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An estimation of improvement effects of geotextile on bearing capacity of soft ground

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ASTRACT: An investigation using laboratory loading test under a plane strain condition was carried out in order to examine the applicability of the generally used formula for an ultimate bearing capacity based on Terzaghi's theory. Two boxes used in the model tests were filled with a soft layer of remoulded Kaolin clay. Effects of tensile force of geotextiles, width of loading plate, moisture content of soil on the load-settlement relationships were investigated. It was found that the bearing capacity depended markedly on the tension (frictional force) of geotextile and the modified theory was applicable to determining a bearing capacity of poor ground.

1 INTRODUCTION

Reinforcement using geotextiles in order to improving a bearing capacity of very poor ground has acquired recognition as effective and economical alternatives to conventional construction methods. Several design approaches have been proposed hitherto. However, the acceptable rational design procedure for it has not been well built up.

At present the extended formula based on Terzaghi's theory is used in general for the ultimate bearing capacity of a very soft foundation. However, its applicability is not clear and there are no rational method to estimate the parameters in the formula.

In this study an investigation using a laboratory loading test under a plane strain condition was carried out in order to examine the applicability of the modified Terzaghi's type bearing capacity equation.

2 EXPERIMANTAL PROCEDURE

2.1 Testing apparatus

Two testing boxes were used in this experimental work. The box used in Test-I was 1000 mm in length, 1000 mm in width and 500 mm in depth. The box used in Test-II was 380 mm in length, 220 mm in width and 240 mm in depth. All tests were carried out in the condition of a plane strain.

In Test-I a surface displacement was measured under the control of stress in which the steel weights were put directly on the loading plate. A compression machine of capacity of 100 kN was also used for Test-II and the soil deformation inside the test box of which the side wall was made of an acrylic resin were observed using the markers.

2.2 Material characterization

The soil used in the tests were remoulded a Kaolin clay of which moisture content was 80, 90 and 100 %. The density of soil particles was 2.62 g/cm^3, and its plastic limit and plasticity index were 75.8 % and 43.8, respectively.

Two different type of geotextiles were used in the experiment. A non-woven fabric of 2.1 mm in thichness, 200 g/m^2 in mass, 0.9 kN/m in tensile strength was used in Test-I. A woven fabrric of 0.3 mm in thichness, 165 g/m^2 in mass, 50 kN/m in tensile strength was used in Test-II.

2.3 Testing conditions

The geotextile was laid down on the top of the ground under a condition of no surcharge layer, in order to measure directly the surface deformation of soft foundation.

In Test-I, the moisture content of soil was prepared at 80 %. Three different widths of loading plates of B = 1.25, 2.5 and 5.0 cm were used and both edges of the geotextiles were tensioned uniformly at 63 and 21.4 kN/m using the counter weights.

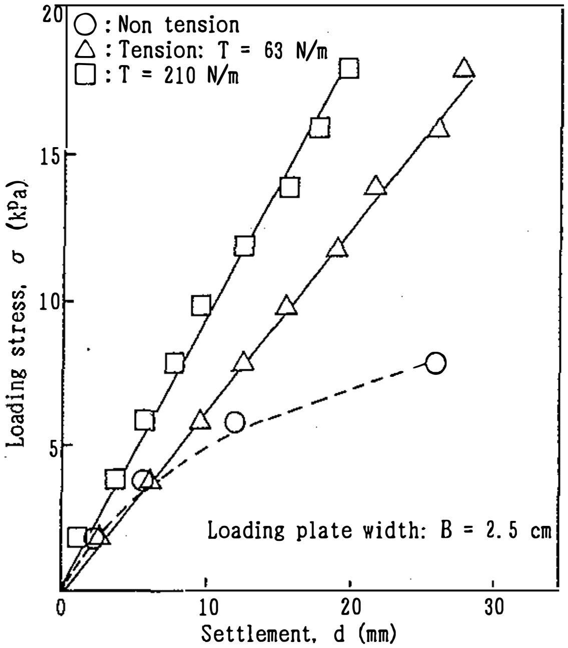

Fig. 1 Effects of tension on stress-settlement curve (Test-I)

