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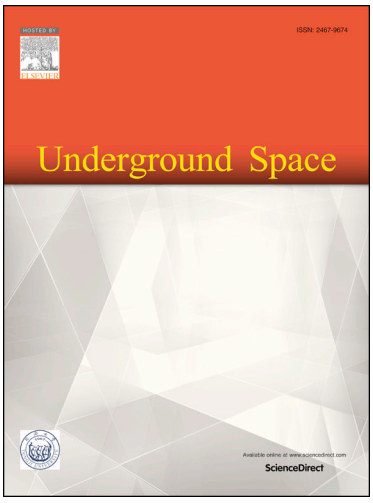

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Qiang Huang, Hongwei Huang, Bin Ye, Dongmei Zhang, Feng Zhang

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Evaluation of train-induced settlement for metro tunnel in saturated clay based on an elastoplastic constitutive model

Qiang Huang[a,b], Hongwei Huang *[a,b], Bin Ye [a,b], Dongmei Zhang [a,b], and Feng Zhang [c]

[a] Department of Geotechnical Engineering, Tongji University, Shanghai 200092, China;

[b] Key Laboratory of Geotechnical and Underground Engineering (Tongji University), Ministry of Education, Shanghai 200092, China;

[c] Department of Geotechnical Engineering, Nagoya Institute of Technology, Nagoya 466-8555, Japan

Abstract: In this study, a two-dimensional (2D) soil–water coupling dynamic finite element (FE) analysis is conducted to investigate the effect of repeated train vibrations on the long-term settlement of a metro tunnel in saturated clay. Particular attention is paid to the leakage problem of the metro tunnel by assuming different permeability conditions, namely fully permeable, fully impermeable, and partially permeable, on the periphery of the tunnel for simplicity. The train vibration load is first evaluated using a rail–fastener–tunnel–subgrade model and averaged over a characteristic length for 2D numerical analysis. Cyclic Mobility model is used to simulate the mechanical behaviors of saturated soft clay in the FE analysis. Excess pore water pressure (EPWP) and associated tunnel settlement in trial operation and normal operation are calculated using the FE code DBLEAVES for different permeability conditions. It is found that a very low EPWP is generated in the trial operation, which then increases rapidly to peak values at the early days of normal operation. Afterward, the EPWP diminishes gradually as the train vibration continues. The permeability of the tunnel lining plays a significant role in the distribution of EPWP around the tunnel but produces a minor influence on the development of tunnel settlement. The train-induced tunnel settlement is mainly caused by the static settlement resulting from the EPWP dissipation during train interval, while the dynamic settlement arising from dynamic consolidation in each train vibration only accounts for a small portion. According to the 2D dynamic FE analysis, the final train-induced settlement of the metro tunnel in saturated clay is estimated to reach 160 mm while the peak EPWP value can reach 26.55 kPa. The settlement discrepancies between the numerical method and empirical method are discussed in detail.

Keywords: dynamic finite element analysis; Cyclic Mobility model; saturated clay; excess pore water pressure; settlement of metro tunnel; permeability

1 INTRODUCTION

Owing to population expansion and rapid urbanization, many cities worldwide are confronted with increasing transportation pressure. The mass rapid rail transit, which is a convenient and safe traffic system, is rapidly developing globally to alleviate the urban transportation pressure. In the deltaic deposition of the Yangtze River in China, metro tunnels are mostly constructed in saturated clay with shield-tunneling method. Such saturated ground