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Numerical analysis of soldier piles construction to reduce surface settlement due to tunneling

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Abstract

Urban development and rapid expansion of cities over the past decades have been accompanied by a considerable growth in mechanized tunneling. The construction of shallow tunnels of large diameter leads to the ground movement which could adversely affect the abutting structures. Excessive vertical and horizontal displacements pose a major threat to these structures. Preventive measures such as diaphragm walls and a row of soldier piles can effectively protect adjacent structures from possible damages.

This research specifically assesses the effectiveness of a simple row of soldier piles by three-dimensional simulation with finite difference approach. Moreover, the relationship between the performance and major geometrical parameters such as spacing among the piles, distance from tunnel axis and piles length in greenfield condition are investigated.

The simulation results show a strong relation between the length of piles and displacement reduction. Piles should be founded at least half a tunnel diameter below the invert and in all cases, a row of piles perform better when the space among them is low.

Keywords: Tunneling, Soldier piles, Finite difference, Settlement

1. INTRODUCTION

The shallow underground tunnels are commonly constructed by using large diameter boring machines and often requires preventive measures to control the ground movements induced by the excavation. A single line of unloaded piles can be installed between the tunnel and the buildings to reduce horizontal and vertical displacement. A few studies have been performed on similar problems. Bilotta [1] performed a series of centrifuge tests which a diaphragm wall was embedded to one side of a tunnel with different its length, thickness and roughness of the wall-soil interface. Bilotta et al. [2] computed the effectiveness of a simple row of piles to reduce displacement due to tunneling and investigated some simple geometrical parameters with finite element simulation and In spite of the adopted 3D mesh, a simple two-dimensional excavation scheme was used to simulate the tunnel construction. Ong et al. [3] investigated the effects of soil movements on free head single pile located nearby tunneling in centrifuge tests and 3D numerical analysis has been performed to back analyze the centrifuge test results.

This paper focuses on the efficiency of a single row of unloaded piles to modify the settlement profile. The piles installed before tunneling to reduce horizontal and vertical displacement. The tunnel excavated via tunnel boring machine (TBM) and simulated step by step excavation process. Although ground settlement due to tunneling is a 3D phenomenon by nature, previous studies have mostly utilized a two-dimensional approach or applied a plane strain condition. This study focuses on the simulation of tunneling process by taking into account self-weight and the face support pressure of TBM along with a detailed modeling of lining, grouting, and over-excavation of the tunnel to bring the numerical results closer to the real tunneling site conditions. Moreover, the effect of spacing between piles in the line of piles which plays a key role in limiting ground movements is evaluated more accurately in the 3D model. The piles length and piles distance from tunnel axis are also investigated in this paper.

2. NUMERICAL MODEL