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Investigation of the Effect of Modeling of Control Tunnel in Retaining Structure of J2 Station of Mashhad Metro Using Plaxis 2D

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INVESTIGATION OF THE EFFECT OF MODELING OF CONTROL TUNNEL IN RETAINING STRUCTURE OF J2 STATION OF MASHHAD METRO USING PLAXIS 2D

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ABSTRACT

Nowadays using of underground concrete arch excavation method is very common for execution of retaining structures (soldier structure) of deep and semi deep metro stations all around the world. In this method executer can use retaining structure as a part of main structure of station in next construction steps with using of piles of retaining structure as a part of main structure's wall.

One of the first steps in building retaining structure of metro station is control tunnel (patrol tunnel) that usually is a prefabricated controlling tunnel in the middle of retaining structure. This tunnel is used for digging bores for concrete piles and arches of retaining structure and will be removed at the end of excavation process.

Usually designers don't consider this tunnel in modeling of whole retaining structures in numerical modeling in computer programs like PLAXIS.

We have done 2 different modeling of retaining structure of J2 station in Mashhad metro (with and without control tunnel) for considering of the impact of modeling of control tunnel on stresses, deflections, axial forces, bending moments, etc of the model using PLAXIS 8.5 2D.
Results and differences between these two kinds of modeling showed that neglecting the patrol tunnel in analyses can cause important reductions in forces and moments of piles and ribs of the retaining structure.

INTRODUCTION

The Mashhad Urban Railway Line 2 has a total length of 13 kilometers. General slope of land is from south to north. J2 Station is between stations I2 and K2 that is the tenth station of 12 stations on this route. In the terms of elevation, station is categorized in the underground stations and rail depth of the station from the street level is about 20 meters and from the sea level 99 meters. Slope of the line of rail in the area of the station is about 2 in 1000 in the longitudinal profile; the downward slope is toward the northeast.

These Entrance and exit tunnels of J2 station is excavated using mechanized excavation (TBM). Thus, problems related to water leaking from the tunnels into the station are negligible. At station location, depth of ground water level is 26 meters. Thus the total height of the station is above the water level, which makes less difficulty during the construction and minimizes water infiltration into the station during the operation.

You can see a 3d view of J2 station body

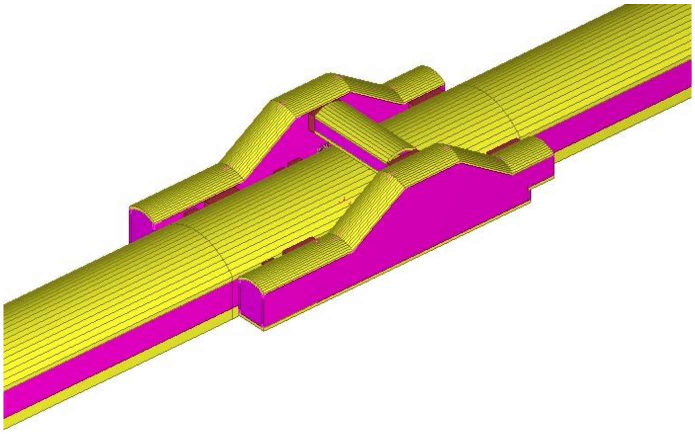
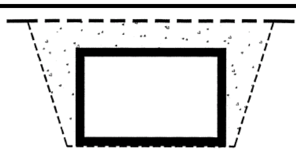
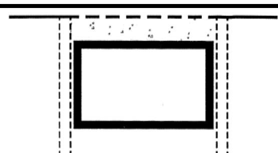
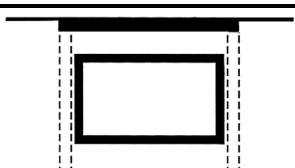


Fig. 1. An outline view of J2 station

Method of Implementation

.J2 station is an underground type of metro station.In general there are two methods for the implementation of underground stations: non-tunneling method and tunneling method. In non-tunneling method there are 3 ways of construction that can be seen in table1.

Table 1. Types of None-tunneling method

	(Cut and Cover with Inclined Walls)
	(Cut and Cover with Vertical Walls)
	(Cover and Cut Method /Enclosed Excavation)

In the tunneling method we have 2 different types : Concrete arch and goat horn. The concrete arch method is best for the situations that there is no way for the diversion of the traffic during the construction and is usually used for the semi deep and deep stations. The other method is best for semi deep and deep stations when there is a significant overhead on the roof of the station. Because of the Damages occurred in the stations that have been running by this way and good reliability of the concrete arch way, in general concrete method is chosen for the excavation. Due to the deep station and also the impossibility of temporary reform of the traffic, we choose the concrete arch underground method for J2 station to have the best safety. A good aspect of this method is also possibility of combining retaining structure and the final structure of the station that reduce manufacturing costs.

