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Three Dimensional Finite Element Analyses to Investigate the Impact of Tunneling on Pile

B.Vafaei[1], M.R.Jafari[2]
1- M.Sc in Geotechnical Engineering, Department of civil engineering, Tafresh University, Tafresh, Iran
2- PhD, PE, Principal Tunnel and Geotechnical Engineer, Geotechnical and Tunnelling Division, CDM, USA
⋮
Babak.Vafaii@yahoo.com
jafarimr@cdm.com

Abstract
Tunnels are an integral part of the infrastructure of modern society and are used for a wide range of applications, including subways and railways, highways, material storage, and sewage and water transport. On the other hand, in urban area many of the surface structures are supported by piled foundations. Thus, tunneling-induced ground movements may cause serious damage to the adjacent piles. Several researchers conducted two-dimensional laboratory tests and centrifuge model tests and presented closed-form analytical solution for the preliminary design purpose. In this paper, a series of finite element simulations were performed to investigate the influence of tunneling on adjacent piles. Results of three-dimensional numerical analysis show that, although there is a good agreement between finite element method and closed-form analytical solution when the tunnel lining is located (installed) at the pile level, magnitude of internal forces and displacement imposed on pile due to the tunneling increase significantly even after the passage of tunnel face from the pile.

Keywords: Tunneling; Pile Foundation; Interaction; Displacement; Internal Forces

1. INTRODUCTION

In urban environments, many high-rise buildings are supported by deep foundations and, if adjacent to a new tunnel excavation, they are likely subject to additional axial and lateral forces caused by tunneling-induced ground movements. Although assessment of the impact of tunneling on the stability and integrity of existing pile foundations is one of the important issues especially in weak soils, relatively little research work associated with this problem can be found in the literature. Mair & Taylor (1997) reviewed case histories, the results of numerical analyses and model tests relating to this problem. Morton and King (1979) investigate the effects of tunneling on the bearing capacity and settlement of pile foundations by carrying out laboratory tests. They concluded that the effects of tunneling on existing adjacent pile foundations in weak soils may be a major and governing concern in the design and execution of underground works. Lee et al. (1994) reported a case where a tunnel was to be driven between newly constructed pile foundations supporting a seven-story building with a two-story basement. The lateral pile deflection was estimated using a 2D finite-element method and the computed maximum value was used to design the piles. Attewell et al. (1986) reported a case in which the pile was anticipated to experience negative skin friction to be caused by a future tunnel construction because bituminous slip coatings were applied to piles. Jacobsz et al. (2001) suggested a critical influence line associated with large settlement of piles during volume loss in the centrifuge model test. Benton & Phillips (1991) analyzed the stress changes and deformations of two existing tunnels beneath a building founded on bored piles using two-dimensional finite element method, and the effects on tunnel during both construction and loading of the piles were considered. Chen et al. (1999) and Loganathan et al. (1999) used a two-stage approach to study the pile response to unsupported excavation. This approach is based on the use of closed-form analytical solutions to estimate the soil movement induced by tunneling in 'free-field' conditions (i.e. in the absence of the pile) and a boundary element analysis to compute the response of piles to soil movements estimated by analytical solutions. Results of this analysis show that tunneling may cause appreciable bending moment, lateral deflection and compressive and tensile axial forces in adjacent piles. Based on these studies an understanding of soil–tunnel–pile interaction mechanisms under plane strain conditions has developed and simplified design charts for estimating the