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Trap Door Test Using Aluminum Blocks

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In order to simulate tunnel excavation in an inclined-layers ground, trap door tests are carried out using aluminum blocks. In this study, aluminum blocks, which are small bricks in the shape of rectangular, are piled up and three kinds of the inclined-layers ground, namely 0-degree, 30-degree and 60-degree formation, are made. Performing a series of trap door tests, the distribution patterns of the earth pressure along the bottom line and the profile of surface settlement are remarkably different due to the angle of the inclined-layers. In the outside part of the trap door, normalized earth pressure on the right part increased greatly, and its highest value is appeared in the condition of 20 *cm* overburden and trap door displacement 2 *mm*.

1. Introduction

There are so many kinds of discontinuities in the field, such as fault, fractured or alteration zone, bedding and joint, etc. When constructing the underground structures in the discontinuous ground, the mechanical behaviors are effected by these discontinuities. However, the mechanical behaviors of the discontinuous ground have not been clarified. Thus, it is greatly demanded to understand the distribution of the earth pressure when the tunnel excavation takes place in the discontinuous ground.

From this point of view, a series of trap door tests are carried out on the inclined-layers ground in two-dimensional condition. For making the inclined-layers formation, aluminum bars and aluminum rectangular blocks are used. Tunneling process are simulated by descending trap door to reduce confining stress in the local area. Testing parameters in this study are the overburden and the angle of the inclined-layers. The distributions of the earth pressure and the profiles of surface settlement are measured. The results are compared with those of previous tests using only aluminum bars.

2. Testing apparatus

Figure 1 shows the schematic view of testing apparatus and the state of ground condition. Descending trap door from the bottom level can simulate the tunneling excavation. The distribution of the earth pressure along the bottom line of the artificial ground can be measured at various steps of the descent of the trap door.

For modeling the inclined-layers ground, a number of aluminum blocks, 25×25 *mm* with 50 *mm* of length, are used.

Table 1 Testing parameters

B		20 *cm*
θ_1		0°, 30°, 60°
Al. Bars	H_1	2.5 *cm*
	H_3	1.5 *cm*
Al. Blocks		2.5×2.5×5.0 *cm*
H_2		10, 15, 20, 30, 40 *cm*
Surface		2, 5, 10, 15 *mm*

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At first, two kinds of aluminum bars whose diameters are 1.6 *mm* and 3 *mm* with 50 *mm* of length are set to be height 25 *mm* on the upper part of frame of testing apparatus. Their mixing ratio is 3 : 2. In the next, some kinds of aluminum prisms are used on the deposit of aluminum bars for making the inclined-layers. Then, the inclined-layers formations are made to become the height which it aimed at by using aluminum blocks in the shape of rectangular.

Finally, every preparations for the modeling ground should be ended by setting up aluminum bars with 15 *mm* of height onto the aluminum blocks.

Testing parameters are summarized in **Table 1**. The trap door is made to descend to 15 *mm*, and the surface profiles are measured at the time of the trap door displacement: 2, 5, 10 and 15 *mm* in every test. The width of the trap door to descend is 20 *cm*. In this study, overburden is defined as H_2.These modeling tests are performed under the normal gravity condition.

3. Experimental results

3.1 The distribution of the earth pressure

Figure 2 shows the distribution of the earth pressure for three kinds of the inclined-layers formation under various overburden, namely 10, 20, 30 and 40 *cm*, when the trap door made it descend 2 *mm*. The abscissa denotes the distance from the center of the testing apparatus while the ordinate denotes the normalized earth pressure. The normalized earth pressure is defined here as the value which divided the observed earth pressure by the initial one. In the above part of the trap door, the earth pressure decreases with the descent of the trap door. On the other hand, the earth pressure of the outside parts of the trap door increases. For the 30-degree formation and 60-degree formation, the normalized earth pressure on the right part increased higher than that on the left part, owing to the influence of the angle of the inclined-layers. In particular, in the case of the 60-degree formation, this tendency is appeared more remarkably than in the case of the 30-degree formation. In 20 *cm* overburden, or the ratio of overburden and width of the trap door 1.0, the highest value is confirmed. From this reason, **Figure 3** shows the distribution of the earth pressure in 20 *cm* overburden. Plotted curves are achieved at the trap door displacement, 0.02, 0.20 and 2.00 *mm*, respectively. After the descent of 0.20 *mm* occurred, clear non-symmetry takes place in the outside of the

