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Centrifugal model test for a stability of the reinforced retaining wall considering three dimensional shape effect

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ABSTRACT: In order to evaluate the influence of the three dimensional shape effect of the reinforced retaining wall, we performed two series of centrifugal tests of three dimensional geometrical shape model and verified them with Three-Dimensional FEM analysis with this research.

1 INTRODUCTION

The force in the reinforcement and the displacement at the face of reinforced soil walls after construction are usually much smaller than calculated by current design methods. A reinforced retaining wall is made up of the fill, reinforcement, facing, and foundation. Evaluation of influence of the three dimensional shape effect of each factor is difficult. That is to say, with a reinforced retaining wall like Terre Armee Method, the three dimensional effective consideration is necessary, in order to evaluate it strictly. From such a point of view, we performed centrifugal tests of three dimensional geometrical shape model.

Firstly, we experimented on a destruction of a model and investigated a critical height of a model from a centrifugal force field. For the next, we measured a deformation of the facing, earth pressure of the facing, vertical stress of the base. On the other hand, investigated deformation and stress distribution of the reinforced retaining wall with three-dimensional FEM analysis. After that, in comparison to a centrifugal model test, we studied a thee dimensional effect and verification of a program precision.

2 CENTRIFUGE MODEL TESTS

The schematic diagram of the apparatus is shown in Figure1. The model wall was constructed in the aluminum model container with inside dimension of 150mm by 450 mm by 300mm. Dry Toyoura sand, compacted to

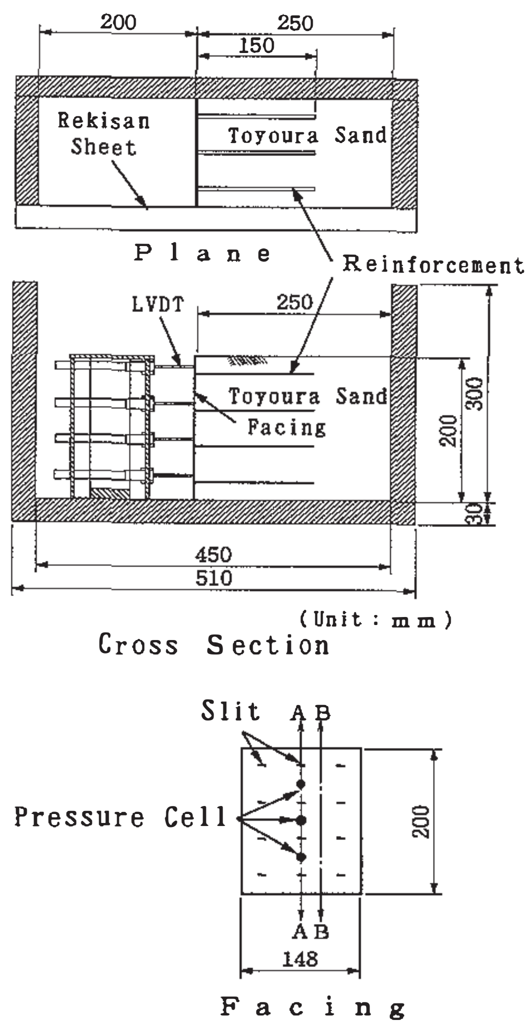

Figure 1 Schematic diagram of the centrifugal apparatus

relative density of 86% (γ=15.7KN/m^3), was used as the backfill material. Dimension of the fill were 200mm high, 250mm long, 150mm wide. A 148mm wide by 200mm high aluminum plate was used as the facing of the model. Reinforcing strips were embedded and inserted through slits in the facing at regular vertical and horizontal spacing. The side walls of the container were greased and lined with a layer of thick Mylar to minimize sidewall friction.

In order to know the centrifugal force causing failure of the wall, a series of breakage tests were performed changing the facing thickness, the length of reinforcing strip, and width of reinforcing strip, as shown in Table 1.

Table 1 Test Case and Condition

Test Case	Facing (mm)	Reinforcement(mm) Thicknees	Length	Width
Failure load Test				
1	0.4	None		
2	0.3	0.2	150	5
3	0.4	0.2	150	5
4	0.5	0.2	150	5
5	0.3	0.2	150	10
6	0.4	0.2	150	10
7	0.4	0.1	150	5
8	0.3	0.1	150	5
Deformation and Earth Pressure Test				
9	0.4	0.2	150	5
10	0.4	0.2	150	5
11	0.4	0.2	100	5
12	0.4	0.2	150~60	5

In another series of tests, four linear variable differential transformers (LVDT) were placed in front of the facing to measure its lateral movement. Three pressure cells were installed to measure the horizontal earth pressure, as shown in Figure1. One pressure cells were also installed to measure the vertical earth pressure acting on the base of model wall.

