Ⅲ－B４

Model Test on Redistribution of Earth Pressure In Multi-excavation Stage

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1. Introduction

It has been understood that the change of earth pressure due to the excavation process of the second tunnel will affect the lining of the first, where the space between the tunnels is less than one diameter. The same phenomenon also appears in the case of multi-excavation stage, example twin CD NATM tunnel.

Based on this view point, a series of tests of five adjacent tunnels was carried out on a laboratory model using multi-trap door equipment and aluminium rods used to represent sandy soil. The purpose of this study is to investigate the mechanism of redistribution of earth pressure when tunnel excavation takes place in multi-stage method.

2. Experimental Technique

2.1. Method and Parameter of Test

During the tests, the earth pressure on each trap door was measured. The parameters investigated were height of overburden (H) of 250 mm, 450 mm, 500 mm and 750 mm; the sequence of movement downward of trap doors in four difference sequences, i.e. ABCDE, ACEBD, BDCAE and CBDAE; the amount of downward movement of each trap door (△h) in five difference values, namely 0.5 mm, 1.0 mm, 1.5 mm, 2.0 mm and 2.5 mm. The order of the downward movement of the trap doors represented the difference of sequences of excavation stage and the amount of this movement represented an allowance value of ground convergence during tunnelling process.

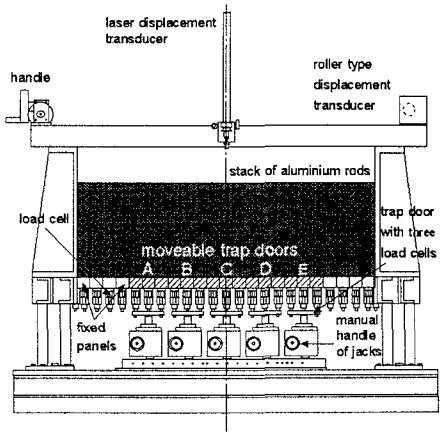

Figure 1 Multi-trap Door Equipment

2.2. Model Material and Apparatus

The sandy soil was represented by a stack of aluminium rods of two diameters, 1.6 mm and 3.0 mm, in the weight ratio of 3:2 respectively. The rods were 100 mm in long, a density (γ) of 2.15 gf/cm^3, internal friction angle (ϕ) of 30° and cohesion (c) of 0 gf/cm^2. The roof of a tunnel was represented by a series of rectangular horizontal rigid panels. Each excavated cavity had 150 mm in width (B_{ms}) of one trap door. Total excavated cavity which represented by five trap doors with total width (B) of 750 mm.

Sequence	1	2	3	4	5
Name of Trap Door	A	B	C	D	E
	B	D	C	A	E
	.....				

Figure 2 Example of Trap Door's Sequence

3. Test Results

To describe the results that found during the test, some graphs from different cases of lowering sequence are represented. Figure 3 shows an example of the increment of earth pressure acting on the trap door at second stage of trap door movement that shown by adjusting the centre of the trap door width at point (0,0). The curves are chosen from ABCDE-case of 750 mm of overburden height. The increment of earth pressure on the right side (undisturbed ground) is less than the increment of earth pressure on the left side (disturbed ground) while the zones of influence are nearly same at both sides.

Figure 4 shows the variations of the earth pressure (P_v) on some trap doors. These curves were values of the trap doors which indicating maximum final earth pressure of each lowering sequence with 750 mm of overburden height (H) and 2.0 mm of amount of downward movement (△h), i.e. B trap door of ABCDE, C trap door of ACEBD, B of BDCAE

[Keywords] Redistribution of Earth Pressure　Multi-excavation　Model Test
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and C trap door of CBDAE, represented by italic letter in Figure 4. It can be seen that after all trap doors were lowered, the earth pressures loading on trap doors achieve in various value from less than the overburden pressure up to greater than the overburden pressure. ABCDE of lowering sequence results the smallest value of earth pressure while the case of CBDAE, the highest value is reached.

The final values of the cases that experience almost same history of lowering are almost same (refer to symbol □ for C trap door of ACEBD sequence and symbol △ for B trap door of BDCAE sequence). Both trap doors receive twice lowering of their neighbor (B, D trap door of ACEBD sequence and C, A trap door of BDCAE sequence, respectively) and the lowering of second neighbor (E trap door of ACEBD sequence and D trap door of BDCAE sequence, respectively) after lowering of itself. The different history are only at 1st lowering of ACEBD which is the lowering of the second neighbor (A trap door) before lowering of referred C trap door and 5th lowering (E trap door) of BDCAE , which is the lowering of third neighbor before lowering of referred B trap door. These difference are enough small.

Figure 5 shows the values of maximum final normalised earth pressures were obtained from the average of the maximum final earth pressure after all trap doors were moved in various lowering sequences. Generally, these values varied between 20% γ H and 140% γ H. It is also found that movements greater 2.0 mm (Δ h/B_{ms} ≒ 1.3%) produce little change in maximum final earth pressure.

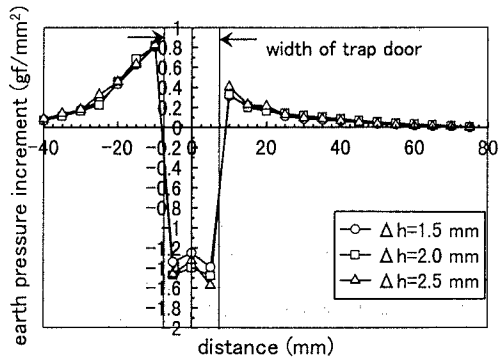

Figure 3 Earth Pressure Increment Curves on Trap Door B Adjusted to the Centre of Trap Door Case ABCDE, H=750 mm

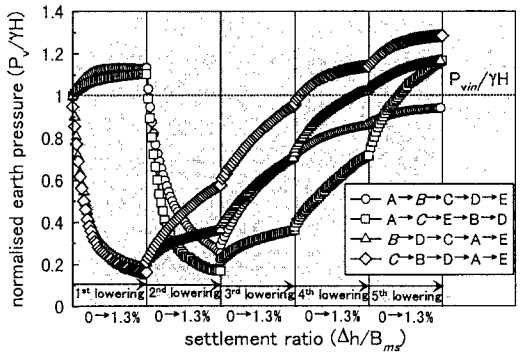

Figure 4 Normalised Earth Pressure From Case of H=750 mm Δh=2.0 mm on Referred Trap Door (italic letter)

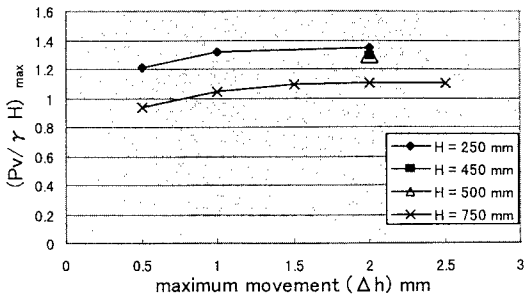

Figure 5 Maximum Normalised Earth Pressure for Different Value of Maximum Movement

4. Conclusion

The following conclusion are remarked.

(1) the maximum of final earth pressure acting on trap door decreases as the ratio of overburden and the trap door width (H/B) increases,

(2) the maximum of final normalised earth pressure varies with the downward movement of trap door and it will reach a constant value after lowering of about 1.3% of a trap door width,

(3) the change normalised earth pressure subsequent to each movement stage is smaller before that trap door had moved than after it had moved,

(4) finally, the earth pressure acting on the roof of a tunnel that the multi-excavation method is applied can be estimated by superimposing the amount of each change of earth pressure which resulted from each stage of excavation.