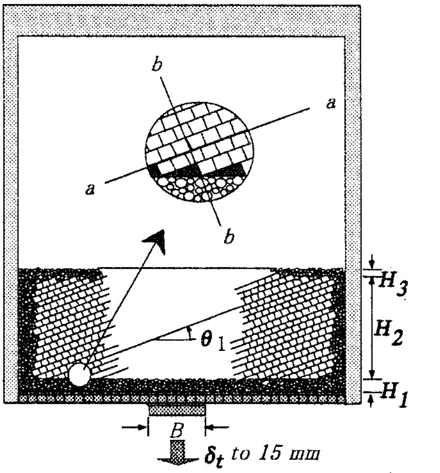

Figure 1 Testing apparatus

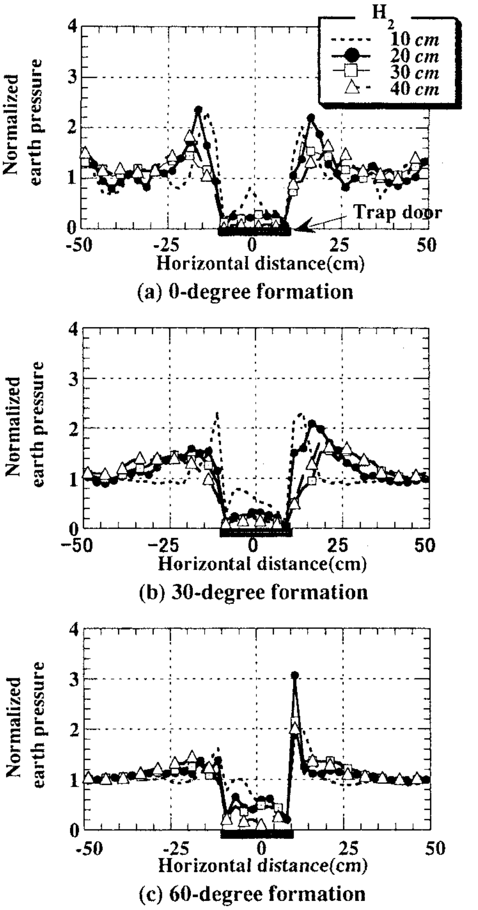

Figure 2 Distribution of the normalized earth pressure at 2.00 mm displacement

trap door.

3.2 Surface settlement

The profile of surface settlement that measured for the trap door displacement 2 *mm* is shown in **Figure 4** at the three kinds of ground condition. This scale of the vertical axis and horizontal axis is the same. In the case of the 0-degree formation, when overburden rises, the amounts of the surface settlement decrease. It occurred on the left side from the center of the trap door in the case of the 30-degree formation though the surface settlement occurred on the right side in the case of the 60-degree formation. The reason of these results can be considered as follows. Because aluminum blocks are rectangular in shape, two kinds of directions can be defined by this study as **Figure 1**. Those are *a-a line*($\boldsymbol{\theta}_l$), means the angle of the inclined-layers and *b-b line*, the angle of joint makes a right angle with *a-a line*. In the case of the 30-degree formation(i.e., the angle of joint is 120 degrees), surface settlement has taken place greatly on the left side from the center of the trap door, and this means that the angle of joint exerts more great influence upon surface settlement. However, when overburden rises, surface settlements decrease gradually, and approach a zero. However in the case of the 60-degree formation, 70~80 % of the amounts of the descent of the trap door are formed even in 40 *cm* overburden, or the ratio of overburden and width of the trap door 2.0.

4. Examination of the experimental results

4.1 Earth pressure of the above part and the outside parts of the trap door

Figure 5 shows the relationship between normalized earth pressure and trap door displacement, which obtained from the above part and the outside part of the trap door for both the 30-degree formation and the 60-degree formation. Two curves in the under part from 1 of the vertical axis are the earth pressure to act on the above part of the trap door, and four curves in the over part are the earth pressure to act on the outside parts of the trap door. Block marks and white marks are the normalized earth pressure to act on the width 10 *cm*, respectively, on the right outside and left outside of the trap door. Only 20 *cm* and 40 *cm* overburden are selected here at the trap door displacement 2 *mm*.

