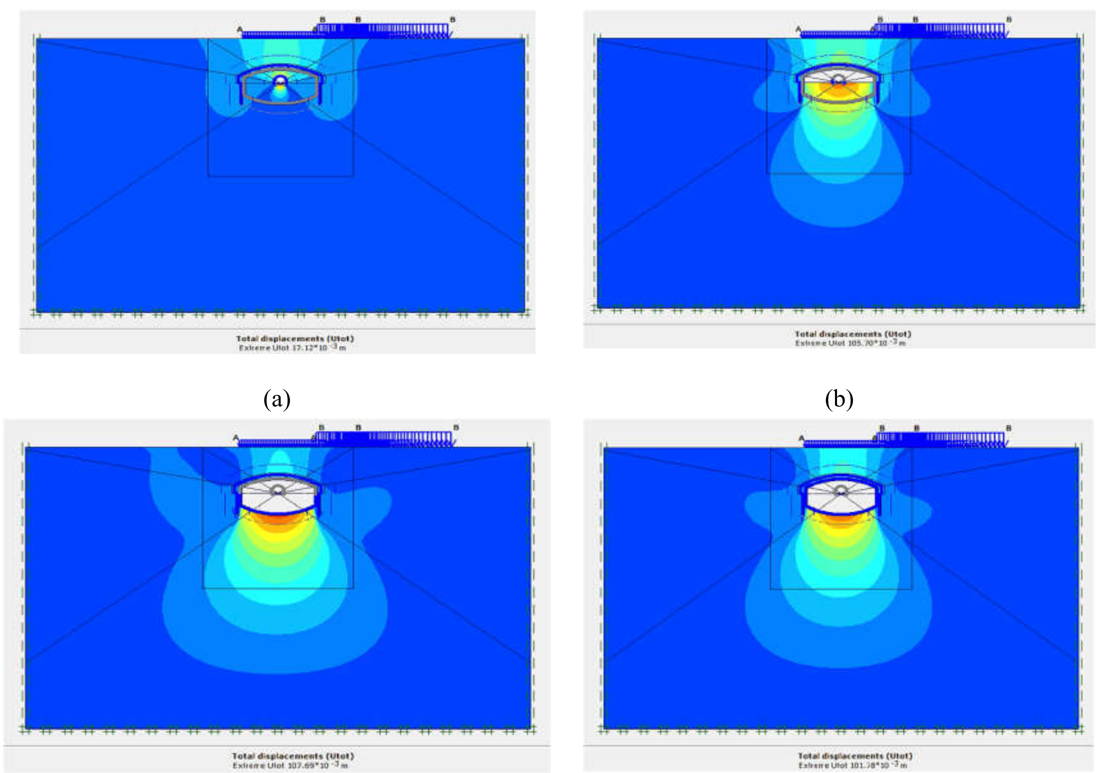


Figure 7. Modeling the retaining structure, the main structure with the access gallery



(a) (b) (c) (d)

Figure 8. Maximum settlement a) after excavation of car gallery b) after excavating of tunnel upper part c) after excavating of tunnel lower part and d) after executing of main structure

[DOI: 10.22068/IJRARE.5.1.19]

level that is due to the presence of the building and the street loads. Due to the Rankin method conservative assumption, this size of settlement has no structural effect on the buildings and on the street.

6. Concluding Remarks

Regular servicing and parking of trains are fundamental to subway systems. This study that focused on the different arrangement modes of parking lines, started with AHP analysis technique to select the best mode of parking arrangement. After the selection for the best possible mode the construction feasibility and the parking structure modeling from the geotechnical viewpoint was performed by using the so called Plaxis 2D code. The fundamental results of the current study are listed hereunder.

- The AHP analyses show that while considering the main criterions including the possibility for daily inspection and cleaning up of the trains, operation desirability and construction costs, the large span tunnel with four lines is favored over other possible modes for the construction of north parking in line 7 of Tehran subway.
- The numerical analysis from the geotechnical aspects by using PLAXIS 2D software shows that the ribbed pile method is a suitable technique for executing a large span tunnel. The numerical results indicate that the settlement occurrence due to the excavation, execution of retaining structure and the main structure is in the permissible range according to the Rankin theory.

Acknowledgments

The authors of this article would like to thank Tehran Urban & Suburban Railway Operation Co. for providing information and facilitating access to its technical archives.

References

[1] M.H. Sadaghiani, S. Dadizadeh , Study on the effect of a new construction method for a large span subway underground station in Tabriz-Iran, Tunneling and Underground Space Technology, Vol.25, No.1, (2010), pp.63-69.

[2] C. Zou, Y. Wang, P. Wang, J. Guo, Measurement of ground and nearby building vibration and noise induced by trains in a subway depot, Science of the Total Environment, 536, (2015), pp.761-773.

[3] D. Kaliampakos, A. Benardos, A. Mavrikos, A review on the economics of underground space utilization, Tunneling and Underground Space Technology, 55, (2016), pp.236-244.

[4] S. Durmisevic, The future of the underground space, Cities, Vol.16, No.4, (1999), pp.233-45.

[5] W. Broere, Urban underground space: Solving the problems of today's cities, Tunneling and Underground Space Technology, 55, (2016), pp.245-248.

[6] O. Gamayunova, E. Gumerova , Solutions to the urban problems by using of underground space, Procedia Engineering, 165, (2016), pp.1637-1642.

[7] Y.M. Hashash, J.J. Hook, B. Schmidt, I. John, C. Yao, Seismic design and analysis of underground structures, Tunneling and underground space technology, Vol.16, No.4, (2001), pp.247-293.

[DOI: 10.22068/IJRARE.5.1.19]