International Journal of GEOMATE, July, 2018 Vol.15, Issue 47, pp.186-192
Geotec., Const. Mat. & Env., DOI: https://doi.org/10.21660/2018.47.GTE84
ISSN: 2186-2982 (Print), 2186-2990 (Online), Japan

BEHAVIOR OF DRY-RETAINING WALL

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ABSTRACT: The research objective was to study the behavior of dry-retaining wall bricks. The general method for constructing the retaining wall used the reinforced concrete structure. This research used interlocking bricks was an alternatives material from community products. There was a low price and operated cost and simply can construction by local general workers. The research was to create a model of the interlocking bricks, retaining wall used size in width x height x thickness to 1.50 x 2.00 x 0.125 m respectively. Selected distribution horizontal earth pressure by materials was sand, rubber plate, steel molding, steel plate, hydraulic jack. Rubber plate thickness to 2.00 mm for cover sand in mold to 0.15 m of radius in a semicircle shape and height 1.60 m thickness 8.0 mm. Used hydraulic jack 30 tons for apply load circle step by step and measure displacement value by dial gauge. The models had 4 patterns was half and full bricks wall, reinforced bars in half bricks wall with tight force and reinforced bars in half bricks wall with tightly force and anchor. The results were found a reinforcement bars with a half arrange interlocking bricks wall with anchorage pattern shown a maximum stability with an applied force of 10 lb for increasing the strength of the retaining wall.

Keywords: retaining wall, full bricks, half bricks, reinforce bar, anchorage.

1. INTRODUCTION

Structural work of retaining wall is another vital component of structures in civil engineering, where both the design and construction control are very important. Some engineers design retaining wall in a steel-reinforced concrete structure, which is strong but expensive. Thus, other engineers prefer other alternative materials for retaining wall[1, 2, 3].

There is to date little research on retaining wall models due to the complicated preparation of the simulation models themselves. Therefore, information related to the movement behaviors of retaining wall is not available. However, some researchers are still interested to study retaining wall models because they will be useful for those wanting to investigate further related topics [4, 5, and 6].

The research team is therefore interested to develop a retaining wall model, to study its movement behaviors. The outcomes would increase study approaches and chances for those interested in retaining wall work as regards the use of a locally manufactured material, which is inexpensive, saves transportation cost and is easy to construct without skillful technicians by community people. This material is the interlocking brick.

Digging soil for constructing the foundation, an underground structure or dam requires retaining wall, where the lateral pressure of soil has to be taken into consideration as one component in the design of retaining wall. The lateral pressure of soil exerting on retaining wall can be categorized into 3 types:

-At-rest condition or no movement

-Active condition or movement away from earth filling

-Passive condition or movement toward earth filling

Retaining wall failures are caused by two major factors:

-Internal instability, structural failures occur because of the design strength which is not sufficient to accommodate moment or shear force.

-External instability, Retaining wall have external stability when they do not slide, settle, or collapse due to load on soil bearing under the foundation [7].

Retaining wall is constructed to prevent soil movements. They can also be utilized in other engineering work such as earth filling, earth digging, bridges and flood barriers. There are 2 types of retaining wall, gravity wall and cantilever wall [7,8]. Combined structure means a structure that is composed of two or more materials adjoined tightly until they function as one material. The objective of a combined structure is to increase strength to the structure by adding a high-strength material to a low-strength material.

A combined structure behaves in such a way that slides at the contact surface will not happen since shear force is sufficiently transferred horizontally to the two materials. In a non-combined structure, the contact surfaces between

the structures slide, resulting in each individual structure receiving moment separately [9].

2. MATERIALS AND METHODS

This research began from studying and producing a small-scale model, compiling information, understanding all relevant components including approaches, patterns, and the possibility of the project before appropriately planning work on material selection, designing the study format, planning experiments and variables control. The retaining wall test cases installation details as following

-Testing retaining wall with half-bricks interlocking bricks

-Testing retaining wall with full-bricks interlocking bricks

-Testing retaining wall with half-bricks interlocking bricks and reinforced bars (1.50m*2.0m)

Combined structure:

-Exerting force of 10 pounds

-Exerting force of 20 pounds

-Exerting force of 30 pounds

-Testing retaining wall with half-bricks interlocking bricks, reinforced bars and anchorage (1.50m*2.0m)

-Exerting force at 10 pounds

2.1 Materials and Equipment used in the Tests

-Interlocking bricks

Interlocking bricks as shown in Fig.1 are the load-bearing material for laying. They were developed to have a hole and a dowel on each brick for the constructional purpose. Indigenous raw materials are recommended, namely, lateritic soil, crushed stone, sand, or suitable left-over materials. The raw materials are mixed with cement and water in an appropriate proportion, pressed into bricks using a pressing machine and cured for about 10 days until set into strong concrete bricks of specially designed shape that can be used in building construction or a water storage tank more quickly, beautifully and economically than other construction work.

