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Application of RBSM analysis to earth reinforcement method

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ABSTRACT: The numerical analysis is carried out to many kinds of slope using the Rigid Body and Spring Model (hereafter called RBSM) proposed by Prof.Kawai (Kawai 1977). This paper reports on the application of the RBSM analysis to a model retaining wall test and a polymer-grid reinforced embankment assuming that RBSM is an effective analytical technique for earth reinforcing mechanisms.

1 INTRODUCTION

For designing the earth reinforcement system,it is desired that a numerical method, with which properties of the interface of soil and reinforcement can be assessed properly, be established.

In RBSM analysis, the interface of them will be modeled by the beam element and the plane element, as shown in figure 1, using stress (τ , σ) of the interface directly. Stress of the RBSM are transmitted by two springs (a shearing spring and a normal spring) distributed over the contact surface of two adjacent rigid elements. The deformation is defined by the relative displacement between two elements represented by displacement (u,v,θ) of the center of gravity of each elements, moving the elements themselves as the rigid body.

The discrete surface as illustrated in figure 2 can be easily assessed by properties of the RBSM and is being accepted as an analytical model useful for simulation of failure (Takeuchi 1981).

2 ANALYSIS OF MODEL TESTS

The model tests that were analyzed by the authors were conducted with the back filling as shown in figure 3, to which vinyl sheets were installed. The lower end of the movable wall on the left of the figure was connected by a pin. The wall was moved until horizontal displacement at the top reached 80mm (Ohkawa 1986a,1986b). Table 1 lists the conditions of sheets analyzed.

This paper studies the results of analyses of Case No.1,2,and 3. Table 2 outlines the material constants applied to the analyses.

2.1 Earth pressure

Figure 4,5,and 6 show the relation between the displacement of the movable wall and earth pressure, and figure 7 compares between the earth pressure distribution and the individual experimental values at the wall displacement of 30mm. Solid lines in the figures represent the experimental values and the broken lines the computed values.

The variation in earth pressure to the displacement of the movable wall is thought to be in good correspondence with experimental values, except for

Table 1. Condition of model tests

Case	Sheet condition
1	None
2	3 sheets
3	1 sheet
10	2 sheets
14	3 sheets(20cm away from the wall)

Table 2. Material constants applied to analyses

Materials	γ KN/m3	E MPa	ν	Φ degree
Onahama sand	14.4	0.92	0.28	38.0
Sheet	0	660	0.33	-
Movable wall	76.4	2100	0.33	-
Contact surface	-	0.92	0.28	19.0

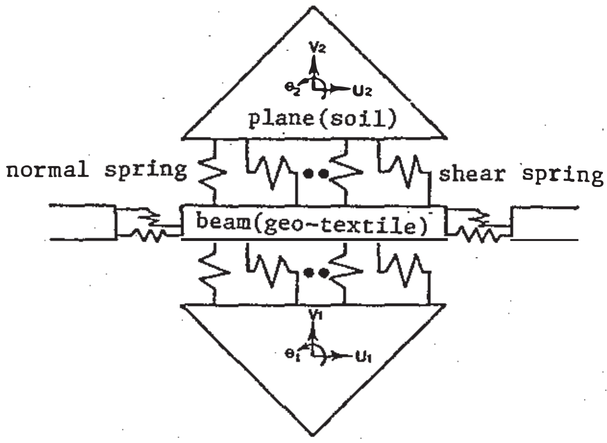

Figure 1. Model of the interface

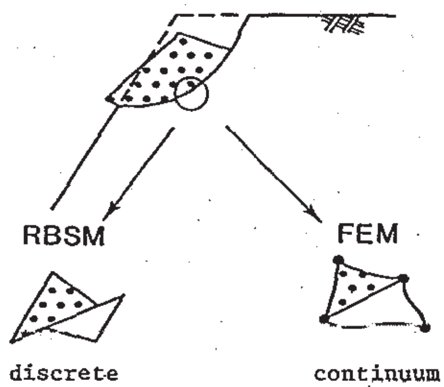

Figure 2. Difference between RBSM and FEM

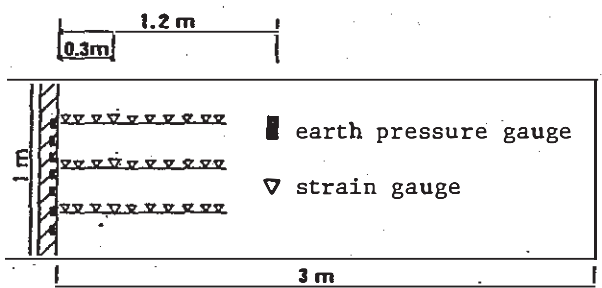

Figure 3. Diagram of the model test

the values of earth pressure gauge E6 in fig. 4 and 5, and E8 in fig. 6. As shown in fig.7,it has become clear that the earth pressure was reduced of depths where the reinforcing sheets were installed.

