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Restraint effects on deformation of soft foundation with geotextile

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ABSTRACT: This study aims at investigating the effects of geotextile on the reduction of two dimensional displacement and the addition of the ultimate bearing capacity in the model saturated clayey foundation (120 cm long, 25 cm wide and 47 cm high)by carrying out plate load test in the laboratory. Geotextile is placed on the surface of this model foundation. The rate of loading is controlled at 0.2mm/min to simulate the drained condition. When using geotextile, observational values of displacement and ultimate bearing capacity are compared with those calculated by the finite element method (FFM) and again with those observed in natural state (without use of geotextile).

1 INTRODUCTION

The use of geotextile has been increasing for the purpose of reinforcement of soft foundation, stabilization of soil structure, separation of adjacent different materials, etc. since the early 1980's(Zanten 1980:2).

It is reported that geotextile provides the function of filtration(Saitoh et al. 1985:6).

Settlement and lateral displacement are conspicuously reduced with the use of geotextile, which in turn means the reduction of stresses within the foundation(Yamaoka et al. 1985:31). Ultimate bearing capacity is increased in case of the construction employing geotextile. This is supposed to be due to the fact that geotextile makes the condition of local shear failure transfer to that of general shear failure in the foundation. The settlement is little affected depending on the physical properties of geotextile used(Yamaoka et al. 1985:31).

For the numerical analysis for adjacent different materials such as rock joints, the introduction of joint element is desired to obtain reasonable results(Goodman et al. 1968). In the FEM analysis for saturated clayey layers, the Biot equation is generally chosen as the governing equation. The numerical solution proves in good agreement with observational values by the use of the elasto-viscoplastic model(Sekguchi 1977)as constitutive equation(Kang 1988.) In this study, the FEM analysis on the deformation of the saturated clayey model foundation is carried out in order to scrutinize the restraint effect on the settlement and lateral displacement including the increase of the ultimate bearing capacity of the two dimensional(which consists of large length compared with small width)model foundation (120 cm x 25 cm x 47 cm) covered with geotextile by performing plate load test (25 cm x 18 cm x 3.5 cm). Observation of horizontal and vertical displacement is also made for the above foundation during plate load test.

2 APPARATUS AND METHOD OF MODEL TEST

2.1 Loading and measurement

The measurements of two dimensional deformation, stresses and pore water pressure and the calculation of ultimate bearing capacity in saturated clay soft layer subjected to loading are carried out by the use of an apparatus, 120 cm long, 25 cm wide and 100 cm high of inside dimension. Uniformly reconsolidated samples are obtained with the apparatus.

Both stress and strain controls are carried out. The rate of loading is arbitrarily controlled depending on the simulation of drained and undrained conditions. In designing the apparatus for this study, the following points must be observed,

1. Two dimensional plate load test of model foundation and the production of

homogeneous sample for consolidation test.

2. Achivement of stress and strain controls.
3. Control of rate of loading ranged from drained to undrained condition.
4. Horizontally or vertically movable driving gear apparatus.
5. Auto self-recording system of stress, pore water pressure and earth pressure.
6. Preservation of water-proof and alleviation of side friction.

The apparatus is shown in Photograph 1.

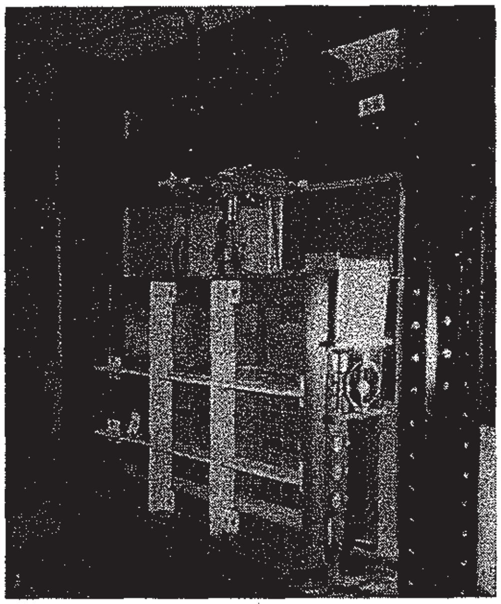

Photo. 1 General view for test apparatus

2.2 Model soil tank

Model soil tank(120 cm long, 25 cm wide and 100cm high of inside dimension)made of steel plate and channel attached with acrylite transparent plate for observation through the front face and with another auxiliary steel channel to prevent lateral displacement of the frame was used for the preparation of the model foundation.

