2D and 3D Model tests and Numerical Analyses in Shallow Tunneling

Surface settlement, Earth pressure, Excavation
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ABSTRACT
2D and 3D model tests and the corresponding numerical analyses are carried out for shallow tunnel. Numerical analyses are performed with finite element method using elasto-plastic subloading \( t_e \)-model. Experiments and analyses both are conducted with various soil-covers of tunnel for simulating the influence of soil-cover on tunnel excavations. Different types of excavation processes are considered in both model tests and numerical analyses. Surface settlements and earth pressures at the top of the tunnel are measured. Variations of 2D and 3D results are presented in this paper. Result of finite element analysis shows good agreement with the result of corresponding model test.

1. INTRODUCTION
Recently usage of under ground as subway, sewerage, underground passage and many other facilities has increased all around the world. In mountainous area, settlement at ground surface is not an important consideration during the excavation of tunnel. But in urban area surface settlement is a prime important factor during the excavation of the tunnel. It is because of the existence of huge structures in urban area. Again, during the construction of tunnel earth pressure is another important factor, which varies with the excavation processes. To get a clear conception and to know reasonable mechanism of surface settlement and earth pressure in tunneling, a brief description of model tests and the corresponding finite element analyses are presented in this paper. Here, some results and discussions are described in successive sections.

2. LAYOUT OF MODEL TESTS
Two types of apparatus are used for model tests, one is pulling out tunnel apparatus whose schematic diagram is shown in Figure 1 and another is trap door apparatus whose schematic view is shown in Figure 2. In both types of apparatus, a wooden frame with 80 cm in width, 80cm in length in the direction of excavation, is placed on an iron table and its height can be varied for required soil cover. Model tests are carried out for two kinds of ground having 4cm and 16cm soil covers. In the 12cm tunnel apparatus whose schematic diagram is shown in Figure 1 and 2. LAYOUT OF MODEL TESTS

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3. OUTLINE OF NUMERICAL ANALYSES

Table 1. Parameter for FEA

| \( \lambda \) | 0.008 |
| \( \kappa \) | 0.004 |
| \( N_e (e_{sc} at p=98kPa & q=0kPa) \) | 0.30 |
| \( R_{sc} = (\sigma_1/\sigma_3)_{comp.} \) | 1.80 |
| \( \beta \) | 1.20 |
| \( v_e \) | 0.20 |
| \( a \) | 1300 |

The parameters for materials used in numerical analyses are shown in Table 1 and with these parameters stress-strain relations under constant minor principal stress are drawn which are shown in the Figure 4. From this figure we can say that these parameters reasonably characterize the properties of both 2D (aluminum rods) and 3D (aluminum balls) model grounds. Numerical analyses are conducted for all patterns.
4. RESULTS AND DISCUSSIONS

In the Figures 5 to 7, vertical axes represent normalized settlements at observation section and abscissas demonstrate the transverse distance from the center of the tunnel. In the legends of these plots, D is the soil cover above the tunnel, B is the width of the tunnel and d is applied displacement, which represents the amount of excavation. Figures 8 to 10 show the earth pressure distributions just above the tunnel, vertical axes represent normalized earth pressures and abscissas are the transverse distance in cm. Figures 5 and 6 show that surface settlements at measurement section are almost same for 3D simultaneous and 2D sectional excavations. Also, earth pressures are almost same of these two patterns. Since pattern1 can represent both pattern 1 and pattern2, only pattern 1 is carried out in numerical analyses. Again, surface settlements for 3D sequential excavation (Fig. 11) are slightly less than those of 2D sectional excavation (Fig. 6). Since in case of surface settlements numerical analyses show the similar results of the model tests, we can consider that it will be true also for earth pressures. It is seen in the Fig 11 that at the measurement section almost no settlement occurs before reaching the excavation front at this section and it reaches its maximum value when excavation front passes 4cm position and after further excavations there is almost no influence at that section. On the other hand, Fig. 13 shows the earth pressure which is almost zero when excavation front is at the measuring section and it increases gradually with the face goes away from this section. It is because when excavation advances it breaks the arching effect in the longitudinal direction. Arching effect is seen even in D/B=0.5, especially in 3D calculation (Fig. 13). It is also seen that earth pressures in 3D calculation are less than those of obtained from 2D results. So, for proper prediction of earth pressure 3D analysis is preferable. We can conclude that finite element analysis using the subloading $t_g$-model can simulate tunneling properly.

REFERENCES:  