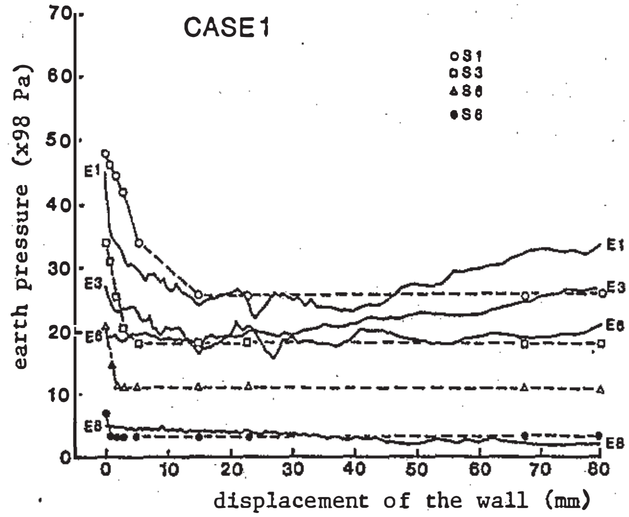

Figure 4. Variation of earth pressure

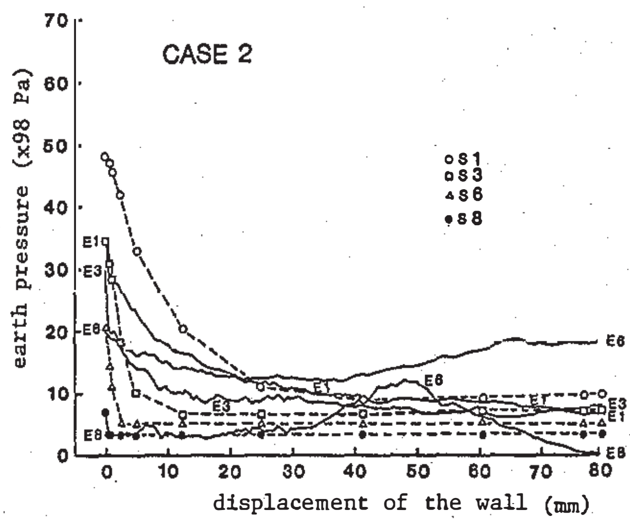

Figure 5. Variation of earth pressure

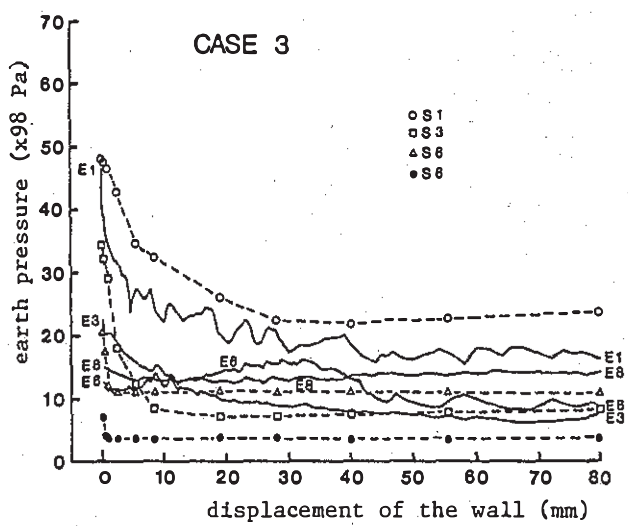

Figure 6. Variation of earth pressure

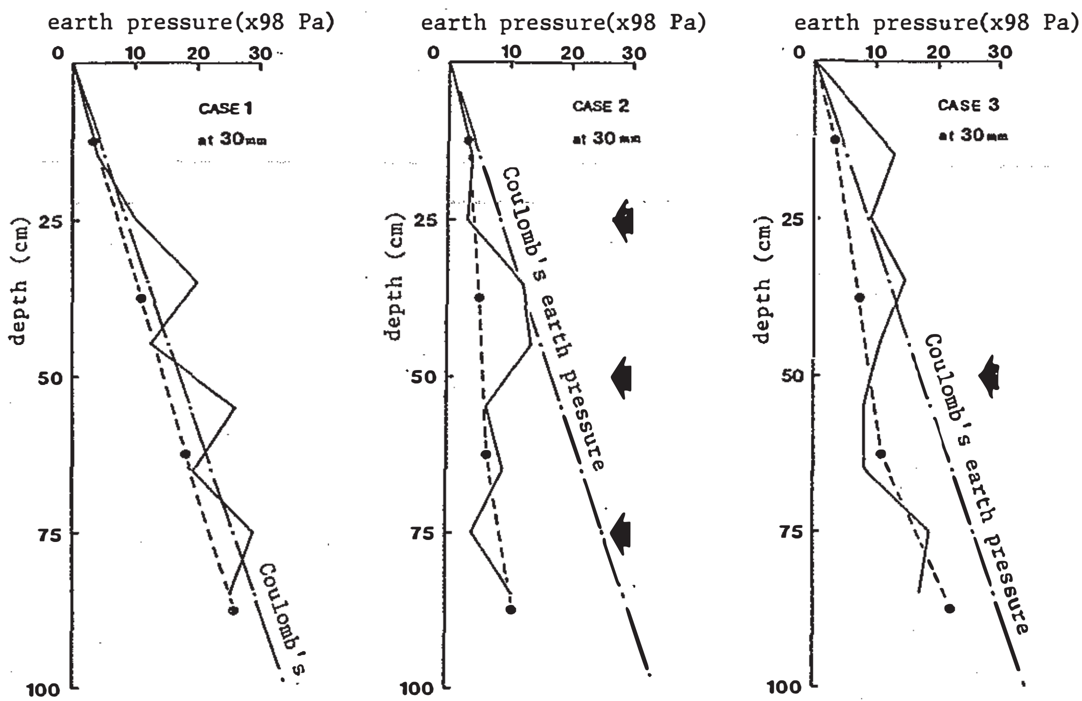

Figure 7. Earth pressure distribution

2.2 Slip line

Figure 8,9, and 10 respectively show the analysis results of slip lines inside the filling caused by shifting of the wall.

As shown in these figures, slip lines started commonly in the vicinity of a surface close to the wall, and they progressed deeper along Coulomb's active wedge. But the development of them differs according to intervals of sheet installation, which is thought to occur as follows :

Case 1 : Figure 8 shows that slip lines are formed along Coulomb's active wedge.