Those plates and channels are bolted for disassemblage which is necessary for plate load test after consolidation. The transparent observation window is slice-marked with grid-line of 5 cm spacing. The front face of the sample is also slice-marked with grid-line of 5 cm spacing in order to determine the displacement.

For preparation of reconstituted model foundation, The clay slurry passing #120 sieve mixed with water is put into model tank. The model tank is equipped with porous plates in the upper and lower parts.

The clay slurry is subject to uniform consolidation all over the horizontal area by filling the water into the water bag through hose connected to water source over the frame.

Water head control is chosen in applying load for consolidation. The height of water source is arranged to obtain the required consolidation pressure. The pressure of 100kpa is secured by the difference of 10m in height between model soil tank and water source on the roof.

With the lapse of 30-60days, consolidation is almost completed. The soil sample obtained through the procedure is used for various soil laboratory tests such as model plate loading, consolidation, direct shear and triaxial test.

2.3 Lay out of geotextiles

Usually geotextiles is horizontally placed every certain interval of depth of foundation or banking. However in this experiment, only one layer of geotextile (A type) is covered on the surface of model foundation in order to examine the restraint effect on displacement and the increasing effect on ultimate bearing capacity. Another type of geotextile (B type) is used to determine the effect of the geotextiles used. The properties of geotextiles are shown in Table 1 while the layout of geotextile is shown in figure 1.

Table 1. Physical properties of geotextiles used.

Type	Nomen-clature	Weight (g/m^2)	Tension force(kg/m)
A	SM PP 300	220	75
B	SM PP 200	180	50

Type	Rate of elongation (%)	Coefficient of permeability (cm/sec)	Remarks
A	10-30	$\alpha^* \times 10^{-10}$	reinforcement
B	10-30	$\alpha^* \times 10^{-10}$	

α^*: coefficient ranged from 1 to 10

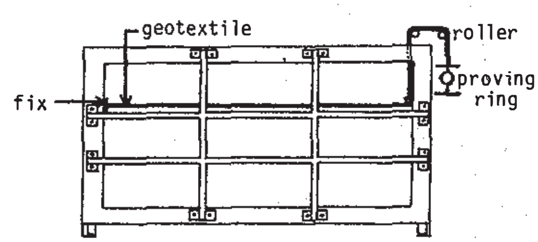

Fig. 1 Apparatus for measuring tension of geotextile

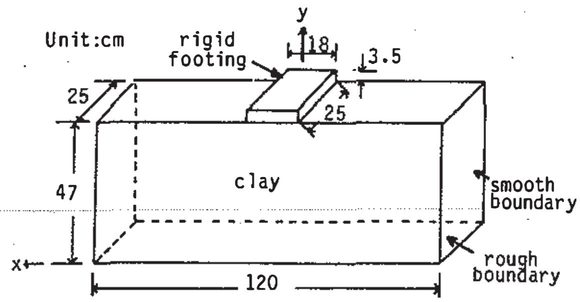

Fig.2 Test model

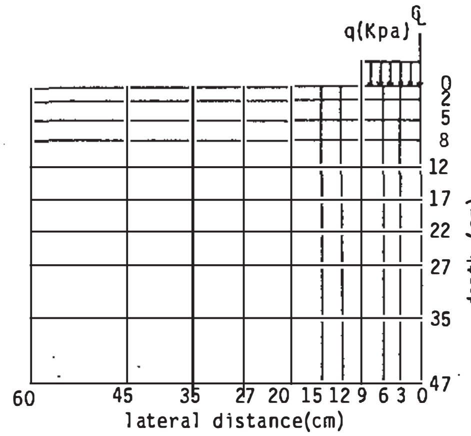

Fig.3 FEM grid

2.4 Test procedure

Loading is applied using the plate as shown in figure 2 with the choice of strain control of the rate of 0.2mm/min at which pore pressure does not generate because of drained condition.
During applying load, the stresses in soil and pore water pressure were measured at 5-minute intervals while displacement was measured every 30 minutes. The process was continued while the foundation failed completely.