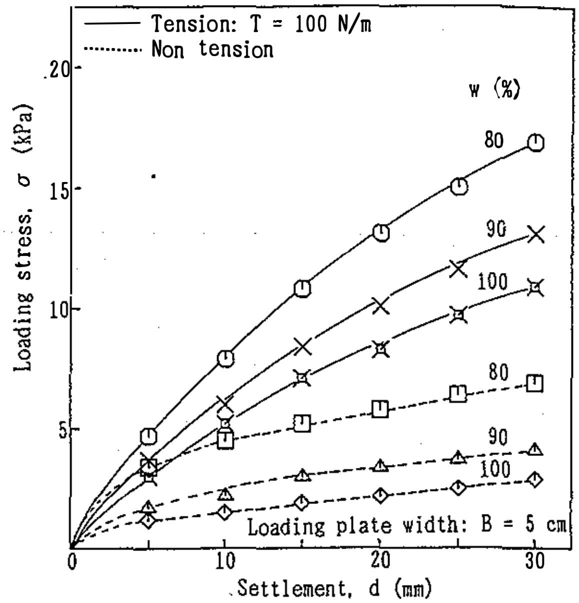

Fig. 2 Effects of moisture content on stress-settlement curve (Test-II)

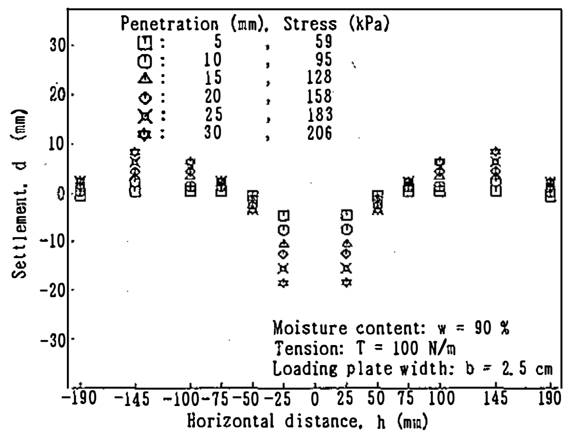

Fig. 3 Surface displacement under loadings (Test-II)

In Test-II, the moisture content of soil tested was 80, 90 and 100 %. The widths of loading plate employed were 2.5 and 5.0 cm, and the tension force T of geotextiles was from 49 to 196 kN/m.

3 RESULTS AND DISCUSSION

3.1 Increase in bearing capacity

Figure 1 shows the load-settlement relation in the case of the plate width B = 2.5 cm, and the moisture content w = 80 %, in Test-I. The settlements are the mean value of the loading plate penetration. In the case using no geotextiles the intensity of bearing value yields under 10 kPa and a large deformation occurs. On the contrary, the load-settlement curves with geotextiles are almost straight and the stresses are increasing in proportion to the tension. The other cases of different plate widths demonstrates the same pattern.

Figure 2 shows the load-settlement curves of the plate width B = 5.0 cm and the tension T = 100 N/m in Test-II. It can be seen from this figure that two or three times of the incease in bearing capacity is obtained by the use of geotextiles.

3.2 Deformation

An example of surface settlement pattern caused by to the plate penetration under loading is shown in Fig. 3 . A sliding flow of soil at both sides of loading plate occurs gradually with the increase in stress intensity, and it can be seen that the geotextile gives effects of restraint of the soil movement, namely "hammock effect".

Figure 4 shows the typical deformation of foundation soil during loadings. In the case using geotextiles, it will be seen that the foundation soil shows almost a circle slide around the point of ±75 mm in horizontal distance and 25 mm in depth.

3.3 Relationships between radius and plate width

Figure 5 illustraits the bearing capacity model of soft ground. Modified Terzaghi's