Case 2 : Figure 9 shows that developing of the slip lines is different from case 1 because of the tensile resistance of vinyl sheets. Horizontal lines appearing in figure (c) indicate the slip lines on sheet surfaces. The slipping caused the redistribution of stress, developing other slipping apart from these positions in the direction further from the wall. This tendency becomes clearer in figure (d) and (e).

Case 3 : Figure 10 shows that the slipping develops as if the filling is divided into the two parts because of the sheet installed in the middle. In other words, while the shifting of the wall is small, slip lines are formed in almost the same way as for filling without inner sheet installation. When the wall displacement reaches 5mm, slipping occurs above the sheet along Coulomb's active wedge. If the displacement progresses further, slipping occurs on this

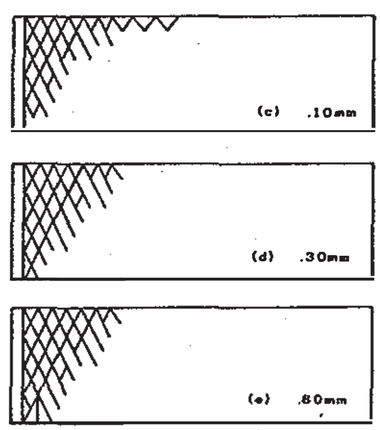

Figure 8. Slip line (case 1)