3 NUMERICAL ANALYSIS

3.1 Program

In analysing results obtained from testings, the Sekiguchis' elasto-viscoplastic model (Sekeguchi 1977) was chosen as constitutive equation and the joint element method (Goodman et al. 1968) was introduced for the adjacent different materials. The results of the analysis were compared with observed values to examine the accuracy of the program developed by authors.

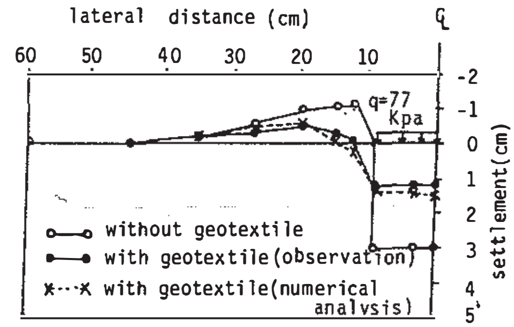

Fig.4 Settlement of surface

3.2 Boundary conditions

The FEM grid is shown in figure 3. As for boundary conditions, the surface is free, vertical sides are smooth so that vertical displacement is allowed to occur along these planes and the bottom is fixed. As for geotextile the one end is fixed and the other is connected to the proving ring to measure the tension force.

4. THE RESULTS OF PLATE LOAD TEST AND FEM ANALYSIS

4.1 Settlement

The observed and numerical values of vertical displacement on the surface reinforced with (photograph 1) geotextile are shown in figure 4 with satisfactory results.
Also this figure shows observed values without geotextile. Settlement and heave are noticeably reduced with geotextile.

4.2 Lateral displacement

In natural state, at ultimate load, 77kpa, a quite large lateral displacement develops vertically at the edge of load plate as shown in figure 5 & photograph 2. However with the construction of geotextile the constraint effect on displacement is remarkable without large difference in observed and approximate values.
Maximum displacement is located at depth of a quarter of plate width from the surface.

4.3 Displacement vector and crack zone

Displacement pattern and crack zone are shown in figure 6 and figure 7 respectively.

