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STRENGTH AND BEHAVIORS OF DRY-JOINT RETAINIG NANO-BLOCK

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ABSTRACT: This research studied the strength and behaviors of dry-joint retaining walls built with nano blocks, a new product made from wet-cast concrete of the size 20×40×18cm, with the weight of 15kg/block, and the compressive strength of 94kg/cm². Construction of retaining walls with these dry-joint nano blocks– both for permanent and temporary walls – is simple, convenient and fast without having to rely on skillful workers. The research started from producing a prototype scale model of 1:12.5 for determining appropriate experimentation. The structure of the retaining wall using 2.00×1.65×0.20meters dry-joint nano blocks allowed distribution of lateral earth pressure through the sand in a semicircular-cut cylindrical mold of 15cm radius and 1.60 meters height. Pressure was applied step by step all through the test. Gauging of both horizontal and vertical displacements was performed using a dial gauge. The testing program for the nano-block retaining wall comprised 5 patterns of walls: half-block, half-block with 1.38kg-m steel reinforcement, half-block with 2.77 kg-m steel reinforcement, half-block with 4.15kg-m steel reinforcement, and anchored half-block with1.38kg-m steel reinforcement. Horizontal displacement was checked stepwise.Comparison of the efficiency of the 5 patterns showed that the half-block nono-block retaining wall demonstrated the highest horizontal displacement the retaining wall yielding the highest efficiency was the anchored half-block with 1.38kg-m steel reinforcement, with the least horizontal displacement of 2.90mm. It can be concluded that steel reinforcement and structural anchoring increases stability of nano-block retaining walls in terms of lateral compressive strength.

Keywords: Retaining wall, Nano blocks, Steel reinforcement, Anchored

1. INTRODUCTION

The present construction operations need to take into account the cost, ease, and convenience of work as well as short project period. Nevertheless, for some types of construction, soil retaining walls have to be built before the main structure. In engineering construction, retaining walls are usually designed with reinforcement for structural strength. The researchers are interested in nanoblock concrete, which is an alternative and promising material for constructing retention walls. Nanoblocks are made from wet-cast concrete that offers better engineering properties than dry cast or compression. Wet concrete is strong, durable, and locally available. Construction can rely on local labor and can be done without the use of bulky machinery. Nanoblocks, as an innovative material, do not require a high cost of transportation and are easy to remove without skilled workers. [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 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 has external stability when they do not slide, settle, or collapse due to load on soil bearing under the foundation [7].

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 prototype model(Fig.1), 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- nano block

Combined structure:

-Exerting force of 10 pounds (1.38 kg-m)

-Exerting force of 20 pounds (2.77 kg-m)

-Exerting force of 30 pounds (4.15kg-m)

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

-Exerting force at 10 pounds

2.1 Materials and Equipment Used in the Tests

- nano block as shown in Fig.2 measures20*40*18cm(width*length*height) and weighs roughly 15kg per block, compressive strength of about 94 ksc per block .

-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]

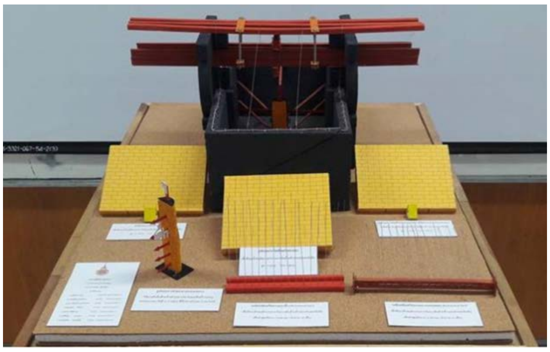

Fig.1 small-scale prototype model

-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.

Fig.2 Nano blocks
http//:www.thainanohouse.com

-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 steel plate and nut to the C-shaped restraining beam so as to prevent movement while being tested.

2.2Retaining Wall Test Set Up

The retaining wall test installation details as following (Fig.3, Fig.4, and Fig.5)

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

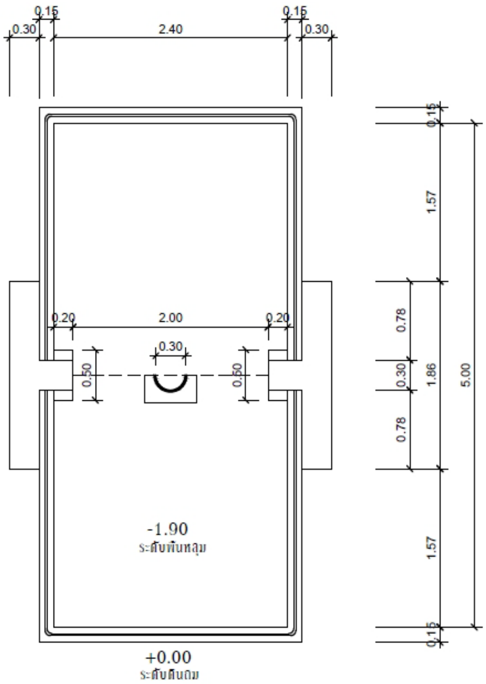

Fig.3 Pond Test (Top view)