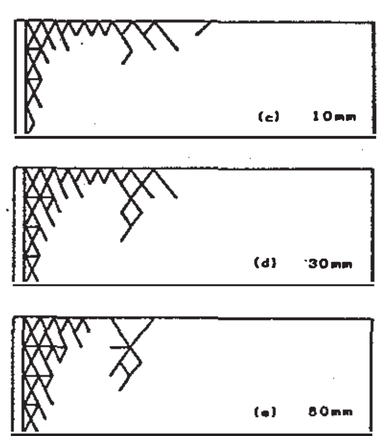

Figure 9. Slip line (case 2)

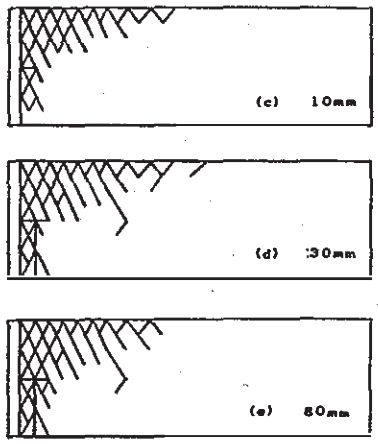

Figure 10. Slip line (case 3)

sheet. Finally, a slip area completed is similar to that of the filling having no sheet inside.

2.3 Tensile strain of sheet

Figure 11 and 13 show the variation of tensile strain caused to the sheet by the shift of the movable wall. Figure 12 and 14 show the distribution of the tensile strain in the longitudinal direction.

The solid lines in the figures indicate the experimental values and the broken lines the computed values. The numbers in rising order at the end of the solid lines in figure 11 and 13 are proportional to the distance from the wall. Markings ●, ○, □, and △ also correspond to the distance accordingly.

Case 2 : Figure 11 shows the computed values and experimental values correspond well to each other except for the lower sheet. The computed value ● of the upper sheet indicates that the slip line starting on the sheet surface at the wall displacement of about 3mm becomes constant thereafter and corresponds with the actually measured value up to the displacement of 30mm. The two computed values ● and ○ of the sheets in the middle correspond with the actually measured values. Computed values in the lower sheet show the occurrence of slipping on the sheet surface at the wall displacement of about 30mm, and the strain becomes greater than the actually measured values.

Case 3 : Figure 13 shows that the computed values correspond well with the experimental values (No.21). Furthermore, as shown in figure 10, it is thought that slipping occurs on the sheet surface from about 10mm of displacement. Figure 14 shows that strain distribution tends to be greater than the experimental values by two to three times.

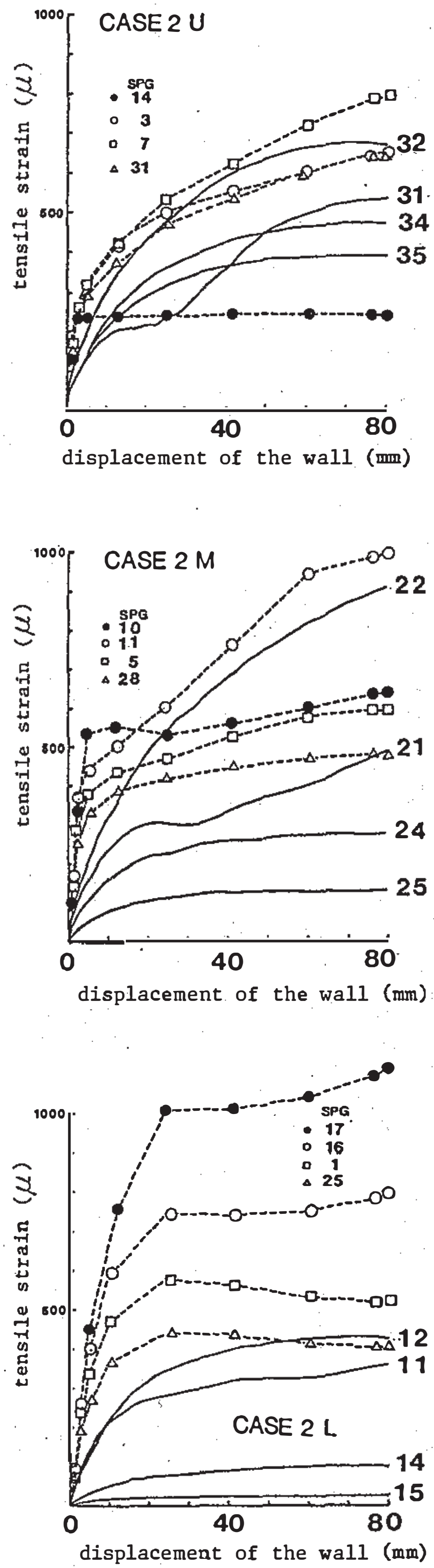

Figure 11. Variation of tensile strain

3 ANALYSIS OF REINFORCED EMBANKMENT

The mesh division diagram figure 15 shows a reinforced embankment of about 4 meters with slope grade of 1:0.2.

