Int. J. of GEOMATE, Dec., 2012, Vol. 3, No. 2 (Sl. No. 6), pp. 413- 418
Geotec., Const. Mat. & Env., ISSN:2186-2982(P), 2186-2990(O), Japan

Sliding Stability of Dry Masonry Block Retaining Wall Structure with a Resistance Plate

Akihiro Hashimoto[1], Noriyuki Yasufuku[1], Yoshio Suematsu[2], Kazuo Fujita[1] and Toshimitsu Komatsu[1]
[1] Civil Engineering, Kyushu University, Japan; [2] Toeishoko Corporation, Japan

ABSTRACT: There are two types of block masonry in the structural retaining wall, one is "dry masonry" and the other one is "wet masonry". However, the sliding stability of the dry masonry type retaining wall may be inferior to that in wet masonry block. In this study, a new dry masonry type retaining wall is discussed, which is not only environmental friendly but also structurally stable. A resistance plate is newly attached to the boundary between upper and lower blocks to enhance the sliding resistance, which is due to the passive earth pressure mobilized in the plate. A series of model tests was carried out, paying attention to the position of the resistance plate, mobilized earth pressure in the plate and the horizontal movement of the blocks. It was indicated from the model tests results that the position of the resistance plate becomes very important to effectively increase the block stability.

Keywords: Sliding resistance, Retaining wall, Dry masonry, Resistance plate, Passive earth pressure

1. INTRODUCTION

There are two types of retaining block masonries namely "dry masonry" and "wet masonry" to construct the retaining wall. There is a "dry masonry" and "wet masonry" in the construction of retaining wall block masonry. Since, wet masonry cannot offer certain safety factor against the sliding, a projection at the bottom of basis [1] is given to enhance the sliding resistance on dry masonry retaining wall. In the case that a certain safety factor against sliding cannot be secured in wet masonry retaining wall, there is a method to enhance the sliding resistance by providing a projection at the bottom of basis [1]. However, this method has not been used much in clayey ground because the contact between the projection and the surrounding ground becomes loose. At the same time the construction cost is also relatively higher.

When the effect of projection in the clayey ground is properly mobilized, the construction of retaining wall can achieve the excellent safety with minimizing the construction cost. When the effect of projection in the clayey ground can be properly mobilized, which can be easily constructed at low cost, the construction of retaining wall with excellent safety and economy becomes possible.

On the other hand, the dry masonry type of retaining wall has an advantage in the environmental and economic efficiency. However, it generally resists against the sliding of the block due to the friction of filling geo-materials, it is considered to be unstable comparing with the wet masonry retaining wall. On the other hand, as the retaining wall in dry masonry type, which has an advantage in environmental and economic efficiency, generally resists against the sliding of the block due to the friction of filling geo-materials, it is considered to be unstable comparing with the retaining wall in wet masonry type. Thus, it is instructed by adding a projection into each block or by using the block with an engagement structure [2] through the method of unifying each block. Thus, it is instructed to use the method unifying each block by adding a projection into each block or by using the block with an engagement structure [2]. In addition, an alternative method to enhance the sliding resistance by connecting each block with furniture has also been studied [3]. However, more effort is still required to eliminate the anxiety of the stability of blocks.

When enough sliding resistance is achieved in dry masonry retaining wall compared to wet masonry retaining wall, the significant advantages can be expected in relation to constructive, economic and environmental aspects. When achieving an enough sliding resistance in retaining wall with dry masonry which exceeds that in retaining wall with wet masonry, the significant advantages can be expected in relation to constructive, economic and environmental aspects.

Corresponding to these concerns, the authors have developed a reinforced dry masonry block retaining wall in which a new plate is set up at the boundary of upper and lower block. Corresponding to these concerns, the authors have developed a dry masonry block retaining wall reinforced the sliding resistance of each block to set up a new plate at the boundary of upper and lower block. In this study, a series of vertical stress loading tests were first carried out for investigating the effect of resistance plate on the sliding stability, and then for evaluating its effectiveness.