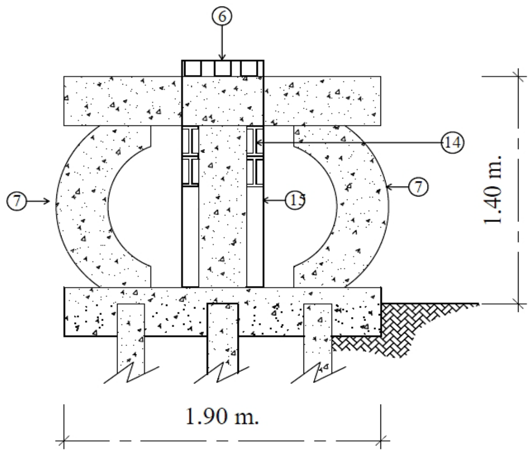

Fig.4 Pond Test (Side view)

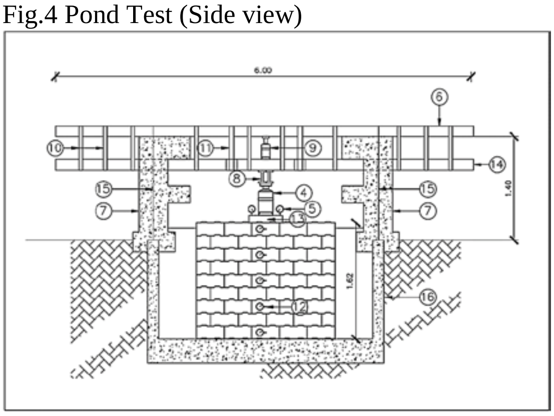

Fig.5 Test set up (Front view)

2.3 The Retaining Wall Test Procedure Detail as Following

2.3.1 Testing movements of retaining wall laid with half-nano block, reinforced bars and anchorages (Fig.6 and Fig.7)

-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 the unit 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.8.

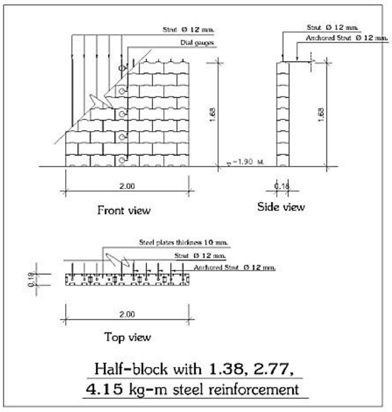

Fig.6 Half nao block with reinforced bar and anchorage test set up (Front view)

The five types of retaining wall studied were: retaining wall laid with half nano block (Fig.9); retaining wall laid with half nano block and reinforced bars given force of 10lb, 20lb and 30lb(Fig.10); retaining wall laid with half nano block, reinforced bars given force of 10lb and anchorage(Fig.11);. Tests were done in triplicate to observe their tendency to deform. The results obtained were used to build graphs for comparing the data.

Fig.7 Half nano block with reinforced bar and anchorage test set up (Back view)

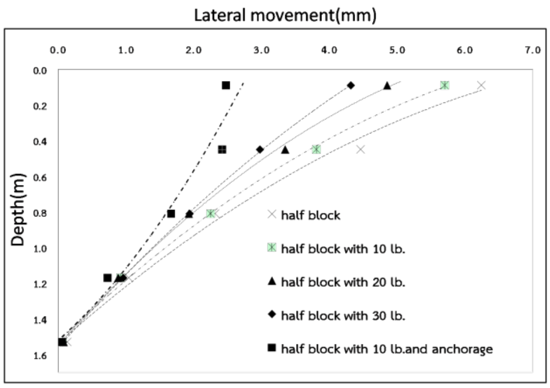

Fig.8Test results

-The results of the five 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 10lb reinforced bars with anchorage.