Strain gauge was attached to the reinforcement on the second and fourth layers from the bottom at five locations at intervals of 50cm. These measured strain during the construction and when the trucks drove on the embankment. Since the strain caused on the reinforcement by the trucks were so nominal, the following describes the computed values and actually measured values during the construction period.

Uniaxial oriented polymer-grid was used for the reinforcement at vertical intervals of 1m for the length of 3m.

The filling material used was a well-graded gravel of Japanese unified soil classification system with the unit weight of 20.1 KN/m3, water content of 6%, uniformity coefficient of 350, and 10% of fine particles of 74 μ or finer.

The slope is constructed with the many amount of sandbag packed with the above mentioned filling material and covered with the reinforcing material.

Table 3 outlines the material constants used for the analysis. The angle of friction of the contact area between the reinforcement and the filling soil was, same as used for the analysis of the aforementioned model test, one half of the internal friction angle of the filling soil.

Figure 16 shows the comparison between the computed values and actually measured values of reinforcement strain caused at the completion of the embankment. Both values show correspond well to each other with the maximum strain being about 0.65%. Since no slipping is observed by analysis, this embankment is thought to be stable.

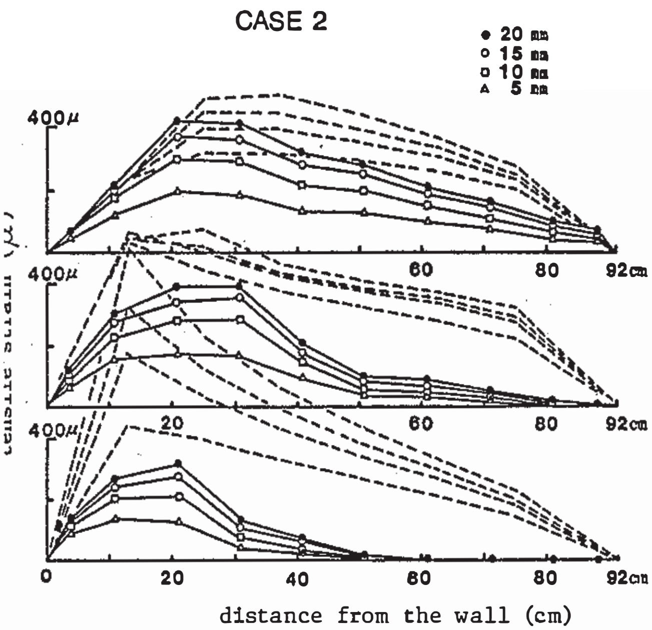

Figure 12. Distribution of tensile strain

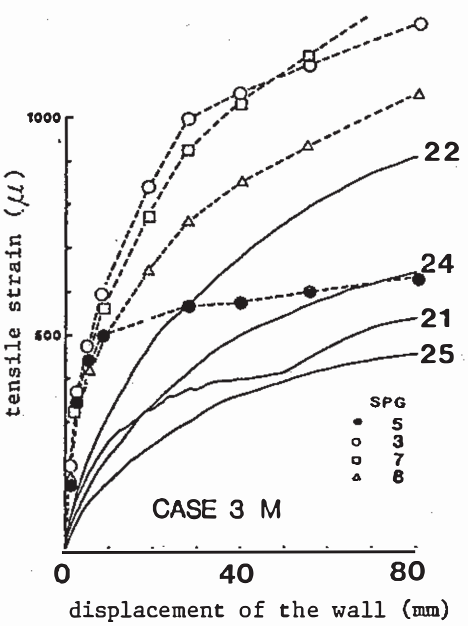

Figure 13. Variation of tensile strain

Table 3. Material constants applied to analysis

Materials	γ KN/m3	E MPa	ν	Φ degree	c KPa
filling	20.1	0.49	0.4	35.0	10
polymer	0.1	220	-	-	-
sandbag	20.1	0.49	0.4	35.0	15
Contact	-	0.49	0.4	17.5	10