2. OVERVIEW OF PROPOSED DRY MASONRY BLOCK STRUCTURE WITH A RESISTANCE PLATE

Fig. 1 shows a conceptual diagram of a dry masonry block structure with a resistance plate. Each block used in the present structure has a side wall connecting the right and left of the front wall and rear wall, which is characterized by bottomless plate shown in Fig. 1. Each block used in the present structure has a side wall connecting the right and left of the front wall and rear wall, which is characterized by that there is no bottom plate shown in Fig. 1. Newly added resistance plate is perpendicular to the horizontal boundary surface between the upper and lower block,

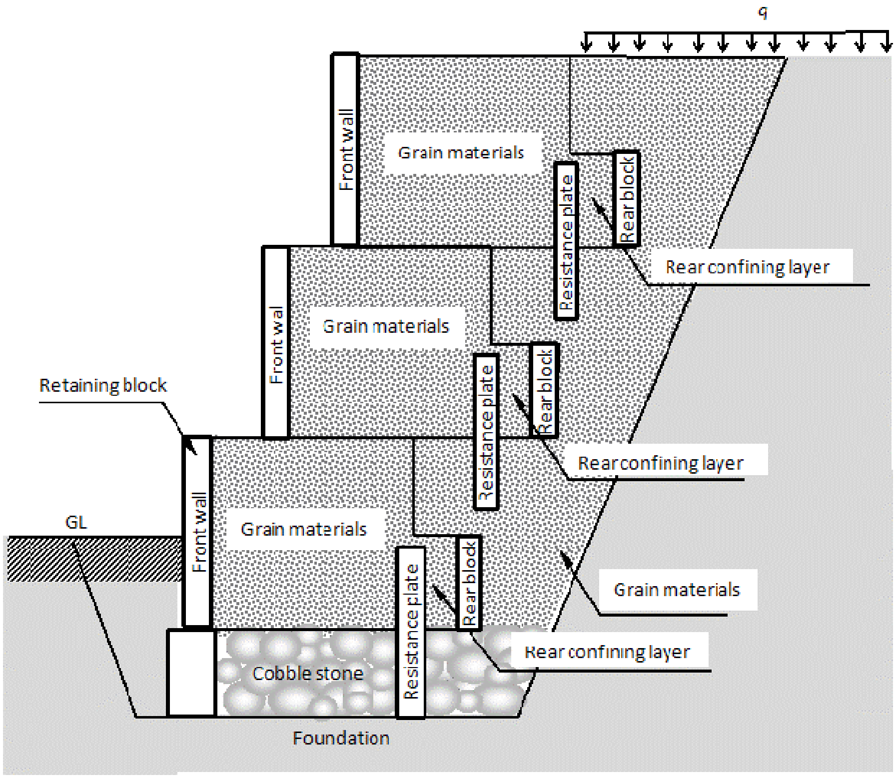


Fig. 1 A conceptual diagram of a dry masonry block structure with a resistance plate