The interlocking bricks used in this study were obtained from the interlocking brick factory at Ban Khamhai, Ban Pet Sub-District, Muang District, KhonKaen. Each bricks measures12.5*25*10cm (width*length*height) and weighs roughly 5.1kg per bricks. The manufacturing ratio this producer used was 1:6:2 (Portland cement Type 1:soil:sand) and tested according to the standard.

-Sand

The sand used for filling here was Puttaisong sand. The weight was 1,495 kg/m3. Sand was selected as a tested material for filling, which was quite close to a research study by Liyan Wang[10]

Fig.1 interlocking bricks

-Rubber Sheet

The rubber sheets were used in the study to prevent sand flowing from the mold. The 10cm wide and 2.0mm thick sheets were freshly made and attached to the mold edges that contact two retaining wall. The height was equal to the retaining wall.

-Vertical reinforcing steel

Sixteen 12 mm threaded steel studs were used to reinforce the retaining wall structure. The studs' tensile strength was tested based on the standard. These studs were as long as the retaining wall and were 1.6m high. Both ends were bolted and the force used for the bolt was set.

-Pound wrench

The pound wrench had the highest acceleration of 90 pounds. It was used to tighten the reinforcing steel stud inserted into the retaining wall structure so that the tightening force was consistent.

-Test pond

The test pond measured 1.90x2.00x5.00m. It consisted of a restraining bar set on top

- Semi-circular iron mold

This is a cylindrical iron mold cut vertically in halves with a radius of 1.5m, height of 1.60m and 8.0mm thickness. Its strength was increased by iron fins at every 0.50m distance. The iron molds are simply used for dissipating lateral soil pressure.

-Iron plate

Iron plates that dissipate force have a radius of 0.15m and are 8.0mm thick. They have been designed to fit the iron mold. These iron plates dissipate the pressure from hydraulic jacks to filling sand.

-Hydraulic jacks

The hydraulic jacks under this study gave external vertical pressure. This simulated an external force exerting on filling sand and soil in the model. The hydraulic jacks used were 30 tons.

- Dial gauge

Dial gauges with 0.01 fineness were used to control vertical settlement of sand and gauge horizontal movements of the retaining wall.

-Sling wires

Two sling wires were used between the 3 upper reaction beams and the anchor set to increase their work efficiency by behaving together.

- Reinforced bars and restraining beam

Reinforced bars functioned like an iron anchor enhancing stability to our retaining wall with interlocking bricks. The 16 reinforcing steel studs used had 12 mm threads all through their length and each was 1.60m long. One end of each stud was joined at the upper end of the retaining wall and the other was locked with a nut to the C-shaped restraining beam so as to prevent movement while being tested.

2.2 Retaining wall test set up

The retaining wall test installation details as following (Fig.2, Fig.3,and Fig.4)

Number 1 A back supporting set to stop movement of mold during the test

Number2 Two sling wires transferring force to the test set below.

Number3 Iron mold 1.50m high, 8mm thick with a radius of 15cm

Number4 One 30-ton hydraulic jack with a raising capacity of 10cm

Number5 6 dial Gauges with 0.01mm gradation, 2 installed at the tops of the test piles and 2 each at the two-sided test anchorages

Number6 Three 4x4in cross-section, 6m long steel rods

Number7 Test anchorages made from reinforced concrete on the left and right sides of

the test piles

Number8 I-Beam 0.50m long strengthened with 6mm steel plate welded at the center

and wings of I-Beam to prevent deformation during the test

Number9 A 10-ton hydraulic jack with a raising capacity of 10cm to transfer force from

Lower beam to upper beam and prevent deformation of lower beam during the test

Number10 9mm RB used to support lower beam to remain at itslevel while other equipment was installed

Number11 Threaded bolts to hold upper and lower beams so that they behaved similarly when moving during the test

Number12 Retaining wall 1.50m high, 2m wide made of interlocking bricks, with the brick size of 12.50x25x10cm

Number13 Steel plate with a radius of 15cm and thickness of 8mm

Number14 6 reaction beams or I-Beams 6m long of the size HxB = 150x75, t1 = 5, t2 = 7,

r = 8, and cross-sectional area of 17.85cm2

Number15 Slings to tie between 3 upper reaction beams and anchors to increase work efficiency from co-behavior

