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Effect of geogrid stiffness on the resistance behavior of reinforced embankment under loading

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ABSTRACT : In this study, the two type model loading tests were carried out to evaluate the effect of geogrid stiffness on the resistance behavior of reinforced embankment which have the wrapped around wall system under loading. One test was to evaluate failure mechanism of reinforced embankment under loading, aluminum bars to simulate ground were used. The another test was to evaluate the relationship between the stability of reinforced embankment and reinforcement behavior in the soil, Toyoura sand was used. Test results are summarized as follows. (1)In the both of the two type tests, slip line in reinforced case arises more inner part in embankment than non-reinforced case. (2)Reinforced using higher stiffness reinforcement, embankment resistance to the higher surcharge. (3)A cause that reinforced embankment behavior in loading change from linear to non-linear is different in according to reinforcement stiffness. (4)The rapped around wall system using high stiffness reinforcement stabilize the active zone in reinforced area.

1 INTRODUCTION

When an over load such as weight of structure applies on the geogrid reinforced embankment, excessive deformation or failure is feared. In order to establish deformation or stability analysis method of reinforced embankment, it is necessary to clarify the failure mechanism and the relationship between the stability of reinforced embankment and reinforcement behavior in the soil. A magnitude of reinforcement force can be change in proportion to reinforcement stiffness, because the reinforcement force is mobilized by soil deformation. H.I.Ling et. al. (1995) discussed on the effect of geosynthetics stiffness on the behavior of GRS-RW by finite element procedure. The purpose of this study is to clarify the effect of geogrid stiffness on the resistance behavior of reinforced embankment under loading by model loading tests. In this study, the stability of reinforced embankment has wrapped around wall system is discussed.

2 FAILURE MECHANISM OF THE REINFORCED EMBANKMENT TO BE SIMULATED BY ALUMINUM BARS

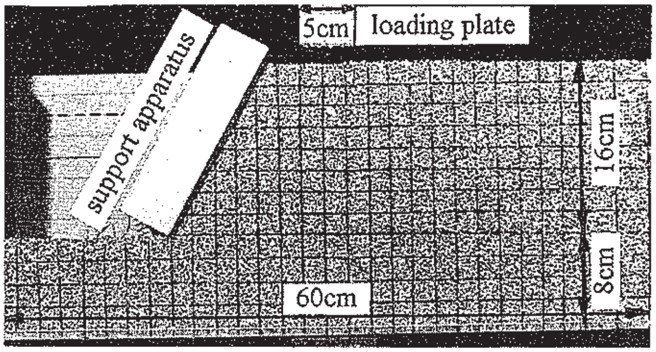
2.1 MATERIALS AND METHOD

Testing method to use the aluminum bars is useful for the investigating failure mechanism of the ground. In order to simulate the ground using aluminum bar, ϕ1.6mm and ϕ3.0mm aluminum bar were used mixing as a weight ratio 3:2. Rubber menbrain was used as a reinforcement, that ϕ1.6mm aluminum bar was pasted in the both side at intervals of 1cm. In making model ground, support apparatus was used. The loading was achieved after removing the support apparatus, and its loading speed was controlled by means of an electric screw jack at the rate of 0.8mm/min. In this test, displacement of model ground was observed by taking a picture, on the other hand applied load to loading plate and vertical loading plate displacement were measured.

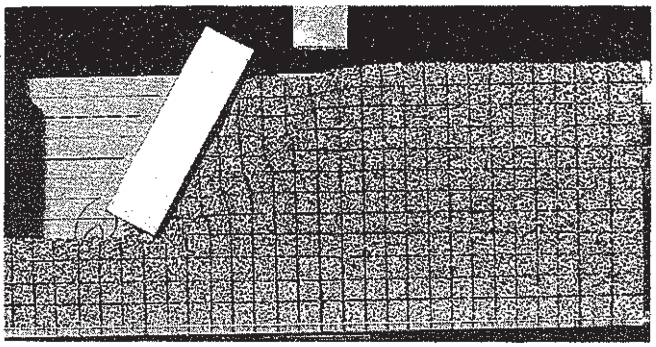
2.2 RESULTS AND DISCUSSION

In the non-reinforced case, when support apparatus was slid, slip line shown in Pic. 2 was formulated. The most of slip line can be seen as straight. A typical example of the critical state of the reinforced case by the loading is shown in Pic. 3. The displacement of noticed points is shown in Fig. 1.