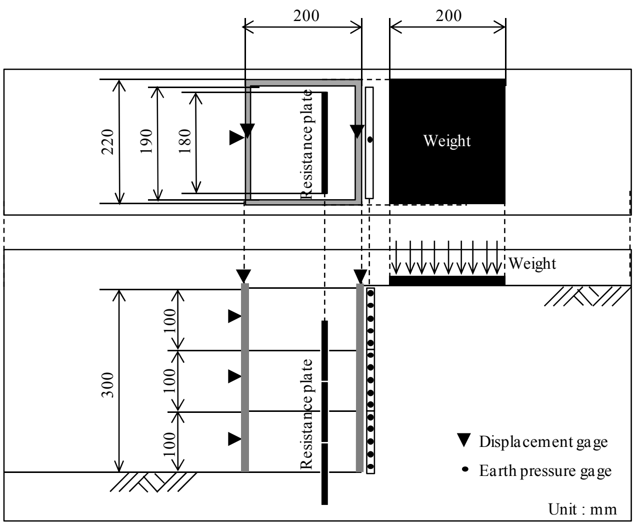


Fig. 2 A schematics of the experimental apparatus and model test specimen

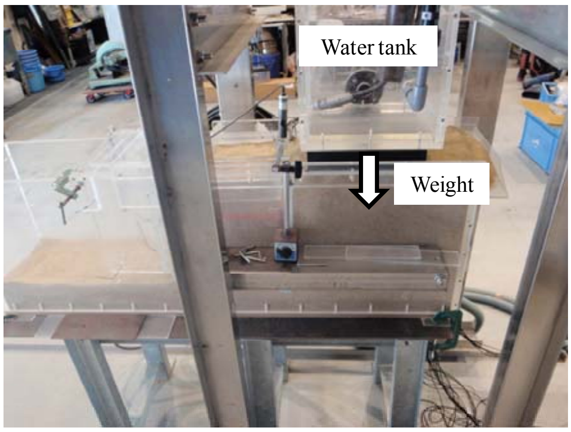


Photo. 1 Experimental setup

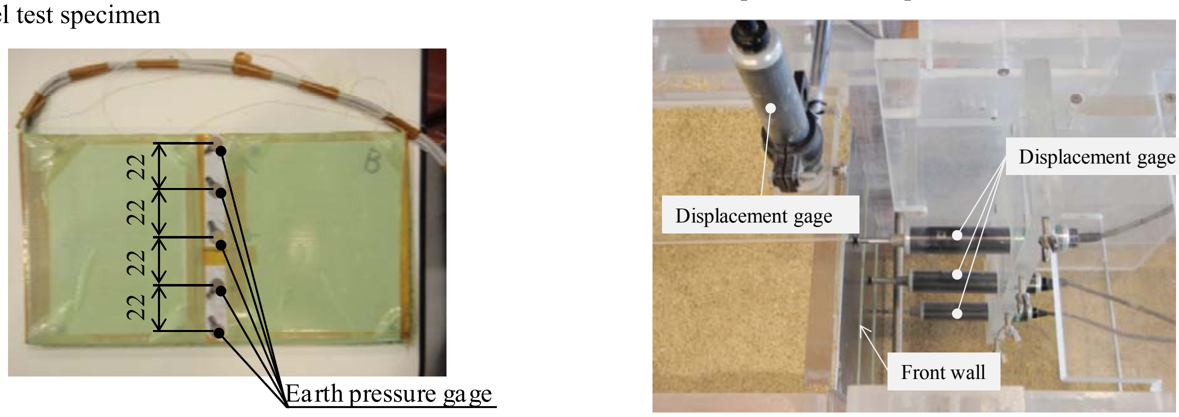


Photo. 2 Earth pressure gage (left hand side) and displacement gage (right hand side)

which is set up by keeping a spacing from the inner surface of the rear wall.

Then, each inner space of the block and the space behind the block are densely filled in grain materials. As a result, a

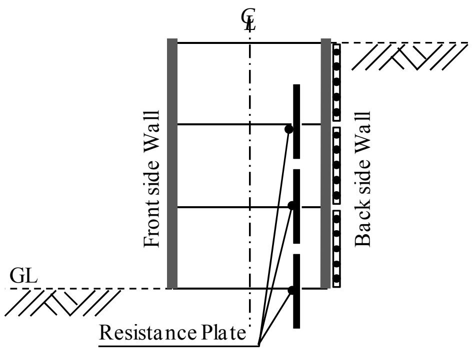


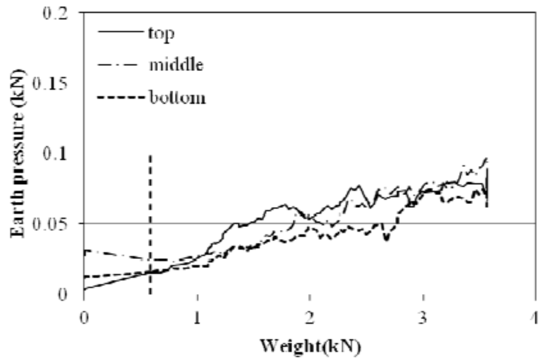
Fig. 3 Position of the resistance plate (ex. Case2)

Table 1 Fundamental properties of sand

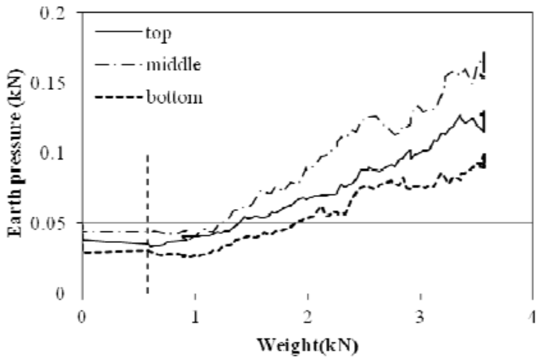
D_{50}	0.412mm
U_c	1.90

Table 2 Experimental conditions

Case	Position of a resistance plate
Case1	No plate
Case2	Back
Case3	Center
Case4	Attached on the back side wall