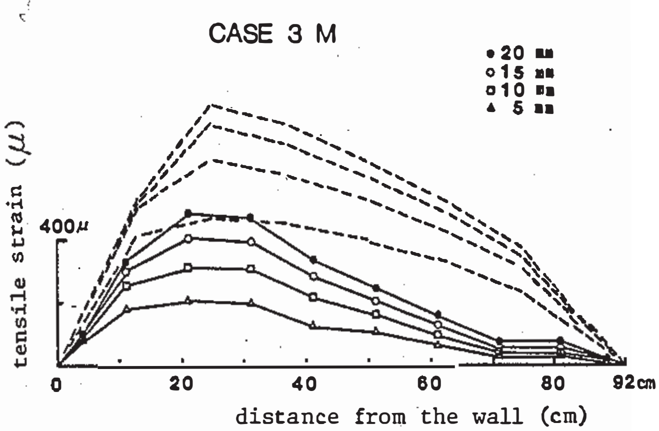

Figure 14. Distribution of tensile strain

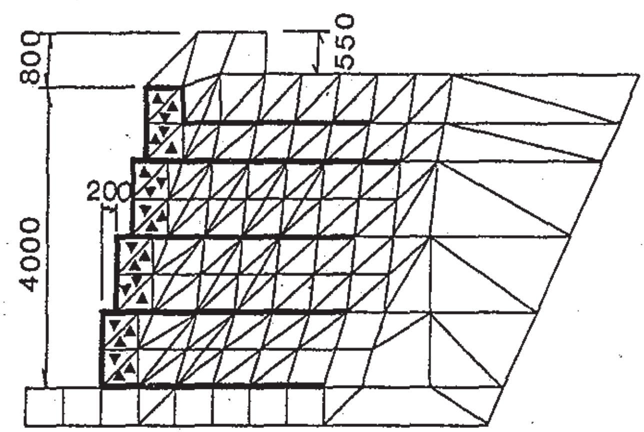

Figure 15. Mesh division of the embankment

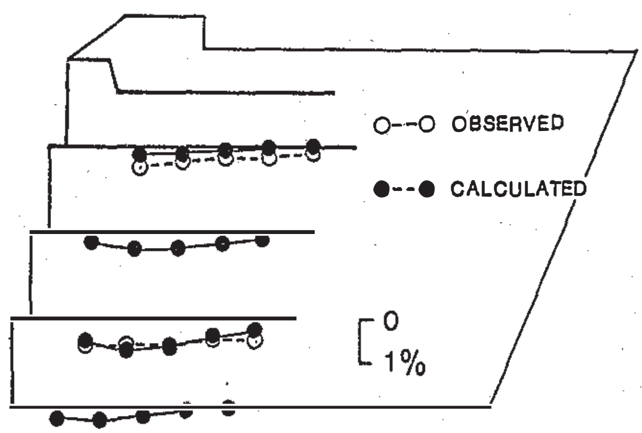

Figure 16. Distribution of strain

4 CONCLUSION

As the results of the application of RBSM analysis to the reinforcement system, the following items have become clearer.

1) Reduced of earth pressure by reinforcement

2) Peak strain to the reinforcement occurs to the boundary between plastic and elastic regions,and that RBSM can be effective means for analyzing earth reinforcement method.

ACKNOWLEDGMENT

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REFERENCE

T.Kawai 1977. A new discrete model for analysis of solid mechanics problems. Seisan-Kenkyu. vol.29 No.4

N.Takeuchi,M.Hada,& T.Kawai 1981. Limit analysis of soil and rock foundations by means of new discrete models (7th report). Seisan-Kenkyu. vol.33 No.7 (in Japanese)

S.Ohkawa,M.Noda,K.Tanaka,M.Nakamura, & H.Ikemi 1986a. Effect of reinforcing sheets for the abutment in model test. Proc. of 41th the annual conference of JSCE (in Japanese)

S.Ohkawa,M.Noda,& K.Tanaka 1986b. Static and dynamic model test concerning the effect of reinforcing sheets laid in the back-filling to the abutment. Proc.of 41th the annual conference of JSCE(in Japanese)