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EXTENDED ABSTRACT

Pile- Tunnel Interaction in Subway Tunnels under Seismic Loads

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1. Introduction

Developing transportation system in populated cities needs to construct subsurface infrastructures, such as tunnels. With a close attention to densely surface structured urban environments, it is most likely that tunnels would inevitably cross near of adjacent structures. It should be considered, whether the settlement induced by tunneling are in allowable range or not. Several factors may affect the magnitude of ground movement due to tunneling and consequently the tunnel- structure interaction, such as ground geotechnical properties, adjacent structure stiffness and relative position of structures and tunnels, and tunnel construction parameters.

When pile foundations are exposed to intense dynamic transverse loads during earthquakes, soil- structure interaction (SSI) plays an important role in allocating the response of pile foundations to lateral excitation. The numerical investigation with analysis subway tunnels and deep foundation interaction behavior under seismic loads by the finite element method was carried out.

2. Methodology

2.1. Material Characteristics

In this research, Mohr- Coulomb Behavioral Model was used to conduct analyzes. This elastic-plastic model is one of the easiest and most used models used in geotechnical analysis. The reason for this is the number of parameters that are difficult to determine, which requires no complex testing. In this study, soft clay was used for soil geometry modeling, whose properties were according to Table 1.

Shell elements are used to make piles. The AIII type of rebar is also used for the manufacture of piles and is used as a volume percent with 6% of the area of the pile. In this modeling, the piles and pile caps are assumed to be an elastic body with a compressive strength of 350 Kg/cm3, and its elasticity is 2.615E+07 KN/m2 and the Poisson coefficient is 0.2.

The shell element was used to construct the tunnel lining. The lining thickness of the shotcrete is 20 cm and the length is 80 meters. Its density is 2500 kg/m, the modulus of elasticity is $2*10^{10}$ Pascal and its Poisson coefficient is 0.2.

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Table 1. Geotechnical parameters used in modeling

Layer Number	Soil Type	γd (KNm^3)	C (Kpa)	ϕ (degree)	E (Mpa)	ν
1	Soft Clay	18.6	14	34	80	0.3
2	Soft Clay	19	30	33	50	0.32
3	Soft Clay	17	31	28	35	0.35

2.2. Numerical modeling

To plot the geometry of the model, a plot of land with a size of 45*60 square meters was chosen, the length of the pile was 27 meters and its width was one meter, the tunnel's crown distance to the surface of the ground was 12.95 meters and the diameter of the tunnel was 9.16 meters. In this analysis, the effect of underground water is neglected and the plot of land is divided into 3 layers and it is assumed that the soil of all layers is the same and the clay type is soft.

For parametric studies the influence of the distance between the pile group and tunnel in the dynamic state will be investigated. Four different models with intervals D, 1.5 D, 2D and 2.5 D have been used for this purpose. D is a tunnel diameter of 9.16 meters and the height of the ground to the tunnel floor is about 23 meters.

3. Results and discussion

In Fig. 1-b, which shows the effect of distance of the pile from the tunnel on the displacement of the pile group in the direction of the earthquake, we see that with increasing distance from the tunnel, the displacement tunnel of the pile group is reduced by twice the diameter, but more than twice the diameter of the tunnel (about 18.5 m) moves the pile group to a constant value and does not change. In general we conclude that the increase in distance to a certain extent reduces the displacement of the pile group, which is a tangible decrease of about 25 centimeter and will not change much during the long displacement of the pile group.

According to Fig. 1-a, the diagram which shows the effect of distance between the pile group and the tunnel on the displacement of the tunnel in the longitudinal direction above, the middle and bottom of the tunnel. We saw that at all three points of the tunnel, the displacement in the longitudinal direction with increasing distance to twice the diameter of the tunnel (about 18.3m) is reduced, but from a distance of twice the diameter of the tunnel to two and a half times the diameter of the tunnel, the maximum amount of displacement increases at every point of the tunnel, which increases as the tunnel proceeds downwards. In general, we conclude that the longitudinal displacement of the tunnel is not continuous with increasing distance and is at its maximum in the distance to the tunnel.

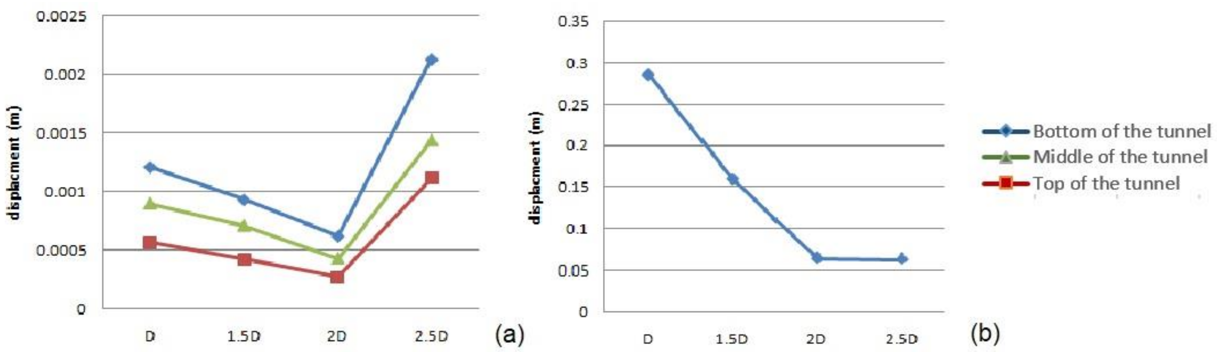

Fig 1. a) Effect of the distance between the piles and the tunnel to move the tunnel in the longitudinal direction, b) Effect of the distance between pile group and the tunnel on displacement of pile group in the direction of earthquake

4. Conclusions

The results show that the displacement of the tunnel in the upper and middle sections increases with increasing distance and then reaches a roughly constant value, but in the lower part of the tunnel, earthquake displacement, increases first with increasing distance and then decreases. The tunnel settlement decreases with increasing distance and then remains almost constant, but the pile group's settlement increases with increasing distance from the tunnel and then decreases. The displacement of the tunnel in the longitudinal direction is also reduced by increasing the distance initially to a distance of twice the diameter of the tunnel and then has a sudden increase, the maximum and minimum stress values increases at the top and the middle of the tunnel, except for lower part of the tunnel, which does not change with increasing continuous distance.

5. References

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