First, as for the upside part of the trap door, the

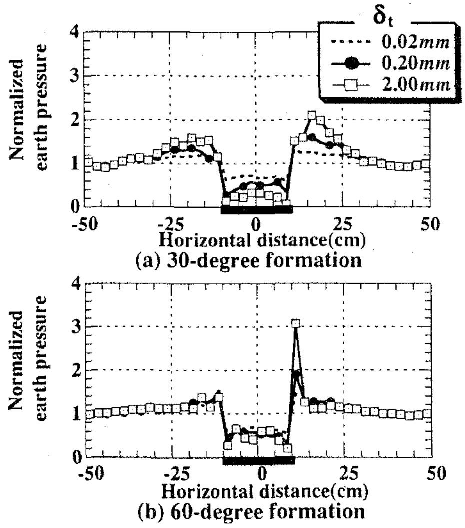

Figure 3 Distribution of the normalized earth pressure in 20 cm overburden

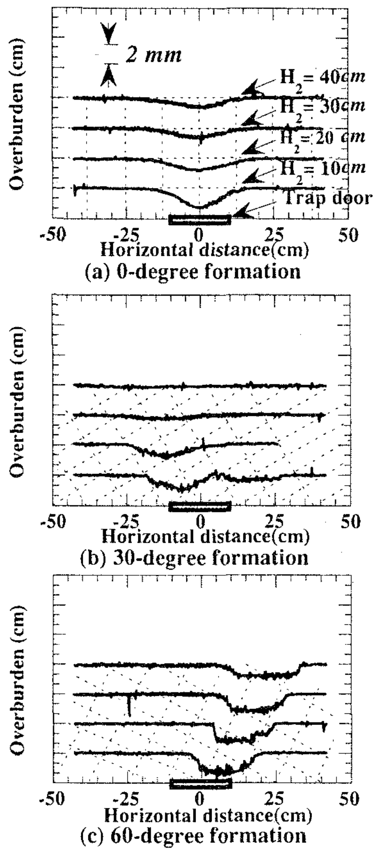

Figure 4 Surface settlement at 2.00 mm displacement

normalized earth pressure decreased rapidly due to the descent of the trap door and converges on the constant value. Their values, however, are clearly different due to the angle of the inclined-layers.

The next is in the outside parts of the trap door. Regardless of overburden, earth pressure shows the value that the right part of the trap door is higher than that of the left part. In the 30-degree formation, significant increase of the normalized earth pressure has been shown in 20 *cm* overburden. In this case, the right part earth pressure is increased rapidly at early level of the descent of the trap door. But in 40 *cm* overburden, increasing values of both parts show the recovery of the original state. And in the 60-degree formation, increasing values of both sides become constant value in 20 *cm* overburden. Increasing values of both parts become equal to each other in 40 *cm* overburden, but it is not happened to recover to the original state of the earth pressure, like the 30-degree formation.

4.2 Comparison with the results of experiment using only aluminum bars

The results from both this study and previous tests aimed at sandy ground using aluminum bars are compared in this section. **Figure 6** and **Figure 7** show the relationship between overburden and normalized earth pressure of the above part of the trap door and outside parts of the trap door, respectively. Plotted data are calculated on the same conditions of *4.1*, and its overburden is 20 *cm*.

Three kinds of experimental results are shown in **Figure 6**. Generally their results shows the same tendency that the normalized earth pressure decreases with the increase of the overburden. However, it is understood that these values are different each other. The normalized earth pressures of the 30-degree formation show lower values than those of the 60-degree formation. Especially, in less than 20cm overburden, it has also been shown that the normalized earth pressure decreases rapidly in the 30-degree formation. It means that arching effect can be easily developing in the 30-degree formation.

From **Figure 7**, while symmetry is observed in the tests used aluminum bars, non-symmetry is observed in the inclined-layers formation used aluminum blocks. And the highest value of the normalized earth pressure is observed in 20 *cm* overburden on the case of the 30-degree formation.