Number16 6 square anchorage piles of the size0.18x0.18x4.00m, 3 on each side bolted onto the foundation of the pile test set

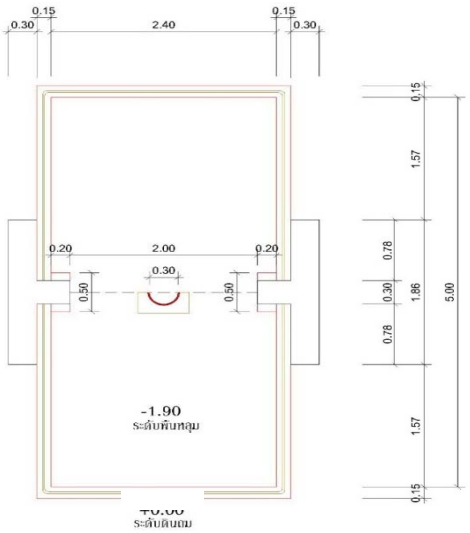

Fig.2 Pond Test (Top view)

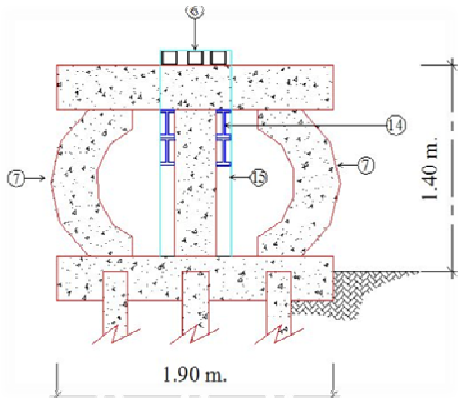

Fig.3 Pond Test (Side view)

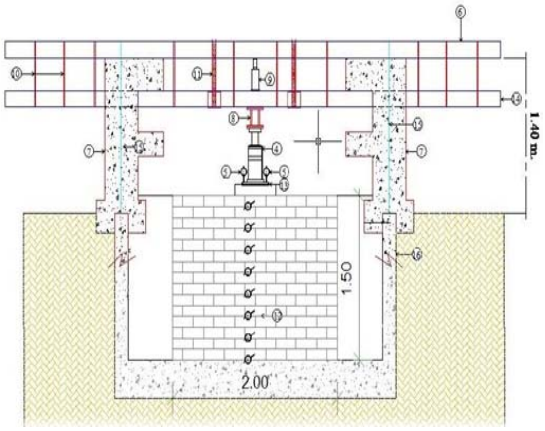

Fig.4 Test set up (Front view)

2.3The retaining wall test procedure detail as following

2.3.1 Testing movements of retaining wall laid with half-bricks interlocking bricks, reinforced bars and anchorages (Fig.5 and Fig.6)

-Prepare the reinforced barest set with sixteen 1.60m high, 12mm threaded studs, turn tightly with pound wrench for accelerating internal force of interlocking bricks

-Weigh the sand and fill in 13 more kg of sand every 2 layers so that the weight was 1,495 kg/m3 until the last layer

- Install steel studs and the anchorage set with the vertical studs

- Add 10-pound force to vertical studs and horizontal studs, tighten the nut so that they adjoin the restraining beams

-Install hydraulic jacks and 2 dial gauges to measure sand vertical settlement

-Install dial gauges to measure horizontal movements of 7 retaining wall at 0.05,0.25,0.45,0.65,0.85,1.05 and 1.25m, with the top position of retaining wall being 0.00m

-Add load layer by layer, each at 1.00mm settlement of filling sand and record results of horizontal movements of retaining wall

-Perform the testing until the settlement of filling sand reached 25mm; record the results of horizontal movements of retaining wall

-Repeat the tests in triplicate to obtain accurate information of movement trends

3. TEST RESULT AND DISCUSSIONS

When we were confident of the results from the study of the small-scale model, the large-scale model was constructed to study the behaviors of each type of retaining wall' lateral pressure resistance as shown in Fig.7. The four types of retaining wall studied were: retaining wall laid with half-bricks interlocking bricks (Fig.8, Fig.9); retaining wall laid with full-bricks interlocking bricks(Fig.10, Fig.11); retaining wall laid with half-bricks interlocking bricks and reinforced bars given force of 10lb, 20lb and 30lb(Fig.12, Fig.13); retaining wall laid with half-bricks interlocking bricks, reinforced bars given force of 10lb and anchorage. Tests were done in triplicate to observe their tendency to deform. The results obtained were used to build graphs for comparing the data.