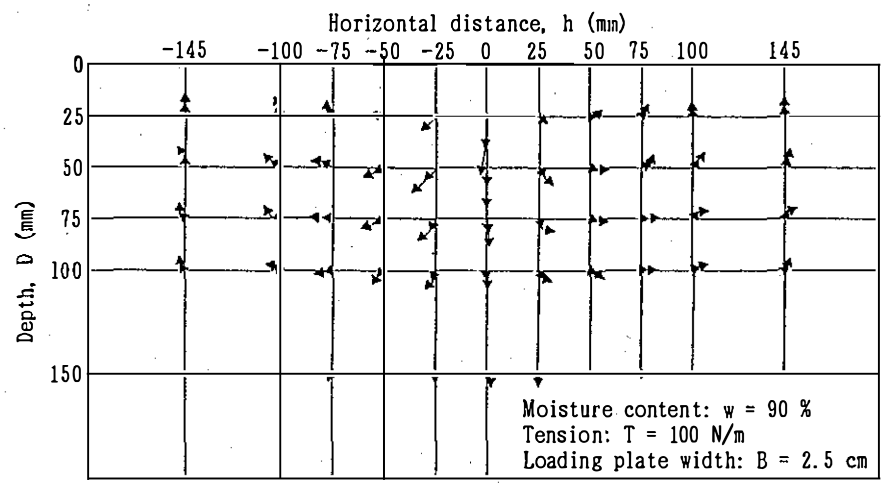

Fig. 4 Sectional deformation (Test-II)

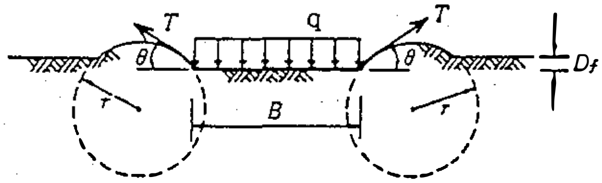

Fig. 5 Estimation model of bearing capacity

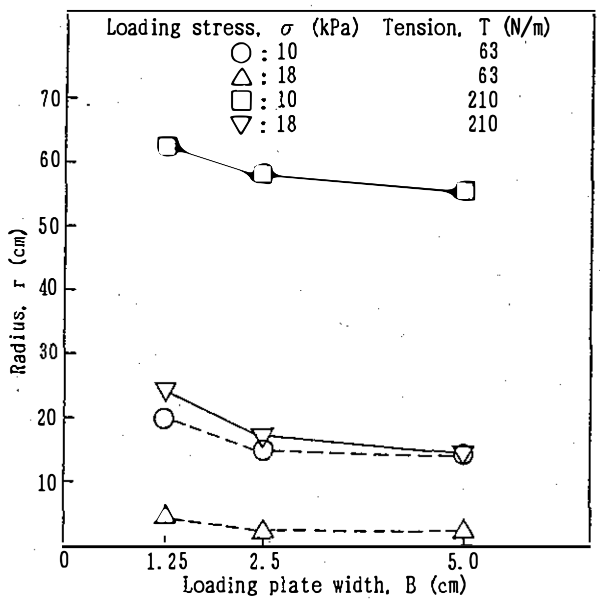

Fig. 6 Effects of loading plate width on radius (Test- I)

formula[1)2)] gives the bearing capacity q as follows;

$q = q_1 + q_2 + q_3 + q_4$

$= \alpha cN_c + 2T \sin\theta/B + N_qT/r + \gamma_t D_f N_q$

where,

α : shape factor

c, γ_t : cohesion and bulk density of soil

N_c, N_q: coefficients of bearing capacity

T: tension of geotextile

r: radius of adjacent circle

θ : tangential angle

B: width of loading plate

D_f: settlement of loading plate

Figure 6 shows the relationships between the radius of adjacent circle and the width of plate in the case of w = 80 % in Test-I. It is observed that the radius decreases slightly with the increase in width of plate. On the other hand, it is also obtained from the results that the tangent angle θ increase in proportion to the radius. Therefore the value of $\sin\theta/B$ does not shows a significant change due to the plate width. The radius, at the given tensile force of geotextiles, decreases with increasing in settlement under loadings, and hence the effects of degree of settlement is remarkable on the bearing capacity.

3.4 Relationships between radius and tension

It is possible to determine the radius based on the deformational shape near the loading plate, although drawing the adjacent circle sometimes gives errors. The radius and tension of geotextiles are shown in Fig. 7 . It may be seen from this figure that the radius increase with the increase in the tension and can find the almost constant value of T/r.

Figure 8 shows the radius - tension relation at the settlement d = 30 mm. It can be seen from Figs. 7 and 8 that the bearing value of q_3 in the equation mentioned above increases markedly with increase in tension.