2.1 Failure load Tests

The critical height of a model from a failure load test is shown in Figure 2. In this figure, it is found that the length of reinforcing strip, and width of reinforcing strip is important factor, but the effect of facing thickness is very small.

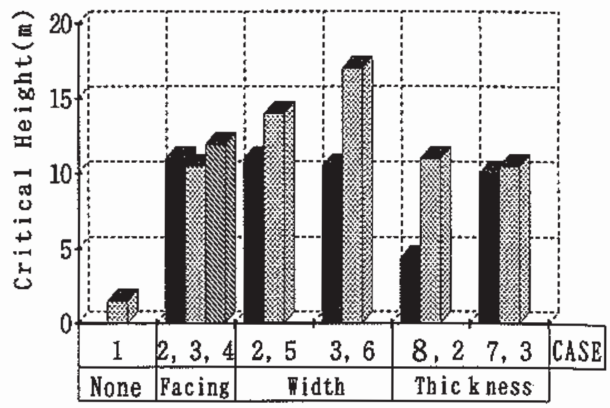

Figure 2 Critical height from a failure load test

2.2 Wall movement

Figure3 shows the facing movements for different magnitude of centrifugal force, which is expressed with gravitational acceleration g, in Case9. The facing movement increase with g-level, and it is consisted reinforced rigid body translation and body tilting toward the front of wall face.

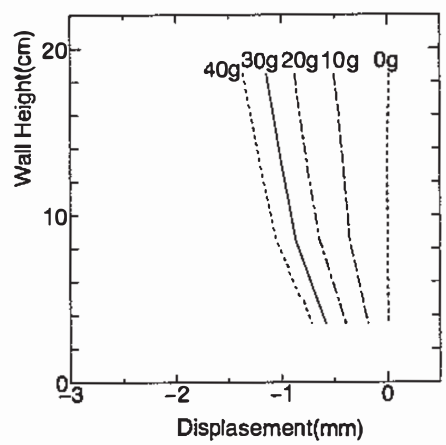

Figure 3 Facing movements for the centrifugal force

The relation between the facing movements and the reinforcement length when the centrifugal force corresponding to 30g were applied to the model as shown in figure4. The ratio of reinforcement length to wall height L/H is 0.75(case9) and 0.5(Case11). In case 12, the reinforcement length are decreased from 150mm to 60mm according to the depth. This figure shows that the reinforcement length of the wall has an effect of restraint the wall deformation.

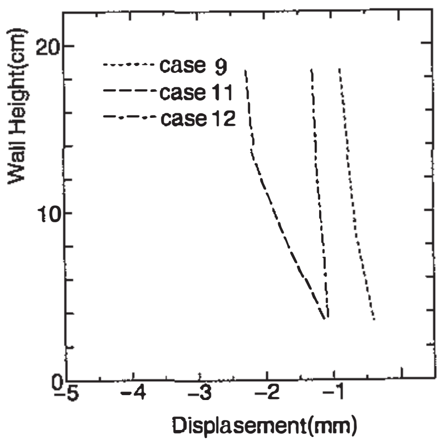

Figure 4 Relation between facing movements and reinforcement length

2.3 Earth pressure distribution

Figure5 shows the horizontal earth pressure distribution along the facing at the A-A cross section for different g-level (Case9). The horizontal earth pressure increases almost linearly with a centrifugal force, and the value increases according to the depth.

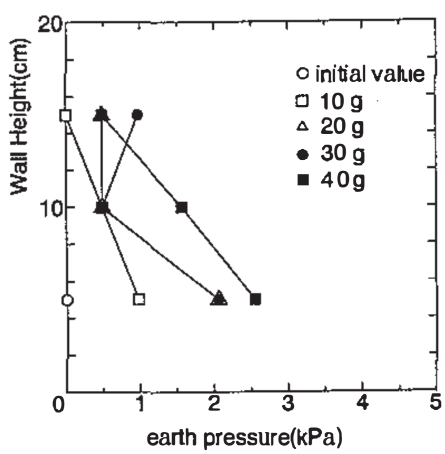

Figure 5 Horizontal earth pressure distribution at A-A cross section

The horizontal earth pressure distribution of facing at the B-B cross section (Case10) is shown in Figure6. The value are almost same with those Case9 up to 20-g, but the value increases at upper part of the wall over 30-g.

Figure7 shows active earth pressure observed in the experiment without reinforcement and horizontal earth pressure distribution along reinforced wall facing at the A-A cross section for 30-g(Case9), and the Rankin active earth pressure ($\sigma_h = K_a \gamma H$, $K_a = (1 - SIN\phi)/(1 + SIN\phi)$). The experimental value of active earth pressure is a half of Rankin theory. It is considered that the difference of experimental value correspond with the tension of the reinforcement.

