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Research article

Predicting the intensity of the vulnerability of the building due to tunneling-induced settlement by studying the geomechanical behavior of the surrounding medium

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English Extended Abstract

Summary

This paper investigates the effect of geotechnical parameters on the prediction of building damage severity due to tunneling-induced settlement. The influence of soil elastic modulus, cohesion, and internal friction angle on ground displacement and building deformation was studied using the numerical finite element method in the Tehran Metro Line 7 tunnel project. The severity of the building damage was analyzed based on an assessment of building deformation parameters. The results indicate that building damage severity is significantly sensitive to changes in soil elastic modulus. Minor changes in elastic modulus can lead to a shift in damage severity from structural and severe (damage grades 4 and 5) to non-structural and minor (damage grades 0 and 1). In contrast, changes in internal friction angle do not have a significant impact on damage severity. However, an increase in cohesion can be somewhat effective in reducing damage severity.

Introduction

One of the major challenges in urban tunneling is the occurrence of settlement and its detrimental effects on buildings [1]. Proper understanding of ground behavior in geotechnical projects, particularly tunneling, requires a sound comprehension of the relationship between soil strength characteristics and the surrounding environment, which enables accurate prediction of tunneling-induced building damage severity. Researchers have proposed various approaches for the evaluation and control of tunneling-induced settlement, including experimental methods [2], numerical modeling [3], physical and laboratory modeling [4], in-situ monitoring and measurements [5], and analytical methods [6]. However, adjacent buildings still suffer from minor and structural damage due to settlements [7]. Some researchers have also analyzed the tunnel-building interaction using analytical [8] and semi-analytical [9] methods.

Methodology and Approaches

In this study, the tunnel construction process was modeled using the three-dimensional finite element method. Numerical models were validated based on the results of the instruments' data deployed in the Tehran Metro Line 7 tunnel project. After reviewing the building damage criteria, five out of nine building deformation parameters induced by tunneling-induced settlement, namely maximum settlement ($S_{v,max}$), maximum differential settlement ($\delta S_{v,max}$), maximum building slope (θ_{max}), maximum tensile strain (ε_{max}), and maximum angular distortion (β_{max}), were selected as evaluation criteria for damage severity. Then, to investigate the effect of elastic modulus changes on damage severity, numerical models were constructed by assigning a range of elastic modulus values to the soil layers. The 5 deformation parameters were analyzed based on different elastic moduli, and the damage severity level was determined. The same

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procedure was followed for internal friction angle and cohesion, and the results were analyzed.

Results and Conclusions

The results show that changes in the geomechanical behavior of soil layers caused by variations in geotechnical parameters affect building damage severity. Building damage severity is significantly sensitive to changes in elastic modulus, and minor changes in soil elastic modulus can lead to a shift in damage severity from structural and severe (damage classes 4 and 5) to minor and negligible (damage classes 0 and 1). This sensitivity is minimized for internal friction angle, and changes in internal friction angle do not have a significant impact on ground displacement and consequently on damage severity to buildings. The effect of increased cohesion on reducing damage severity is more pronounced than that of internal friction angle and less than that of elastic modulus, leading to a shift in damage severity from structural (damage class 4) to moderate (damage class 3). Figure 1 illustrates the impact of each geotechnical parameter on tunneling-induced building damage severity. The area of each parameter's surface represents its influence on building damage severity changes. As can be observed, building damage severity is highly sensitive to elastic modulus changes, and with increasing and decreasing elastic modulus, damage severity shifts from classes 4 and 5 to classes 0 and 1. This can be attributed to the significant impact of elastic modulus on soil cohesion and integrity. Increased soil elastic modulus reduces ground displacement and movement caused by tunneling, resulting in less severe building damage.

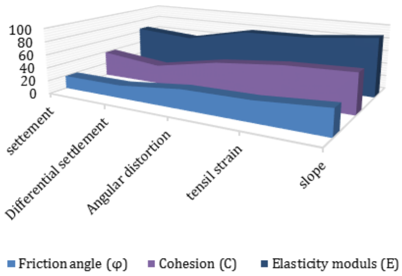

Fig. 1: Comparison of geotechnical parameter effects on tunneling-induced building damage severity

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