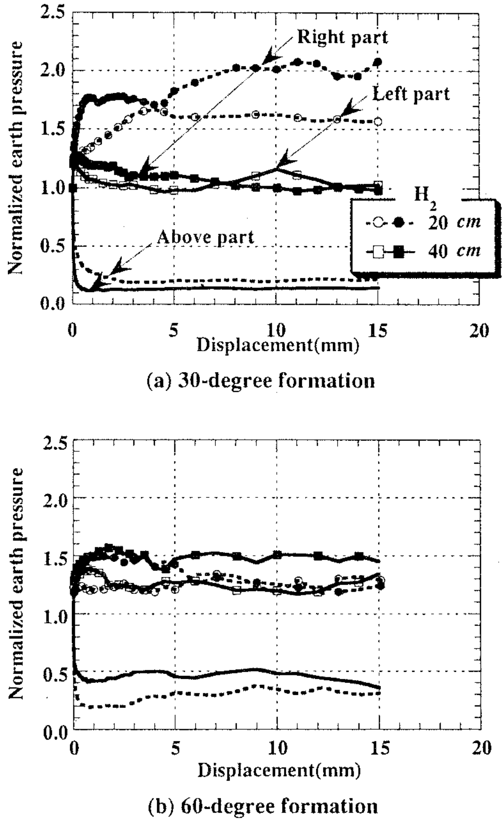

Figure 5 Earth pressure of the above part and the outside parts of the trap door

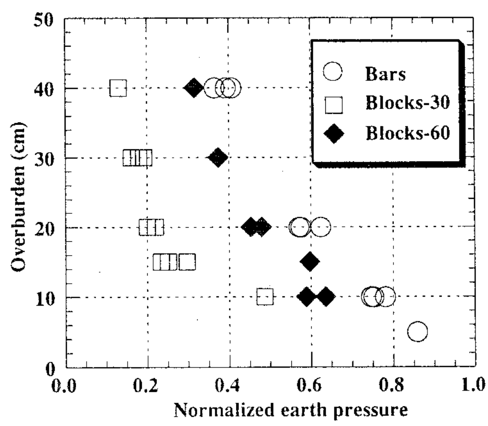

Figure 6 Relationship between overburden and normalized earth pressure on the above part of the trap door

5. Conclusions

The following conclusions are remarked.

1. As trap door descending, the distribution patterns of the earth pressure to act on the above part of the trap door and the outside parts are precisely different due to the angle of the inclined-layers.
2. Regardless of the overburden, normalized earth pressure on the right part of the trap door increased greatly. Also its highest value is observed in the condition of 20 *cm* overburden and trap door displacement 2 *mm*.
3. Arching effect caused by overburden is clearly confirmed in the 30-degree ground condition.

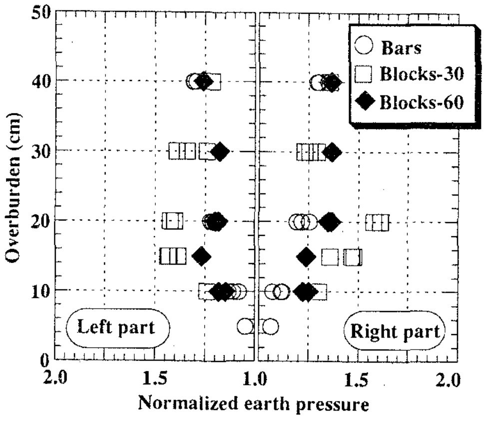

Figure 7 Relationship between overburden and normalized earth pressure on the upside parts of the trap door

REFERENCES

1) Murayama, S. and Matsuoka H. : Earth Pressure on Tunnels in Sandy Ground, *Proc. of Japan Society of Civil Engineers*, No. 187, pp.95-108, 1971(in Japanese).

2) Adachi T., Tamura T. and Yashima A. and Ueno H. : Surface Subsidence above Shallow Sandy Ground Tunnel, *Proc. of Japan Society of Civil Engineers*, No. 370, pp.85-94, 1986(in Japanese).

3) Adachi T., Kimura M., Tamura T. and Aramaki S. : Experimental and Analytical Studies of Earth Pressure, *Computer Methods and Advances in Geomechanics(Balkema)*, pp.70-75, 1994

4) Adachi T., Kimura M., Tamura T. and Aramaki S. : Earth Pressure Distribution in Trap Door Test, *Proc. of 29th Japan National Conference on SMFE*, pp.1989-1992, 1994