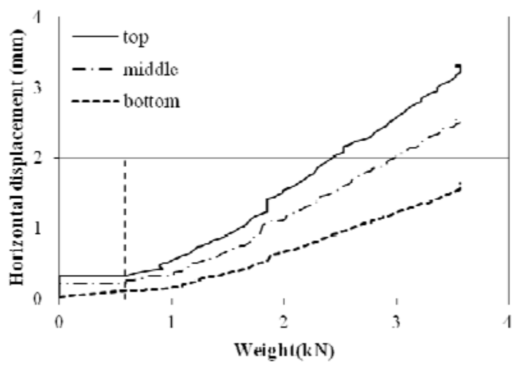


(a) Case 1 (No plate)

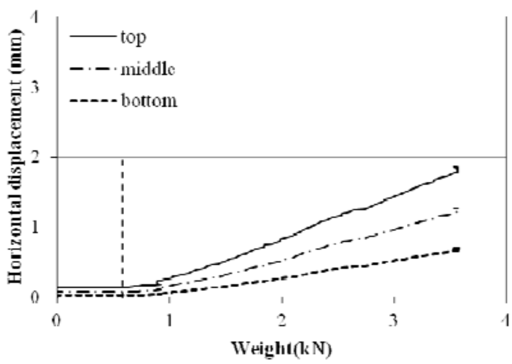


(b) Case 2 (Back)

Fig. 4 Relationship between earth pressure and vertical load



(a) Case 1 (No plate)



(b) Case 2 (Back)

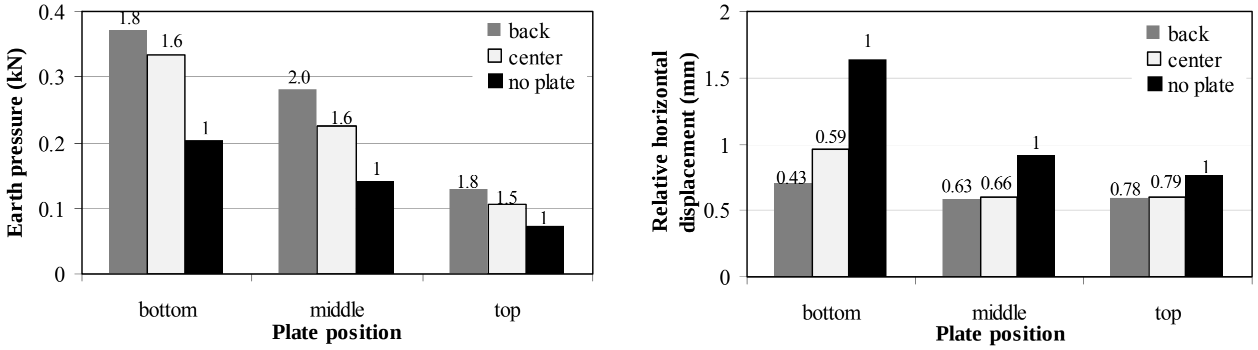
Fig. 5 Relationship between horizontal displacement and vertical load

confining layer is produced in the space between the resistance plate and the rear wall, which is named as “rear confining layer”.

3. OUTLINE OF CONDUCTING MODEL TESTS

Fig. 2 shows schematics of the experimental apparatus and model test specimen used in this experiment. All of model tests were conducted by applying the vertical load to the back filling and then resultantly by giving the horizontal load to the back side wall of the block. Scale of a model block made of acrylic with 15mm in thickness has 220mm front wall width, 200mm depth and 100mm height. Specimen with 300mm high wall has been created by overlaying a 3-stage block. Scale of a model block made of acrylic with 15mm in thickness is around 220mm in front wall width, 200mm in depth and 100mm in height. Specimen with 300mm high wall has been created by overlaying a 3-stage block. In this experiment, the steel plate with 2.3mm in thickness, 100mm in vertical height and 180mm in horizontal width were used as a model resistance plate.

