Experimental and Numerical Study of Interactions Between Parallel Tunnels

평행근접터널의 상호가동에 대한 실험 및 수치해석적 연구

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요지

이 연구는 기존터널과 근접하여 새로운 터널을 시공할 경우 이에 따른 터널의 상호가동에 대한 연구이다. 특히 이 연구는 연약지반에서의 근접터널 시공에 따른 기존터널 라인의 변위 및 응력 영향에 대하여 수행되었다. 이와 같은 터널가동을 연구하기 위하여 시험실 모형시험을 수행하였다. 이 시험 결과는 터널의 상호가동에 대한 보다 정확한 결과를 얻기 위한 시뮬레이션 기법 개발을 위하여 유한요소법을 이용하여 수치해석을 수행하여 비교 분석 하였다.

Abstract

This paper describes a study of the influence of shield tunnel construction on the displacements and stresses induced in the linings of existing nearby parallel tunnels. The paper presents a brief review of a set of laboratory scale model research programme investigating the influence of tunnel proximity and alignment, liner stiffness on the nature of the interactions between closely spaced tunnels in clay. A total of two sets of carefully controlled physical model tests were performed. A cylindrical test tank was developed and used to produce clay samples of Speswhite kaolin. In each of the tests, three model tunnels were installed in order to conduct two interaction tests that have been carried out to investigate the interaction problem between parallel tunnels. The results of these tests are compared with the results of finite element analysis to investigate the techniques that must be used to obtain reliable numerical solutions to this type of problem.

Keywords: Closely spaced tunnels, Liner stiffness, Model tunnelling machine, Parallel tunnels, Shield tunnel

1. Introduction

In recent years many new tunnels have been designed or constructed in urban areas in order to develop or extend underground transportation systems. In the design of new tunnels, it is important to ensure that any existing underground transportation systems in close proximity to the proposed tunnelling activities can continue to operate safely both during, and after, construction. The stresses and displacements in existing tunnel liners may be affected by the new tunnelling work when the distance between the tunnels is small. The influence of new tunnelling activities on nearby existing tunnels depends on various features including the magnitude of the in-situ stresses in the ground, the pillar width, the liner stiffness, and the method used to install the tunnel.

A certain amount of information about the interaction

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that occurs between closely spaced tunnels is given by various reported field measurements and numerical studies. Terzaghi (1942) and Ward and Thomas (1965), for example, reported a set of field measurements made on tunnels constructed with a centre-line spacing of 1.425 tunnel diameters in Chicago Clay and 1.6 tunnel diameters in London Clay respectively. In both cases, the two tunnels were installed consecutively. The measurements indicated that significant liner deformations occurred in the first tunnel as the second tunnel was constructed. The maximum radial displacements, expressed as a percentage of tunnel radius, were measured to be 0.10 % and 0.12 % respectively. Give an excellent summary of the available field data prior to 1969. In most cases, measurements were made as a second tunnel was driven past a test section.

Typical numerical analyses of this interaction problem were described by Ghabezoussi and Ranken (1977) and Leca (1988). In these studies, a variety of tunnel spacings and procedures to model tunnel construction were adopted. In both cases a two-dimensional approach was used in which the soil model was elastic. The results indicated that, for the configurations investigated, the computed interactions between two parallel tunnels were small when the centre-line spacing was greater than about two tunnel diameters. Addenbrooke and Potts (1996) report numerical analyses of the interaction between two tunnels constructed within the interval of a month. These analyses were based on a small strain non-linear soil model. They concluded that the interaction between two adjacent tunnels depends on relative tunnel position (to the side or vertically above) as well as spacing. Driving a new tunnel above an existing tunnel was shown to have significantly less influence on the existing tunnel lining than was the case for equivalent side-by-side tunnels.

In this paper, the influence of shield tunnel construction on the moments and displacements induced in the linings of existing nearby tunnels are studied by a set of carefully controlled physical model tests. In these tests the tunnels were installed using a miniature shield tunnelling machine. The tests were supplemented by a limited amount of two-dimensional finite element analysis. These computations are based on a similar approach to that described by Ghabezoussi and Ranken (1977), with the exception that special numerical procedures were used to model the ground loss associated with tunnel installation.

2. Physical Model Tests

A set of five tests have been carried out using samples of kaolin clay consolidated in the plane strain tank shown in Figure 1. Three tunnels were installed in each of the tests in order to carry out two interaction experiments in one clay sample. One of these experiments was for a ‘distant’ tunnel (centre-line spacing of 2.0D) and the other was for a ‘close’ tunnel (centre-line spacing of 1.4D) where D is the tunnel diameter.

The plane strain rig consisted of a rectangular tank of internal dimensions of 1000 mm by 300 mm in plan and 600 mm in height. The two 25 mm thick perspex walls contained three holes (corresponding to the positions at which the model tunnels were installed).

During this research project, a set of additional tests were carried out in which the tunnels were perpendicular rather than parallel. Discussion of these tests, however, is beyond the scope of the paper. Details of these tests are given by Kim (1993, 1996).

The geometry and soil properties of each of the plane strain tests are specified in Table 1.

The clay samples were obtained by consolidating a