In this method, piles as the retaining structure of the station will function as a part of the wall of the final structure (together with the wall of the main structure). Steps of the implementation of J2 station are:

1. Digging the galleries in the station and implementation of the interim maintenance system (a prefabricated tunnel with the name of patrol tunnel) the station during it.(shown in the fig2).

2. Drilling the side accesses and up- tunnel gallery
3. Drilling Lateral piles
4. Filling the pile bores with concrete
5. Drilling concrete arch along the piles
6. Filling the concrete arch with concrete
7. Excavation under the protection of piles and concrete arch to the foundation level
8. Implementation of the station (shown in the fig3)

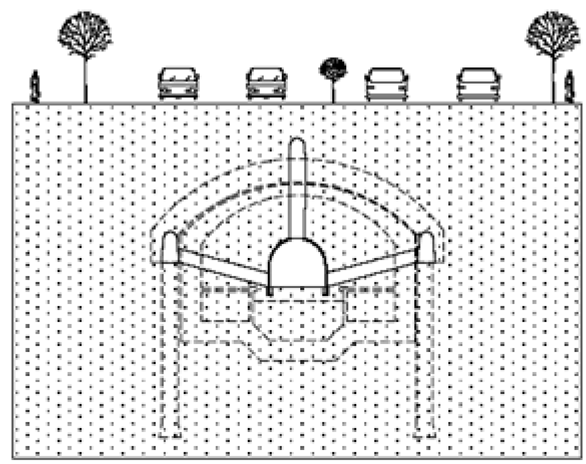


Fig. 2. Digging galleries and implementation of patrol tunnel

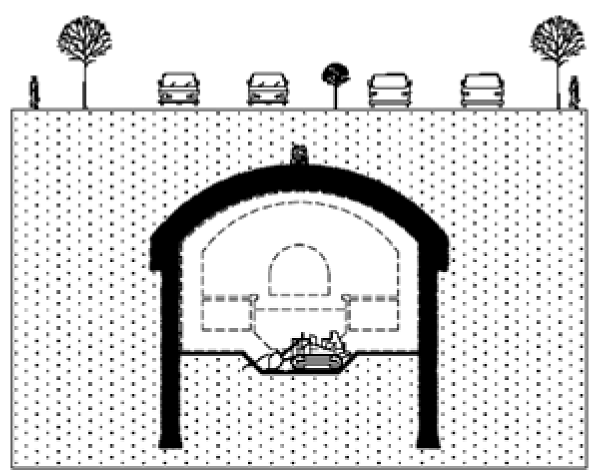


Fig. 3. Final face of the retaining structure

STRUCTURAL FORMATION

Retaining structure of the station with a height of 1.7 meters is consisted of ribs lied on concrete piles with a diameter of 1.2 meter and span of 18.55 meters at intervals of approximately two meters. Connection between piles and ribs are a rigid connection. For this purpose rib element with a 1 meter width is connected to a element with a high flexural rigidity that is connected to the pile. All analyzes were performed as two-dimensional where the tonnage area of each rib was considered. Live load overhead on the surface during the use of retaining structure will be 2 tones per square meters. In the Fig 4 you can see a schematic 3D view of retaining structure after construction. In Fig 5 dimensions of retaining structure is shown.

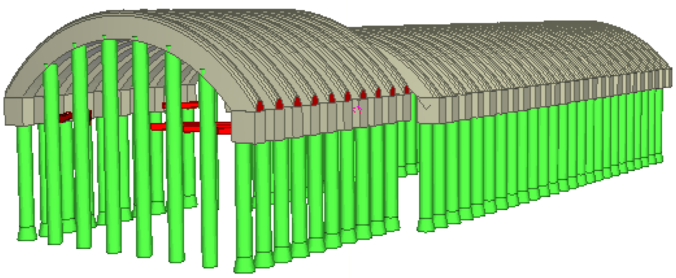


Fig. 4. a schematic 3D view of retaining structure after construction.