Horizontal geostatic stress acting on the rear of the specimen was measured by ultra-compact earth pressure gauge (PDA-200KPA) as shown by Photo 1. Five earth pressure gages are installed to a plate with 100mm in length, 180mm in width and 7mm in thickness, which was bonded to two acrylic sheets and an aluminum sheet with 1mm thickness. As shown in Photo 1, the pressure gages are vertically attached to the central part of the plate at intervals of 22mm. Then, the lateral earth pressure was measured in a total of 15 points by attaching the plate with the pressure gages to the back of each block. A typical sea sand is used as filling and backfilling materials of the model ground,



(a) Total rear earth pressure (b) Relative horizontal displacement

Fig. 6 The characteristics of (a) total rear earth pressure and (b) relative horizontal displacement at final loading stage

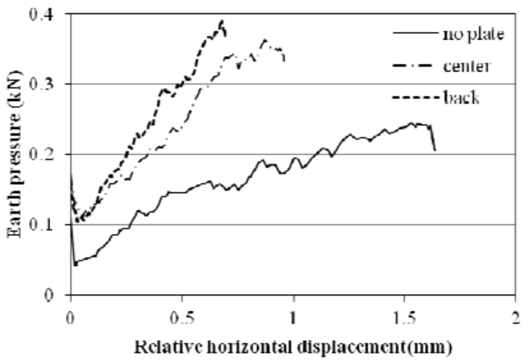


Fig. 7 Relationship between total rear earth pressure and relative horizontal displacement at the bottom block

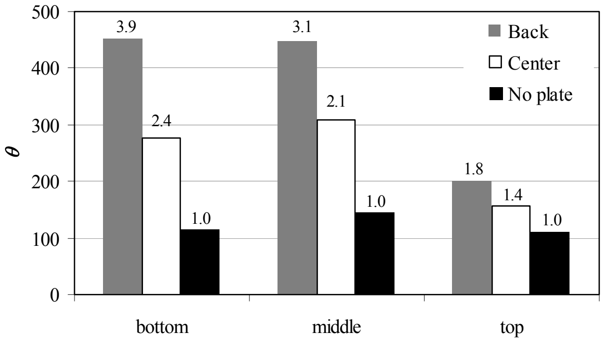


Fig. 8 Relative effect of resistance linked with plate position, θ defined as a gradient in the relationship between P_H values normalized by $\gamma H^2B/2$ and the relative horizontal displacement δh normalized by the depth of the block D

whose fundamental properties are summarized in Table 1. In order to prepare the model ground, all the specimens were prepared by compacting the sea sand under air-dried condition.

Vertical load was applied to the rubber plate put on the surface of backfill model ground through the water tank in which the increasing rate of amount of water is constantly controlled. In this study, the rubber plate with 220mm width, 200mm in length and 50mm in thickness is set up to 50mm behind the back side of the block as shown in Photo 2 and the applicable applied load was limited to be around 4kN.

Also, in order to measure the lateral displacement of each block and the vertical displacement on the surface of the top block, the displacement sensor was set in the center front of each block wall. At the same time, two sensors were also put on the surface of the front and rare sides of the top block. Figure 3 shows the position of the resistance plate. A series of experiments were conducted paying attention to the effect of the position on the sliding stability. The position of a resistance plate selected is summarized in Table 2.

4. RESULTS AND DISCUSSIONS

4.1 Characteristics of mobilized rear earth pressure and horizontal displacement

Fig. 4(a) and (b) show the results of rear earth pressure acting on the block body without and with resistance plate against applied vertical loads respectively. Fig. 5 (a) and (b) also show the results of the horizontal displacements of the block body without and with resistance plate against applied vertical loads, respectively. Dotted lines in each figure indicate the start point of the loading which is around 0.59kN. Here, the total force acting on each rear of the block body (kN) was calculated by multiplying the average value of the five measured earth pressures by the area of the plate resistance. It can be confirmed from these figures that the horizontal displacement and earth pressure at each block have increased with the increase of the loading in both cases. However, paying attention to the increment rate, the rate of earth pressure in case with resistance plate becomes greater comparing with that in case without resistance plate. On the other hand, the incremental rate of horizontal displacement in case with resistance plate is kept smaller comparing with that in case without resistance plate.