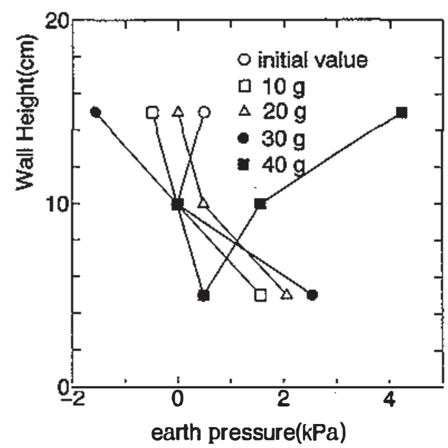

Figure 6 Horizontal earth pressure distribution at B-B cross section

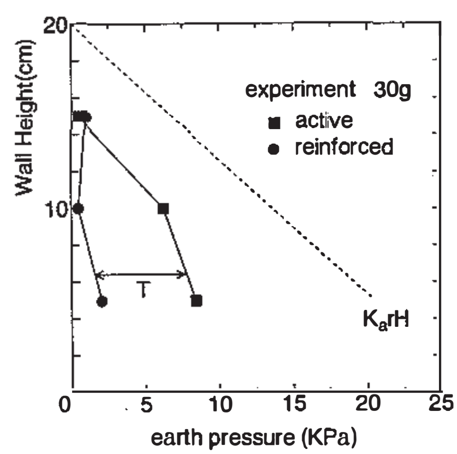

Figure 7 Active earth pressure observed and reinforced earth pressure

The comparison of vertical earth pressure acting on the base behind 50mm from the facing is shown in Figure8. In case9, the magnitude of measured value is almost same with the overburden pressure. In Case11 and Case12 the values are both smaller than the overburden pressure. It is suspected the friction mobilized on the facing due to large wall movement causes the reduction of the vertical earth pressure.

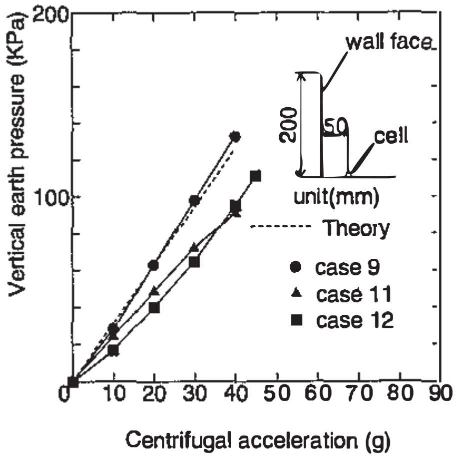

Figure 8 Comparison of vertical earth pressure acting on the base

3 THREE-DIMENSIONAL FEM ANALYSIS

Three-dimensional FEM analysis is used to predict the behavior of the centrifugal reinforced soil wall model as shown in Figure 9.

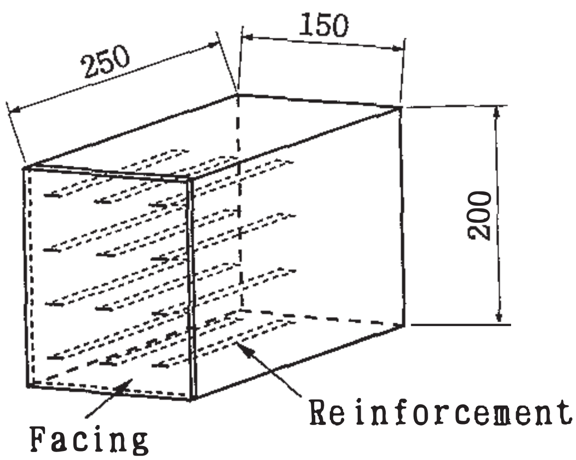

Figure 9 Three-dimensional FEM analytical model

The backfill was modeled as a elasto-plastic cohesionless solid. The yield function is Drucker-Prager type. These element were consist of isoparametric element and it had 27 nodes per brick. The reinforcements and facing were treated as linearly elastic solids. These material properties were shown in Table2. The centrifugal force were given by body force step by step of 10-g.

Figure 10 shows the deformation of the model at 30-g. The confined condition on the base of model is free in the horizontal direction. The displacement is drawn by 10 times scale of the deformation. The settlement of fill were increasing apart from the facing. The facing movement were increasing with the depth.