The tests of lateral pressure resistance of the retaining wall laid with half-bricks interlocking bricks, full-bricks interlocking bricks, half-bricks interlocking bricks and reinforced bars, and half-bricks interlocking bricks with reinforced bars, and anchorage yielded the following results:

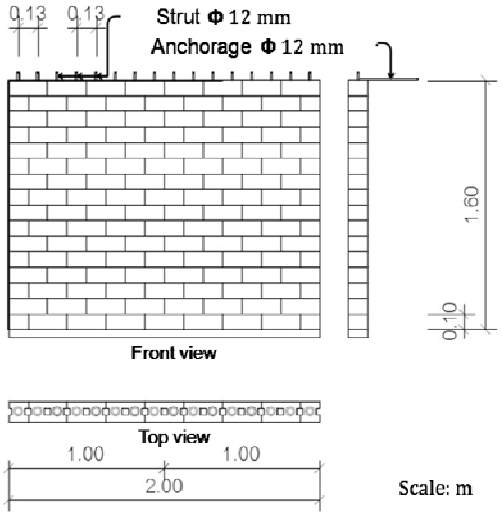

Fig.5 Half brick with reinforced bar and anchorage test set up (Front view)

Fig.6 Half brick with reinforced bar and anchorage test set up (Back view)

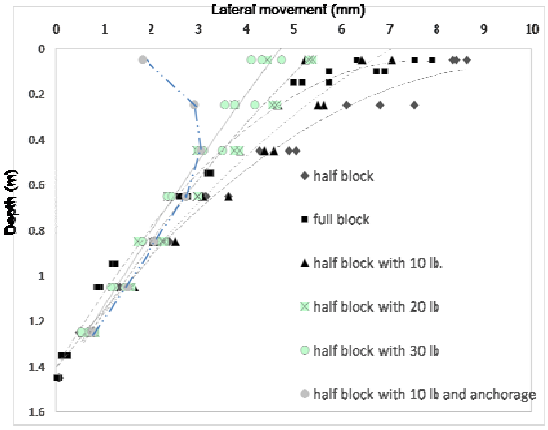

Fig.7Test results

-The retaining wall laid with half-bricks interlocking bricks was tested three times. It was found that this type of retaining wall controlled settlement of filling sand at 25mm, which was the greatest settlement. The horizontal movement was in a curve and the greatest movement was 8.48mm

at the topmost point of the retaining wall.

-The retaining wall laid with half-bricks interlocking bricks, reinforced bars, and 10lb force was tested three times. It was found that the retaining wall controlled settlement of filling sand at 25mm, which was the greatest settlement. The horizontal movement was closer to linear and the greatest movement was 6.24mm at the highest point of the retaining wall.

-The retaining wall laid with half-bricks interlocking bricks, reinforced bars, and 20lb force was tested in triplicate. The retaining wall controlled settlement of filling sand at 25mm, which was the greatest settlement. The horizontal movement was straighter than retaining wall laid with half-bricks interlocking bricks and reinforced bars gave 10lb force and the greatest movement was 5.06mm at the highest point of the retaining wall.

-The retaining wall laid with half-bricks interlocking bricks, reinforced bars, and 30lb force was tested in triplicate. The retaining wall controlled settlement of filling sand at 25mm, which was the greatest settlement. The horizontal movement was the most straight, and the greatest movement was 4.40mm at the highest point of the retaining wall.

-The retaining wall laid with half-bricks interlocking bricks, reinforced bars gave 10lb force and the anchorage was tested three times. It was found that the retaining wall controlled settlement of filling sand at 25mm, which was the greatest settlement. The horizontal movement showed a tendency to be in a curve. The greatest movement was 3.06mm at the area close to the center of the wall.

-The results of the four tests to compare the efficiency of horizontal movement of the retaining wall showed that the control over filling sand was at 25.00mm, which was the highest settlement parameter. The greatest horizontal movement of the retaining wall was studied; the most efficient retaining wall should move the least, which was found to be the retaining wall laid in one layer with 30lb reinforced bars. However, the efficiency did not differ much from retaining wall with 20lb reinforced bars and 30lb reinforced bars.