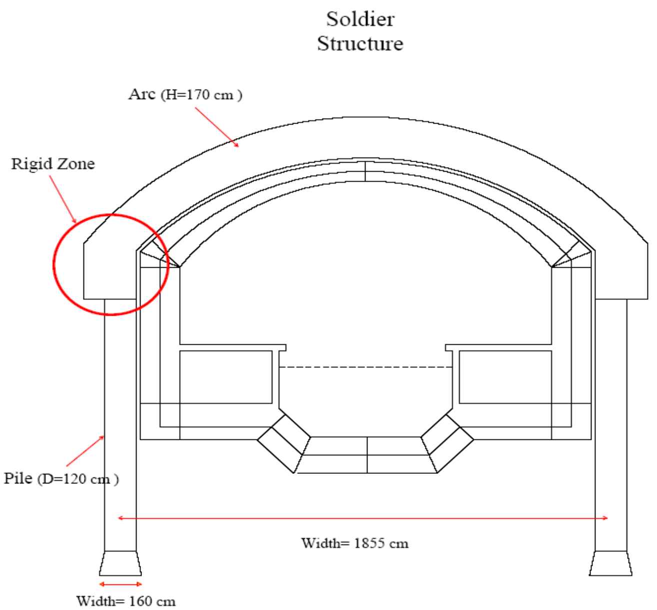


Fig. 5. Dimensions of retaining structure.

MATERIAL AND SOIL PROPERTIES

Type C2 concrete (with a 28 days compressive strength stress of 300 kg/square centimeters for a cubic sample) is used. All steel profiles and plates are ST-37 with a yielding stress of 2400 kg/square centimeters. Ribbed bars are from A-III type with a yielding stress of 4000 kg/square centimeters.

Soil layers' properties based on geotechnical report are provided in table 2. (Later in the next studies of the soil layers, more accurate properties were given that we used in the analyses). Water level is 26 meters under the surface that is considered in the modeling of the soil.

Table 2. Soil layers' properties

Layer No.	Description	Depth	γ_d	ω		C'	ϕ'	C_u	ϕ_u	$E_{proposed}$		C_C	C_S	e_0	ν
		(m)	(kN/m^3)	(%)		(kg/cm^2)	(Deg.)	(kg/cm^2)	(Deg.)	(kg/cm^2)		--	--	--	--
0	Over Burden	0-2	--	--		--	--	--	--	--		--	--	--	--
I	SC-SM	2-8	17	9		0	26	--	--	700		--	--	--	0.30
II	CL-ML	8-20	15.5	15		0.2	28	1	10	150		0.22	0.015	0.75	0.30
III	CL-ML	20-40	17	20m-30m	16	0.2	28	1	10	20-23 m	220	0.10	0.015	0.75	0.35
				30m-40m	21					23-40 m	350				

MODELLING AND RESULTS

Plaxis 2D (8.2 version) a finite element code is used to modeling of the retaining structure to modeling and comparison between 2 different types of modeling, first conventional approach, by neglecting the patrol tunnel and second by considering it in analysis.

Conventional approach

Modeling and analysis has been done in these levels:

- Modeling of the piles and ribs
- Assign the materials to piles and ribs
- Assigning materials to soil layers
- Defining the water level
- Defining the stages of analysis for the program
- Controlling the deflections, tensions, etc.

You can see the modeling of the piles, ribs and the soil layers and traffic loads in figure 6.

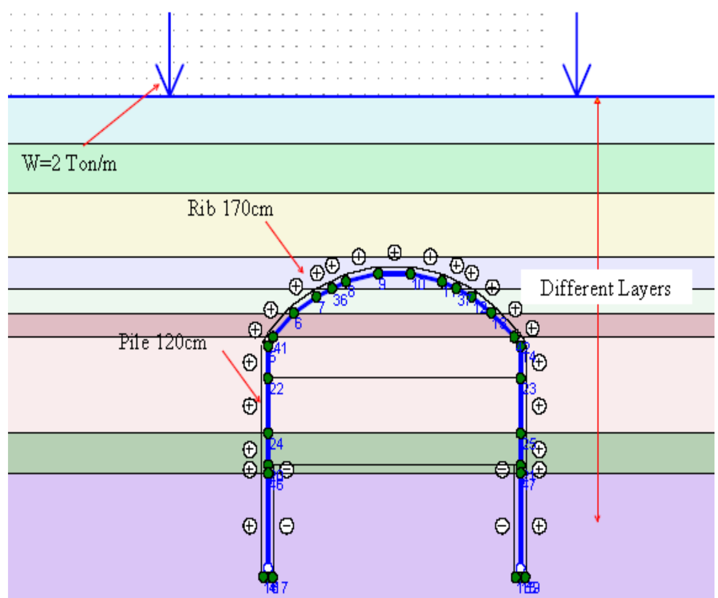


Fig. 6. Modeling of Piles, ribs, soil layers

After defining the water level and assigning the properties to soil and piles and layers, analysis has been done in eight phases. These are the results of this analysis:

