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# Investigation on the efficiency of different methods for evaluation of ground settlement due to excavation of Tabriz metro tunnel, line 2

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**ABSTRACT:** Mechanized shallow tunneling in urban areas and soft grounds leads to horizontal and vertical displacements at the host materials of the tunnel and causes the ground settlement due to tunneling which can have undesirable and even destructive impacts on surface structures and subsurface Facilities. In the present study, ground settlement induced by the mechanized excavation of the Tabriz Metro tunnel, Line 2, is considered a case study using semi-experimental, analytical and numerical methods, and the impact of different factors will be investigated. For this purpose, a section of the studied tunnel was selected for evaluating the settlement via mentioned three methods, and the results were analyzed and compared with the real settlements, measured during the tunnel excavation. The results show that the semi-empirical method releases relatively higher values of settlement because of the intrinsic and fundamental specifications of the method while the analytical and, especially, numerical methods generally provide logical and reliable outcomes because of the utilization of more parameters of tunnel and host soil such as geotechnical characteristics of host soil and geometrical properties of the tunnel. In this regard, to emphasize the valuable capabilities of numerical methods, the effect of several factors on the amount of settlement was studied via FLAC 2D software. The outcomes showed that the ground settlement increases when the elasticity modulus of grout and the elasticity modulus of soil decrease as well as when the surface load increases and the groundwater level is dropped.

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## 1- Introduction

Excavation of tunnels and other underground spaces disturbs the initial stress state of the soil mass. This process induces displacements of the soil surrounding the tunnel. Depending on the depth of the tunnel and other factors such as the soil characteristics, the tunnel boundary convergence, and soil displacement can extend towards the ground surface and causes the phenomenon of "ground settlements due to tunneling". Given to serious environmental effects of the settlement on surface buildings and subsurface infrastructures, many studies have been done on this subject by researchers. Most of the studies are based on the work of Peck (1969) who analyzed a number of cases and indicated that the transverse profile of surface settlements can be described by an inversed normal distribution (Gaussian) curve [1]. However, some of the famous other researches can be pointed as the references of [2-5].

Several methods have been suggested to study this subject among them semi-empirical method, analytical method and numerical method are more common and applicable in professional and technical activities. In this regard, the selection of an appropriate method for studying this subject has made the most challenges for researchers. So, it is important to further study this issue. In the present study, ground settlement due to the excavation of the mechanized tunnel of Tabriz metro, Line 2, is evaluated using several methods considering real settlements, and the efficiency of each of the methods is investigated. Real settlements are basically valuable data and utilization of them is considered a novelty of this study as well as one of the powerful points of it. Finally, the effect of several factors, such as the geometrical dimensions of the tunnel and the geotechnical parameters of the host soils and the variation of grouting pressure, are investigated on the value of ground settlement due to tunneling using numerical model (FLAC 2D).

## 2- Evaluation of Ground Settlement Due to Tunneling

To do the research, the settlement of the ground surface caused by the excavation of the mechanized tunnel of the Tabriz metro Line 2 is evaluated in selected points by several methods and the results are compared to the real settlements of the ground surface, measured during the tunnel excavation. The utilized methods are:

Semi-empirical method: the parameters of VL and k were estimated according to geological and geotechnical characteristics of the soil type at each of the points [6, 7].

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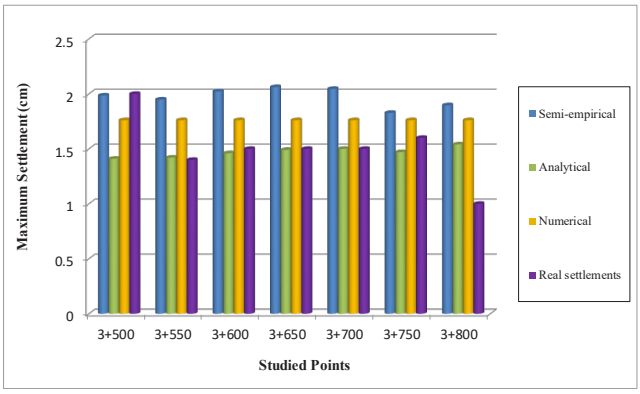


**Fig. 1. Comparison of the evaluated and real settlements**

**Table 1. Quantitative comparison of the settlements**

| Evaluation Method | Evaluated (Predicted) Settlements | | | Real Settlements |
|---|---|---|---|---|
| | Semi-empirical | Analytical | Numerical | |
| **Settlement (cm)** | 1.9 | 1.5 | 1.7 | 1.6 |
| **Difference to Real Settlements (%)** | 18.75 | -6.25 | 6.25 | 0 |

Analytical method: in this method geometrical properties of the tunnel and TBM were determined via approved plan and the amount of ground settlement were calculated using the Loghanathn and polous method [8] as well as with respect to the recommendations of Lee et.al [9].

numerical methods are employed to evaluate the settlement of the ground surface [10-12].

Then, the results are compared with the real settlements, measured experimentally by leveling methods during the mechanized tunneling, to estimate the performance of several methods.

## 3- Comparison of The Results

The amounts of settlements at the selected point were evaluated via three methods including semi-empirical, analytical, and numerical methods and, the results were compared to the real settlements. All three types of settlements in addition to the real settlements are shown in Figure 1 and compared together quantitatively in Table 1.

Comparison between the results indicated that the real (in-situ) settlements are approximately equal to the settlements obtained via numerical and analytical methods and relatively lower than those obtained by semi-empirical methods. The discrepancy can be concerned with the important fact that many of the geometrical, geotechnical, and operational parameters of mechanized excavation processes are included in the numerical and analytical methods but not included in the semi-empirical method. It means that analytical and especially numerical methods are more efficient because of utilizing most of the geotechnical and geometrical properties of the tunnel and host soil, as well as operational parameters of mechanized excavation of the tunnel. So, the numerical method is recommended highly to evaluate ground settlement due to tunneling.

Finally, the effect of several factors, such as the geometrical dimensions of the tunnel and the geotechnical parameters of the host soils and the variation of grouting pressure, are investigated on the value of ground settlement due to tunneling using numerical model

## 4- Conclusion

Evaluation of the ground settlement due to the excavation of the tunnel of the Tabriz Metro Line 2 showed that the analytical and especially, numerical methods are generally more reliable methods for settlement prediction. So the numerical modeling was used for sensitivity analysis and it was seen that the ground settlement increases when the elasticity modulus of grout and the elasticity modulus of soil decreased as well as when the surface load increased and the groundwater level dropped.

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