In order to find elastic modulus of the wall (Fig.12), 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 half nano block 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 nanoblock and reinforcedbars where failure will be partially uncombined. Here, inertia moment values are equal showing that the strength of a retaining wall with half nano block and reinforced bars depends on elastic modulus (Table 1)

Table 1Composites elastic modulus

Cases	Lateral load (P) kg.	Length of retaining wall (L) cm.	Moment of inertia (I) cm^4	Lateral movement (Δ_{max}) cm.	Elastic modulus (E_{total}) ksc.
10 ปอนด์	174	1,620	10,860	0.7	32,437
20 ปอนด์	290	1,620	10,860	0.7	54,062
30 ปอนด์	335	1,620	10,860	0.7	62,451

Fig.9 Half nano block test set up (Front view)

Fig.10 Half nano block test with reinforced bar (Front view)

Fig.11 Half nano block test with reinforced bar anchorage (Front view)

Fig.12 Composites elastic modulus test set up (Front view)

The analysis under this study was conducted by comparing the costs of the construction material against the maximum horizontal movement of the 5 types of retaining walls, namely: 1) half-nanoblock retaining wall, 2) half-nanoblock retaining wall cast with a 1.38kg-m reinforced sheet, 3) half-nanoblock retaining wall cast with a 2.77kg-m reinforced bar, 4) half-nanoblock retaining wall cast with a 4.15kg-m reinforced bar, and 5) half-nanoblock anchored retaining wall cast with a 1.38kg-m reinforced bar. When considering horizontal movement of these structures, the half-nanoblock anchored retaining wall cast with a 1.38kg-m reinforced bar showed the greatest strength because of its lowest movement value. However, the cost of the half-nanoblock anchored retaining wall cast with a 1.38kg-m reinforced bar was the highest. The most appropriate structure, considered by comparing the cost and horizontal movement, was the half-nanoblock retaining wall cast with a 4.15kg-m reinforced bar. Its cost was 1,062THB/m2 and its horizontal movement was 4.30mm.

The researchers investigated the behaviors of the retaining wall built with nanoblocks and anchorage. The test was compared with the result of a relevant study by Pongsagorn et al. (2018). The comparison was performed between the 3 patterns of horizontal movement, the elastic modulus values, the cost per square meter, and the highest horizontal slides of each retaining wall.

The horizontal slide of half-block interlocking-brick retaining wall under control of fill sand settlement at 25 mm reached the maximum movement at 8.48 mm in a curvilinear pattern.

The maximum horizontal movement of the nanoblock retaining wall was less than the interlocking-brick retaining wall with less curvilinear movement tendency.

Half-nanoblock retaining wall cast with a 4.15kg-m reinforced bar.The maximum horizontal movement of the half-nanoblock retaining wall cast with a 4.15kg-m reinforced bar was 4.40 mm in an approximately linear pattern. The maximum horizontal movement of the nanoblock retaining wall was lower, but also in a linear pattern.

Half-nanoblock and anchored retaining wall cast with a 1.38kg-m reinforced bar.The maximum horizontal movement of the half-nanoblock anchored retaining wall cast with a 1.38kg-m reinforced sheet was 3.06 mm in an approximately curvilinear pattern since the anchor at the very end of the wall decreased the horizontal movement. The comparison showed that the maximum horizontal movement of the nanoblock retaining wall was much lower than the interlocking brick wall and was in a concave pattern, indicating the efficiency of the nanoblock retaining wall.

Comparison of the elastic modulus of retaining walls.The elastic modulus of the nanoblock retaining wall was higher than that of the interlocking brick retaining wall, proving its greater stability.

Comparison of reinforcement steel adhering tools.The interlocking brick retaining wall was constructed by placing a washer before steel reinforcing. The nanoblock retaining wall was constructed by using a steel plate to position the reinforcing steel. The plate was cut into a shape equal to the nanoblock so that there was no movement of reinforcing steel during the test.

Comparison of cost per square meter with the maximum horizontal slides of retaining walls.The cost of the interlocking brick retaining wall was 1,020 per m^2.The cost of the nanobrick retaining wall was slightly higher than the interlocking brick retaining wall. Therefore, nanoblock is an alternative material for constructing a retaining wall. The findings provide the information useful for those interested in building a retaining wall with this material.

The half-nanoblock retaining wall cast with reinforcing steel at 20-30 pound reinforcement range was found to be the most appropriate

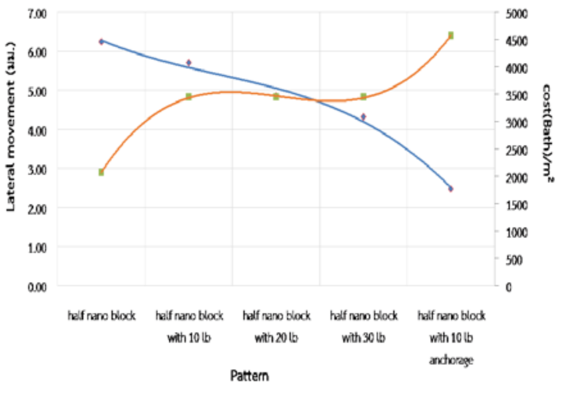

Fig.13 Comparison efficiency

4. CONCLUSION

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

The behavior of dry-retaining wall nanoblock 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 10lb reinforced bars achorage.

5. ACKNOWLEDGEMENTS

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