Table 3. Results of the conventional method

Maximum Vertical displacement	$811.83*10^{-6}$m
Maximum Horizontal displacement	$58.68*10^{-3}$m
Maximum Total Displacement	$212.87*10^{-3}$m
Extreme effective principal stress	$-4.84*10^{3}$KN/m^2
Extreme total principal stress	$-4.88*10^{3}$KN/m^2
Maximum axial force of piles	194 ton/m
Maximum shear force of piles	54 ton/m
Maximum moment of piles	104, -60 ton.m/m
Maximum axial force of ribs	221ton/m
Maximum shear force of piles	58 ton/m
Maximum bending moment of piles	288, -31.4 ton.m/m

In the Figure 7 you can see the deformed mesh of the retaining structure without the patrol tunnel:

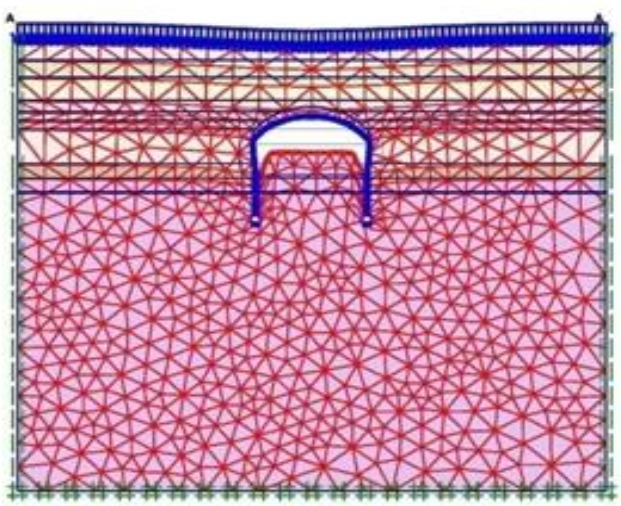


Fig. 7. Deformed mesh of structure without patrol tunnel

Bases on forces derived from piles and rib analyses and P-M-M interaction diagrams based on ACI318-02 code , Piles and ribs have been designed as below:
Note: Designing of the ribs at the two ends of the structure will be a different from the figure 9 due to differences in the moments and forces: 7T32+5T25 on top and 5T28 on the bottom of the rib)

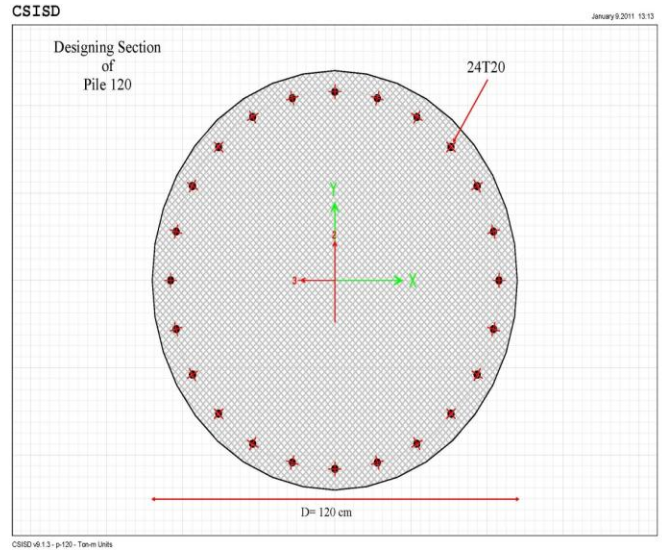


Fig. 8. Designed section of the piles

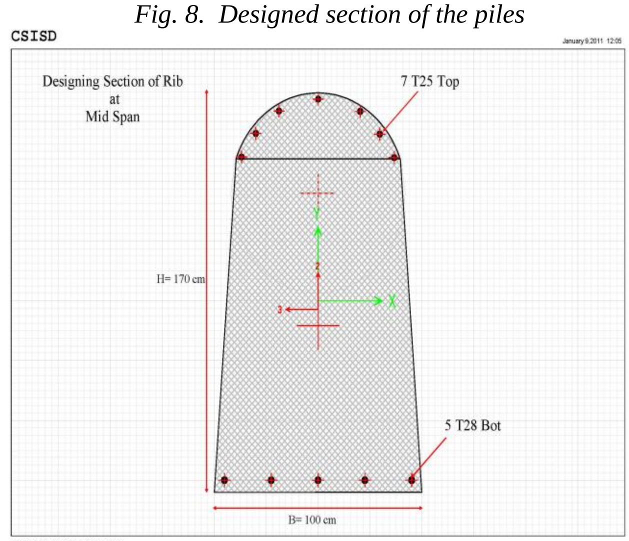


Fig. 9. Designed section of the ribs

<u>New approach</u>

In this approach we have added a patrol tunnel to the structure here is the properties of the patrol tunnel:EA: $1.4*10^{7}$EI: $2*10^{4}$. You can see the results of the analyses in the table 4