Table 2 Material properties of analysis

	Unit Weight γ (KN/m^3)	Elastic Modulous E (KPa)	Poisson Patio ν
Backfill	15.68	1.96×10^4	0.4
Reinforcement	26.36	6.89×10^7	0.345
Wall Face	26.36	6.89×10^7	0.345

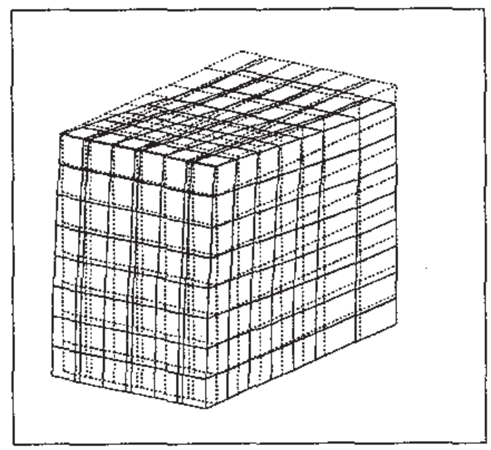

Figure 10 Deformation of analysis at 30-g

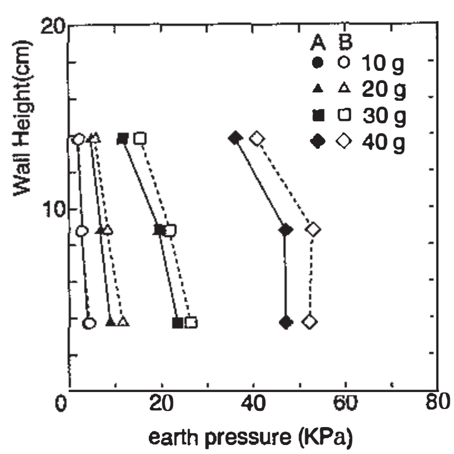

Figure 11 Earth pressure of Facing on A-A and B-B cross section at 30-g

The earth pressure of facing on A-A and B-B cross section at 30-g is shown in Figure11. The value of B-B cross section are bigger than A-A cross section, but the distribution is almost same shape.

4 COMPARISONS OF CENTRIFUGE TEST WITH THREE-DIMENSIONAL FEM ANALYSIS

Figure12 shows the measured and predicted facing movement at an acceleration of 30-g. Numerical results indicate that the wall face deformation due to the condition of the wall base. In case of centrifuge test the wall displacement has different distribution and increasing upper part. The experimental value has almost same order with free wall base condition of analysis.

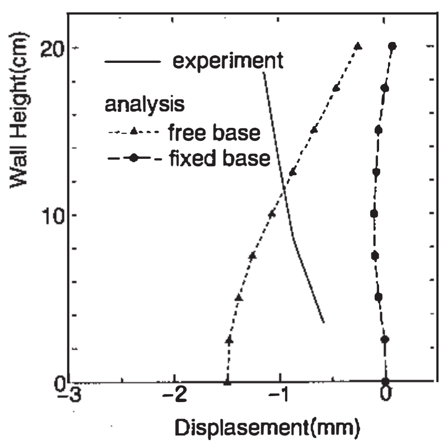

Figure 12 Measured and predicted facing movement at 30-g.

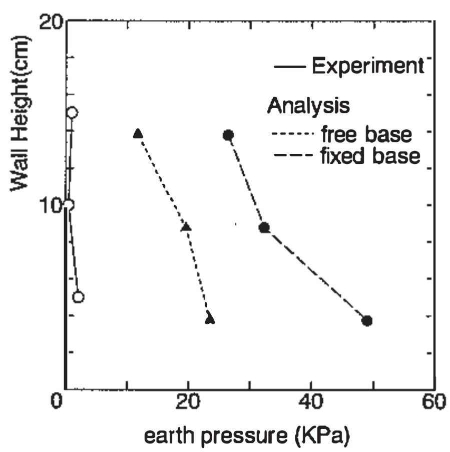

Figure 13 Measured and predicted earth pressure distribution of facing

The measured and predicted horizontal earth pressure distribution of facing(A-A section) at an acceleration of 30-g is shown in Figure13. The centrifuge test result is much smaller than analytical value. In the analysis, the case of fixed condition' s horizontal stress is bigger than free base condition.

We consider that the difference of Centrifuge Test and Three-dimensional FEM analysis is caused by construction condition of reinforcement area, difference of stress transformation mechanism of continuum and granular material.

5 CONCLUSIONS

As the results, the following were made clear.

1)The shape of the reinforcement had greatly influences strength of the whole of reinforced retaining wall.

2)A deformation of the facing increases together with a centrifugal force field. The length of reinforcement of the wall has an effect of restraint the wall deformation.

3)Earth pressures against the wall become very small by installation of the reinforcement.

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