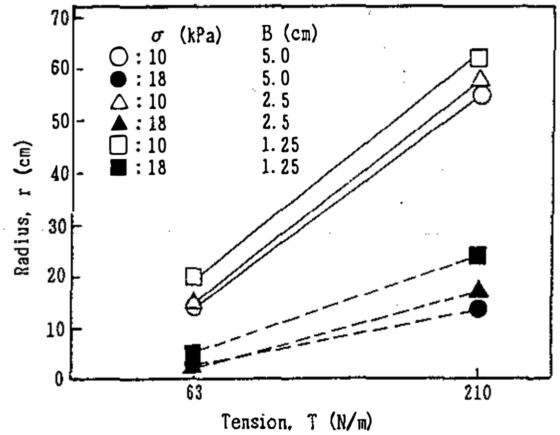

Fig. 7 Effects of tension on radius (Test-I)

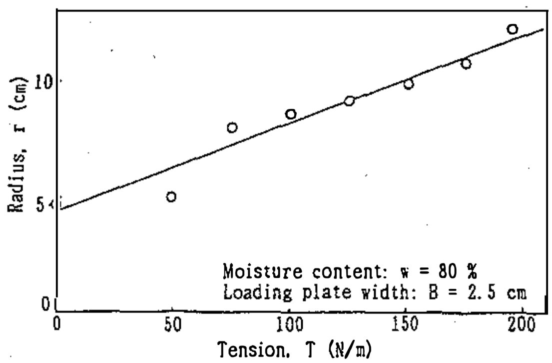

Fig. 8 Effects of tension on radius (Test-II)

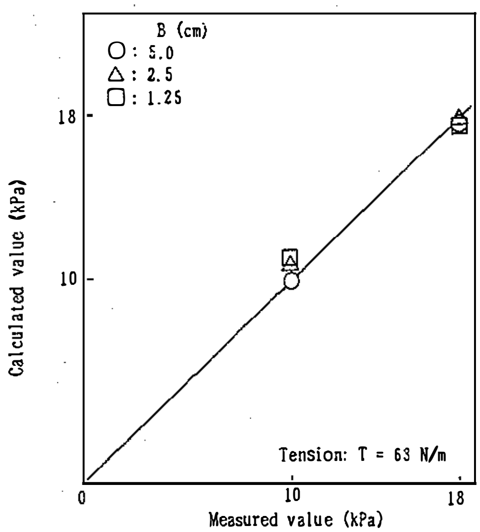

Fig. 9 Comparison between measured and calculated bearing capacity (Test-I)

3.5 Comparison between calculated and observed values

Figures 9 and 10 show the results of comparison between the observed data and the theoretical value based on the modified

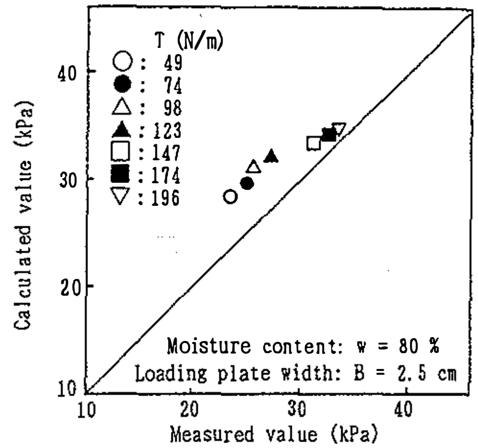

Fig. 10 Comparison between measured and calculated bearing capacity (Test-II)

Terzaghi's formula, in the condition of cohesion of soil, c = 1.3 kPa, and moisture content of soil, w = 80 % . A satisfactory correlation can be found in Fig. 9 . Figure 10 shows the some difference between them. This may be caused by the shortcoming of graphical determination of radius and tangential angle, and others.

4 CONCLUDING REMARKS

Results obtained in this study are summarized as follows.

1) The deformation state such as radius of adjacent circle and tangential angle are influenced by the width of loading plate, degree of settlement and tensile force of geotextiles.

2) The modified equation of bearing capacity based on Terzaghi's theory is satisfactorily applicable to a soft ground; however, it is desirable to have a rational method to determine the radius of tangential angle due to deformation of ground.

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