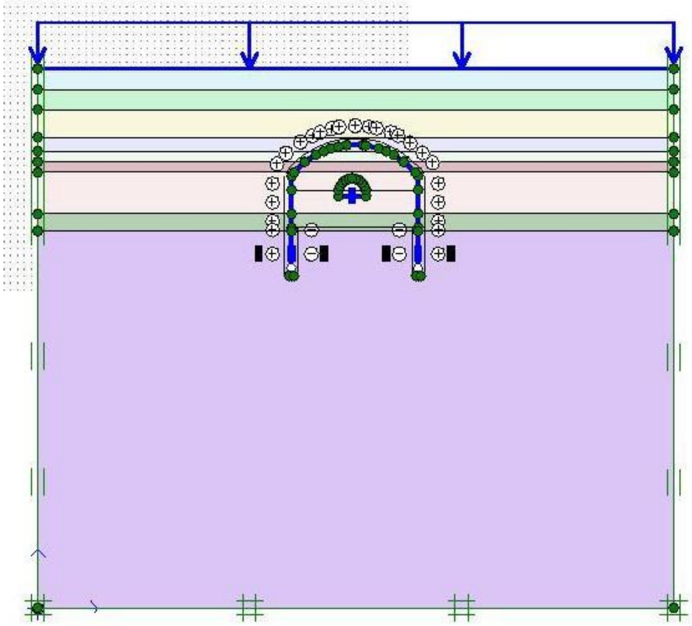


Fig. 10. Modeling of the structure with patrol tunnel

Table 4. Results of the new approach

Maximum Vertical displacement	$219*10^{-3}$m
Maximum Horizontal displacement	$65.73*10^{-3}$m
Maximum Total Displacement	$221.31*10^{-3}$m
Extreme effective principal stress	$-4.28*10^{3}$KN/m^{2}
Extreme total principal stress	$-4.28*10^{3}$KN/m^{2}
Maximum axial force of piles	194 ton/m
Maximum shear force of piles	70 ton/m
Maximum moment of piles	114, -66 ton.m/m
Maximum axial force of ribs	234ton/m
Maximum shear force of piles	79 ton/m
Maximum bending moment of piles	313, -100 ton.m/m

CONCLUSION AND PROPOSALS

As it is clear from tables 3 and 4 displacements, axial forces, shear forces and bending moments in the situation when the patrol station is considered during analysis are clearly bigger than the conventional analysis when the effective stresses are a little smaller the usual results that can be neglected.

As a result the design of the piles and ribs will be changed due to differences in the moments and forces and we should use stronger bars (or bigger sections) in piles and ribs to reach the same safety factor.

At the end of this article we strongly recommend considering of the control tunnel (patrol tunnel) in the analyzing of the retaining structure of the metro stations to avoiding designing failures in such important structures. At least designers should improve their conventional designs to nullify the differences caused by neglecting the patrol tunnel in the analyses.

REFERENCES

Michael Tomlinson, John Woodward. [2007]. "*Pile design and construction practice*". Taylor and Francis, London.

Dimitrios Kolymbas. [2005]. "*Tunelling and Tunnel Mechanics A Rational Approach to Tunnelling*". Springer, Ausria.

Hung Leung Wung, John Woodward. [1975]. "*Dynamic soil structure interaction*". California institute of technology, California.

R . Wang , Z . Z . Ma , D . P . Liu , and G . B . Liu. [2009]. "*Geotechnical Aspects of Underground Construction in Soft Ground*". Taylor and Francis, London.

Hu Anfeng. [April 2011]. "*An analysis on the retaining structures for deep excavation in a crossing interchange metro station*". 2011 International Conference on Electric Technology and Civil Engineering (ICETCE).

ZHENG Da-Rong, ZHANG Cun, ZHANG Hui. [2005]. "*Design and Construction of Retaining System of Xiangxing Road Station of Nanjing Metro*". Tunnel Construction 2005, ISSN: 1672-741 CN: 41-1355/U.

Badband consulting engineers.[2010] "*Retaining structure report of J2 station*". Mashhad, Iran.