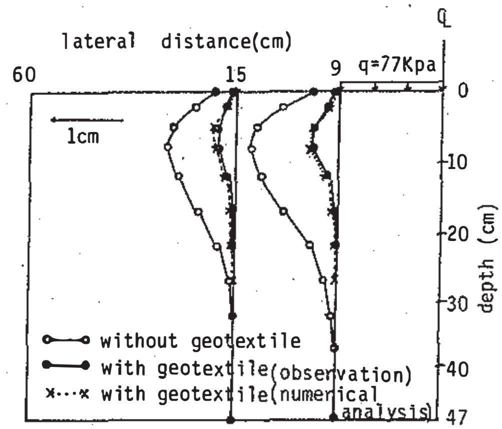

Fig.5 Lateral displacement at edge of model foundation

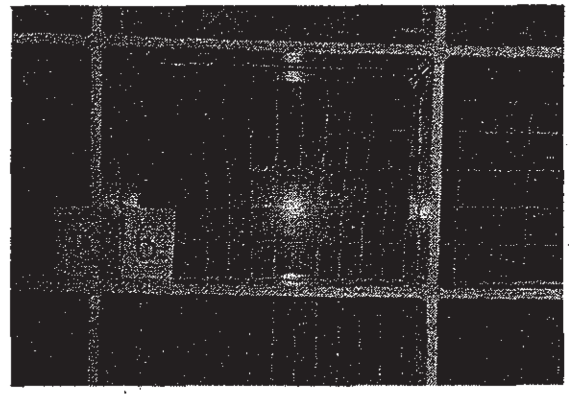

Photo. 2 Displacements at failure

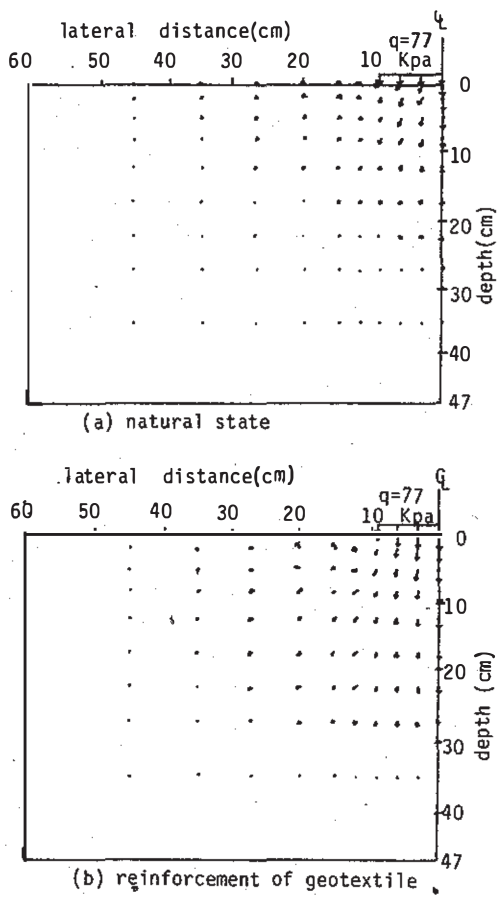

Fig.6 Pattern of displacement

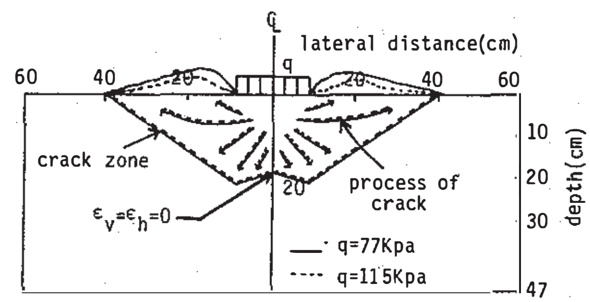

Fig.7 The schematic diagram of crack zone at shear failure

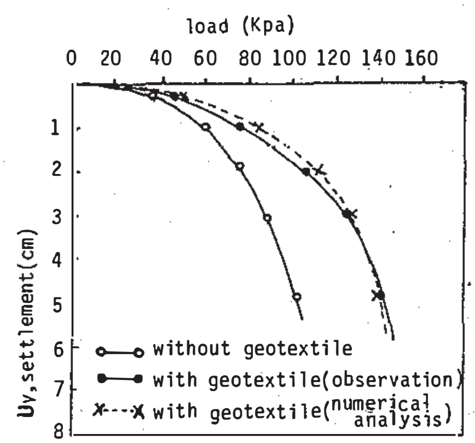

Fig.8 Load-settlement relation

Depending on the cases with or without geotextile, there appears large difference in magnitude but similar in pattern. With geotextile, displacements are conspicuously reduced, which in turn means a reduction in stresses. Crack zone shows the same pattern in both cases. But in natural state crack begins with as half a load as the reinforced state.

4.4 Ultimate bearing capacity

The ultimate bearing capacity depends greatly on geotextile. As shown in figure 8,