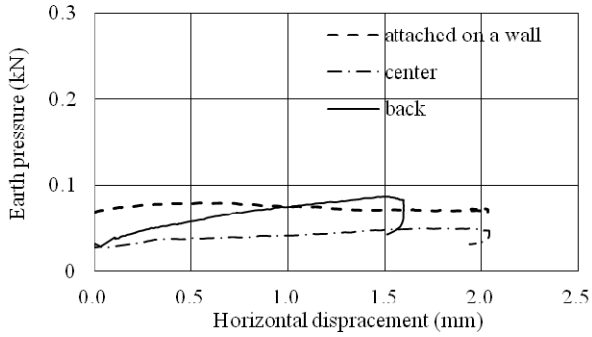
4.2 Evaluation of effect of resistance plate against sliding

It means that the sliding of the block is suppressed more effectively when a horizontal displacement of the block body becomes smaller against a same earth pressure action on the wall. Here, the effect of resistance plate on the sliding of the block is discussed from the relationship between horizontal displacement and mobilized earth pressure. In this study, the sum of the earth pressure acting on each block is defined as a force to slide the bottom surface of the block. For instance, sum of the rear earth pressure action on middle and top block bodies is used, when focusing on total earth pressure at the bottom of the surface in the middle block body. This is defined as total rear earth pressure P_H. In addition, the relative horizontal displacement between each block is used for considering the results obtained. Figures 6 (a) and (b) are summarized in the bar diagram to indicate the characteristics of total rear earth pressure P_H and relative horizontal displacement at final loading stage. The numerical values shown above the bar diagram is obtained by normalizing the magnitudes of P_H in case 2 and 3 by the magnitude in case 3, which corresponds to the case without any resistance plates. It is clear that although the magnitudes of P_H in the cases with resistance plates become much greater comparing with that in case without any resistance plates, the relative horizontal displacement becomes smaller. For instance, the relative horizontal displacement of bottom block in case 3 has been reduced to less than half. In addition, the effect of resistance plate on sliding is clearly dependent on the position. Namely, when the resistance plate is set up on the back side of the block, the effect becomes much greater comparing with the case whose resistance plate is set up on the middle of the block.

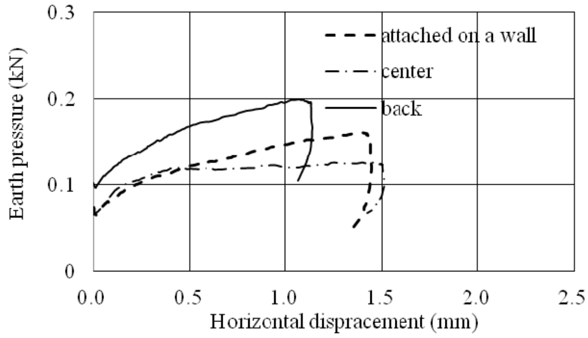
Figure 7 shows the relationship between relative horizontal displacement and total rear earth pressure P_H at the bottom block body in three cases. It is confirmed from this figure that P_H values for the case with resistance plate quickly increases comparing with the case without any resistance plates. A similar tendency was also confirmed in middle and top block bodies. Therefore, the incremental rate of P_H values against relative horizontal displacement is introduced to evaluate the effect of the resistance plate. Figure 8 shows an index θ which may indicate the relative effect of resistance linked with plate position, where θ is defined as a gradient in the relationship between P_H values normalized by $\gamma H^2 B/2$ and the relative horizontal displacement δh normalized by the depth of the block D, where γ is unit weight of soil (=17.5kN/m^3), H is height of the block specimen and B is width of the block. Numbers indicated in Figure 8 mean the value which was calculated by dividing the value of θ for the two other cases by the value in corresponding each block without any resistance plate. It is indicated that the resistance potential against sliding at the bottom block in case 3 whose resistance plate sets up on the back side of the block body becomes relatively 3.9 times greater. Similarly, the resistance potential in case 2 whose resistance plate sets up on the middle of the block body becomes relatively 2.4 times greater. In addition, the resistance potential against sliding is clearly dependent on the position of the block body, even if the resistance plate set up on the same position of the block body. It means that the sliding resistance of the plate is influenced by the induced overburden pressure.