In order to find elastic modulus of the wall(Fig.14 and Table1), strength or weakness of a combined structure is its stiffness value which depends on the elastic modulus (E_{total}) and inertia moment (I) of the cross-section. The walls laid with two rows of half-block and full-block bricks with no reinforcedbars showed uncombined failure. Retaining wall strength depends merely on weight over it and friction of material surface. This differs from a retaining wall with half-block bricks and reinforcedbars where failure will be partially uncombined. Here, inertia moment values are equal showing that the strength of a retaining wall with half-block bricks and reinforced bars depends on elastic modulus (Table 1)

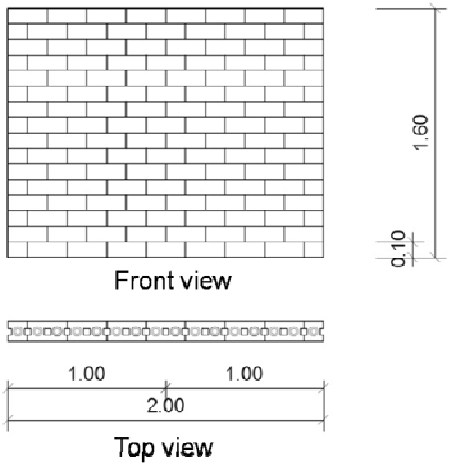

Fig.8Half brick (Front view)

Fig.9 Half brick test set up (Front view)

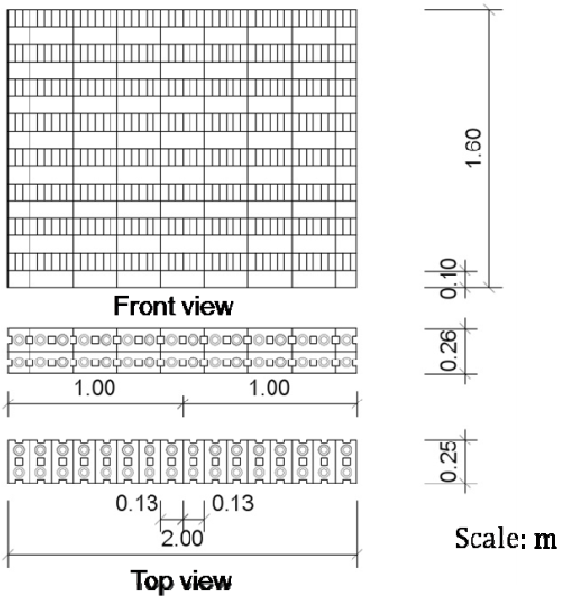

Fig.10Full brick (Front view)

Fig.11Full brick test set up (Front view)

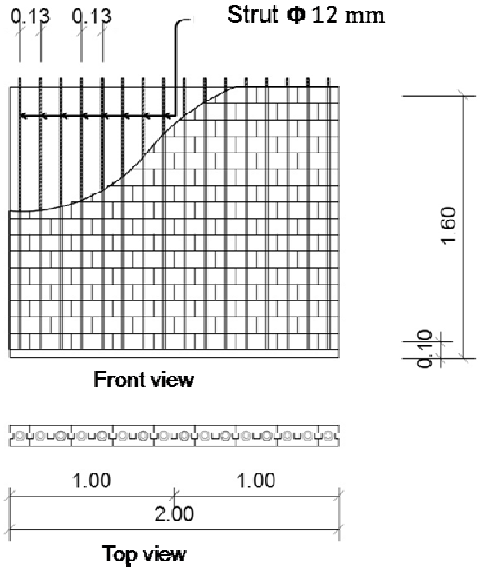

Fig.12Half brick with reinforced bar (Front view)

Fig.13 Half brick with reinforced bar test set up (Front view)

Fig.14Elastic modulus test

Table 1 Elastic modulus

Cases	Lateral load (kg)	Length of retaining wall (cm)	Moment of inertia (cm^4)	Lateral movement (cm)	Elastic modulus (ksc)
10 lb	156	1,500	1,800	7	13,990
20 lb	232	1,500	1,800	7	20,750
30 lb	330	1,500	1,800	7	29,516

4. CONCLUSION

Based on bricks retaining wall model test results, the following conclusions can be drawn:

The behavior of dry-retaining wall bricks without reinforced bars shown uncombined failure and can support low pressure. With reinforced bar and anchor showed partially uncombined.

The addition of reinforced bar to a significant reduction of lateral deformation

The results of the four tests to compare the efficiency of horizontal movement of the retaining wall showed that the control over filling sand was at 25.00mm, which was the highest settlement parameter. The greatest horizontal movement of the retaining wall was studied; the most efficient retaining wall should move the least, which was found to be the retaining wall laid in one layer with 30lb reinforced bars. However, the efficiency did not differ much from retaining wall with 20lb reinforced bars and 10lb reinforced bars.

5. ACKNOWLEDGEMENTS

The authors are grateful to the Khon Kaen Campus of the Rajamangala University of Technology Isan for supporting the research.

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