

Estimation of Minimum Heterogeneous Face Support Pressure in Mechanized Tunneling Using Numerical and Analytical Methods, Case Study: Tehran Metro Line 7

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Abstract

Determination of the optimum face support pressure is one of the fundamental tasks in a excavation using tunnel boring machines (TBM). The optimum face-stabilizing pressure ensures the safety of the excavation, helps to minimize a surface settlement and ultimately prevents the collapse of the entire tunnel. Existing methods have been presented only for homogeneous soil at the tunnel face. The heterogeneity or boundaries of the face layers have a significant effect on the stability of the tunnel face. Practical experiences show that the tunnel face stability in heterogeneous soil is relatively more difficult than homogeneous soils and it cannot be easily solved by the models proposed for homogeneous soil. This study investigates the influence of heterogeneity of the soil on the tunnel face instability in earth pressure balance (EPB) TBM . Therefore, the numerical softwares (Plaxis 3D Tunnel and Phase2) and analytical methods (Broere and Carranza-Torres) were used for the stability analysis of tunnel face in heterogeneous soil. The results of comparing values of safety factor showed that analytical methods are conservative. Moreover, the numerical modeling results showed that when the soils with poor material properties are located in the upper part of the face, they can significantly increase the ground pressure and partial slide. From comparing the face support pressure for one layer (assumption of homogenous soil and averaging of physical and mechanical properties of soil) with multilayers of tunnel face, it can be concluded that assuming of tunnel face as a one layer, causes incorrect estimation of tunnel face support pressure.

Key words: Tunnel, Mechanized Excavation, Heterogeneous Face Support Pressure, Plaxis 3D Tunnel Software

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Extended Abstract:

1. Introduction

The aim of tunnel face stability assessment is to investigate groundwater pressure and earth pressure acting at the tunnel face and to analysis the bearing capacity of the tunnel face. If the self-bearing capacity of the tunnel face is insufficient, a tunnel face support has to be provided. In this case, the support medium must counter the earth and groundwater pressures to stabilize the tunnel face. In the case of an EPB shield, the difficulty of a compressed-air intervention is dependent on the present ground type on the tunnel face. During the advancement of an EPBS, the face-stabilizing pressure is one of the most important factors of critical and principle to be evaluated correctly. In tunneling by EPBS, high face pressure often leads to surface upheaval whereas low face pressure leads to sudden collapse of the face and ultimately settlement of the surface. All available approaches to determine the required support pressure can be divided into four fundamental groups including analytical, empirical, experimental and numerical methods. Current methods have been presented only for a homogeneous soil at the tunnel face. The heterogeneity or boundaries of the face layers can have a significant effect on the stability of the tunnel face. Practical experience shows that the tunnel face stability in heterogeneous soil is relatively more difficult than homogeneous soils and cannot be easily solved by the models proposed for homogeneous soil. Literatures in the subject of tunnel face stability have been shown that researchers have focused on homogeneous and heterogeneous face with two layers and tunnel face stability with multiple layers has not been investigated.

2. Methodology

Tehran's metro line 7 project has been excavated by an Earth Pressure Balance (EPB) machine. The main target of this research is estimation of heterogeneous face pressure for EBP TBM tunneling by numerical (Plaxis 3D tunnel and Phase2 software) and analytical (Broere and Carranza-Torres) methods. Finally, the results of numerical and analytical methods have been compared.

3. Results and conclusions

The result of numerical and analytical methods has been shown in Table 1. The most important results from Table 1 can be summarized as follows:

- It is clear that there is an acceptable difference between the results of Carranza-Torres method and numerical methods for the minimum face support pressure.
- Comparing the safety factor values are obtained from the Carranza-Torres method with Phase2 software showed that analytical methods are conservative.

Table1. Minimum face support pressure and safety factor calculated in numerical and analytical methods

Section Number	Minimum Face Support Pressure (kPa)			Safety Factor	
	Broere method	Carranza-Torres method	Plaxis 3D Tunnel	Phase2	Carranza-Torres method
1	36.4	56.4	43	1.25	0.8
2	60	56.4	51	1.28	1.03
3	62.7	56.4	49	1.76	1.06
4	32	56.4	46	1	0.79
5	58	56.4	55	1.62	1.04
6	50	56.4	51	1.42	0.98

From Comparing face support pressure for one layer (assumption of homogenous soil and averaging of physical and mechanical properties of soil) with multilayers of tunnel face, it can be concluded that assuming of tunnel face as a one layer causes incorrect estimation of tunnel face support pressure. Moreover, the numerical modeling result showed that when the soils with poor material properties are located in the upper part of the tunnel face, they can significantly increase the ground pressure and partial slide.

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