4.3 Earth pressure acting on the resistance plate

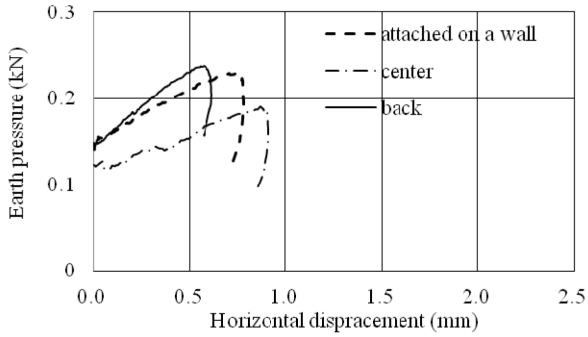
The resistance plate has been confirmed in Chapter 4 to be effective to suppress the sliding of the block body. This is probably due to earth pressure acting on the resistance plate, which is named as a passive mobilized earth pressure in this study. So, in order to make clear the effect of the position of



(a) Top



(b) Middle



(c) Bottom

Fig. 9 Relationship between the total rear earth pressure and acting on the plate and mobilized horizontal displacement of the block body

resistance plate on the block sliding, the horizontal earth pressures action on the resistance plates were measured in case 2 and case 3, together with case 4 that the resistance plate is attached on the back side of the block.

Figure 9 shows the relationship between the total horizontal earth pressure acting on the plate and the mobilized horizontal displacement of the block body, where the total horizontal pressure is estimated by multiplying an average horizontal earth pressure by an area in the resistance plate. Figures 9(a), (b) and (c) show the results in top, middle and bottom block body respectively. In Figure 9(c), the mobilized passive total earth pressure in case 2, 3 and 4 becomes 0.24kN, 0.19kN, and 0.23kN respectively. On the other hand, the amount of horizontal displacement becomes 0.62mm, 0.9mm, and 0.78mm in case 2, 3 and 4 respectively. Based on these results, it shows that greater the mobilized passive total earth pressure, relatively smaller the corresponding horizontal displacement. Conversely, it reflects that smaller the mobilized passive total earth pressure, relatively greater the corresponding horizontal displacement. Similar tendency is also indicated in Figures 9 (a) and (b). It is mentioned that the effect of a resistance plate against sliding is due to the mobilized earth pressure action on the resistance plate. The magnitude of the earth pressure is also dependent on the overburden pressure by the filling materials in the block. Further considering the results, the mobilized earth pressure in case 2 becomes greater than that of case 4. It is concluded that the resistance plate set up on the back side of the block works well for increasing sliding resistance of dry masonry retaining structure, comparing with the case in which the resistance plate was set on the position attached on a wall at block body. It is considered that this is due to a constraining effect induced by a granular layer between the position of the resistance plate and back side of block body.

5. CONCLUSIONS

In this study, a series of vertical stress loading tests were carried out for investigating the effect of resistance plate on the sliding stability. The main conclusions obtained are summarized below:

1) Based on the small model test results, it is clearly confirmed that the resistance plate contributes well to induce a greater horizontal earth pressure acting on the block body and to reduce the horizontal displacement of block body. In addition, the effect becomes greater when the resistance plate set up on the back side of the block body, rather than set up on the middle position of the block.

2) Based on the small model test results, the resistance potential against sliding at the bottom block in case whose resistance plate sets up on the back side of the block body became 3.9 times greater than that of the case without any resistance plate. Similarly, the resistance potential in case whose resistance plate sets up on the middle of the block body became relatively 2.4 times greater.

3) It is confirmed from the characteristics of mobilized earth pressure acting on the resistance plate that the effect of the plate against sliding is due to the mobilized earth pressure action on it. Furthermore, it is concluded that the resistance plate set up on the back side of the block works well for increasing sliding resistance of dry masonry retaining structure, comparing with the case in which the resistance plate was set on the position attached on the wall at block body. One of the reasons is considered that this is due to a constraining effect induced by a granular layer between the position of resistance plate and back side of block body.

6. REFERENCES

[1] Doro dokou kasetsukozobutsu-ko shishin, Japan road association, 1999, pp.74-75.

[2] Doro dokou kasetsukozobutsu-ko shishin, Japan road association, 1999, p.82.

[3] Y. Fuchi, K. Nagatomo, T. Matsuyama and S. Matsubara, "Effect of connecting method on dynamic behavior of concrete block retaining wall", 29(3), 2007, pp. 523-528.

International Journal of GEOMATE, Dec., 2012, Vol. 3, No. 2 (Sl. No. 6), pp.413- 418.

MS No. 283 received June 22, 2012, and reviewed under GEOMATE publication policies.

Pertinent discussion including authors' closure, if any, will be published in the Dec. 2013 if the discussion is received by June, 2013.

Corresponding Author: Akihiro Hashimoto