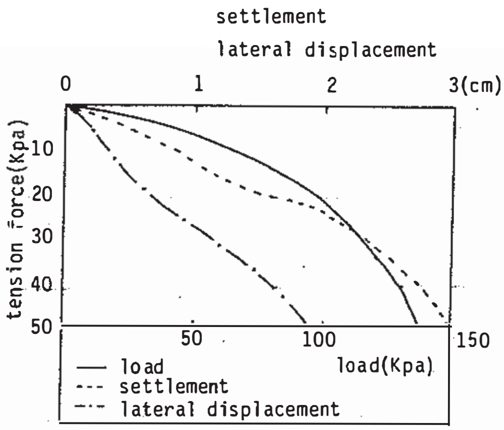

Fig.9 Settlement, lateral displacement and load-tension force relation

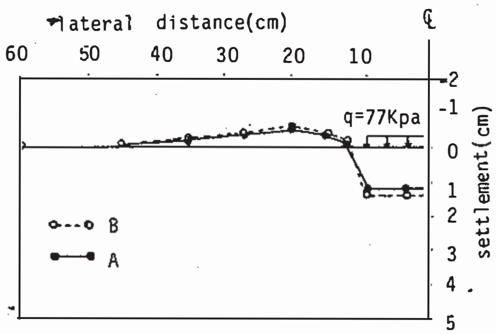

Fig.10 Settlement calculated by FEM analysis

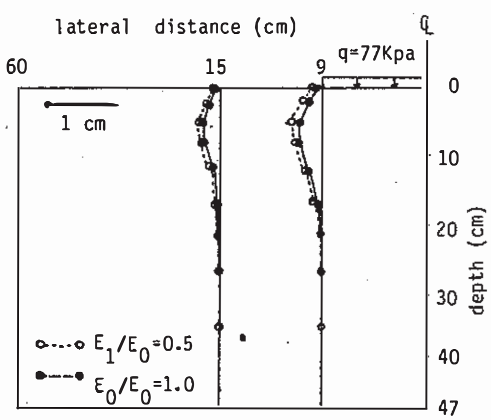

Fig.11 Lateral displacement calculated by FEM analysis

with geotextile the ultimate bearing capacity, 115kpa almost increases one and a half times over that of 77kpa in natural state. Previous study attributed this increase to the fact that geotextile

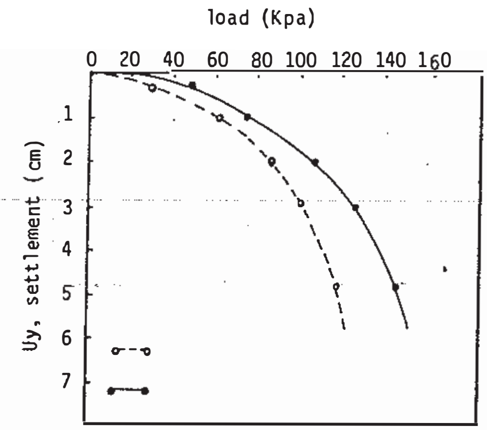

Fig.12 Load-settlement relation by FEM analysis

transfered local shear to general shear failure. This study shows the same tendency.

4.5 Load, settlement and lateral displacement-tension force of geotextile

The relation between tension-load, tension -settlement and tension-lateral displacement seems to be linear as shown in figure 9. The linearity seems due to the yield of foundation before the yield of geotextile. If geotextile yields before clay layer does the pattern of foundation failure will be very complicated.

4.6 The effect of different geotextiles on the behavior of foundation

In order to find out the behavior of foundation depending on the different geotextiles, FEM analysis is performed using 2 types of geotextle (A and B). Figure 10 to 12 show the results. In settlement, there is no significant distinction, which is very consistent with Yamaoka et al's result (1985).

There is a little different in lateral displacements betwen case A and B.

5 CONCLUSIONS

Through plate load test on two dimensional saturated clayey model foundation, following results can be drawn from the comparisons between the FEM analysis and observed values from the start of loading to failure. The comparison is also done between the cases with/without geotextile covered.

1. Both settlement and lateral displacements are notably reduced due to the lay-out of geotextile.
2. With the construction of geotextile, the ultimate bearing capacity increases one and half times as compared with that in natural state.
3. The behavior of the model foundation shows similar magnitude and shape irrespective of the physical properties of geotextile used.

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Table A. Parameters of soil used in calculation.

λ	κ	M	C_α	ν	σ(Kpa)
0.146	0.023	1.34	0.048	0.374	100
G_0(Kpa)	K	q_u(Kpa)	σ_0(Kpa)	K_0	e_0
1500	0.597	45	100	0.597	0.972
γ (KN/m^3)	$\dot{v}_0$(sec^{-1})	λ	k_x(cm/sec)	k_y (cm/sec)	W_n(%)
18	0.1×10^{-6}	0.146	3.75×10^{-7}	3.75×10^{-7}	43

APPENDIX

The physical and mechanical properties of soil sample produced in the model foundation apparatus described in 2.1 & 2.2 are shown in Table A.