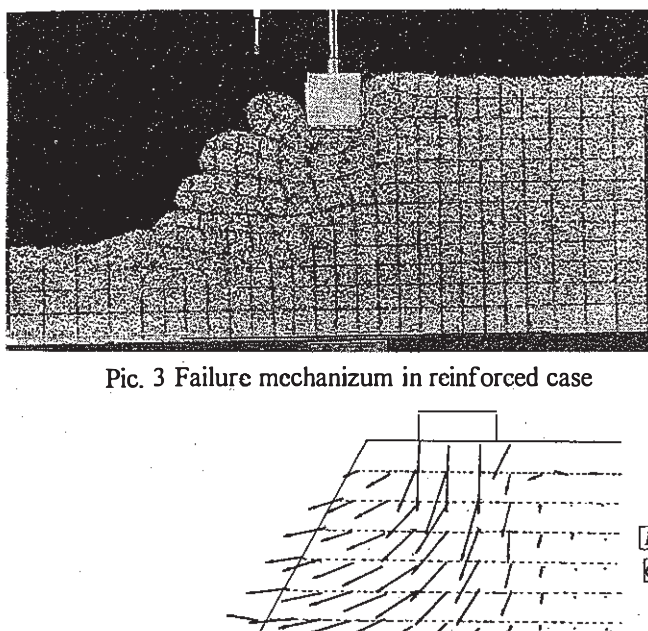
The precision slip line can not be judged from a picture result. But, the part that ground displace and the different part can be distinguished from Fig. 1, distinguished line can be considered to be a potential slip line. The formed slip line is in more inner part of embankment than non-reinforced case. Further, the slip line spread spread into the foundation. Therefore, when we analysis the resistance behavior of reinforced embankment under loading, to consider the space around reinforced area can be important.



Pic. 1 Test apparatus



Pic. 2 Failure mechanizum in non-reinforced case



Pic. 3 Failure mechanizum in reinforced case

Fig. 1 Ground displacement in reinforced case

3 MODEL TEST USING TOYOURA SAND

3.1 MATERIAL AND METHOD

Fig. 2 shows the illustration of the model test apparatus for a reinforced embankment. The side walls of the testing box is consisted of 50mm-shick transparent acrylic plate with steel out side. In order to reduce the effect of side wall friction, the inside surface of each acrylic plate was lubricated by means of a thin silicone grease layer and 0.2mm-thick latex-membrane. In a series of laboratory test, some reinforcing materials having same grid form and different stiffness each other were used. The stiffness was changed by cutting some of the libs in the geogrid. Toyoura dry sand was used in the tests. The model ground was made up by raining sand at constant raining velocity and its condition was managed to Dr=80%. In this test, the facing was made up by wrapping geogrid around gabions. The wrapped geogrid was connected with upper layer geogrid using brass bar. The loading speed was control by an electric screw jack at the rate of 0.5mm/min. The measurement items were applied load to loading plate, vertical loading plate displacement, lateral wall displacement and reinforcement force respectively. The testing program are as shown Table 1. Stiffness Eg in this table is in stretching strain 3%.

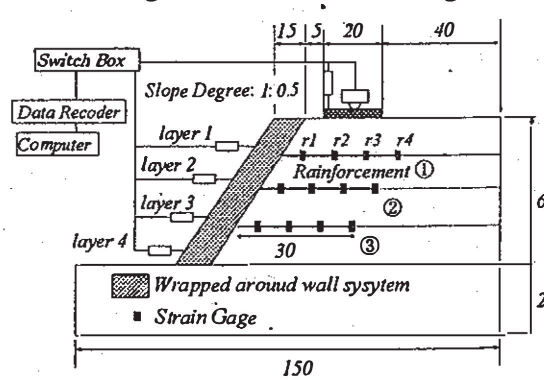


Fig. 2 Illustration of Test Apparatus

Table 1 Testing Program

Case name	Eg(tf/m)	Or *(%)
Non-Reinforcement		
FE03	5.17	
FE09	15.52	72.02
FE12	20.69	
FE18	31.04	

Or *: open area ratio

4 RESULTS AND DISCUSSION

The relationships between the loading plate displacement and applied load for loading plate are as shown in Fig. 3. Each relationship in the begging of loading seemed to be linear. Reinforced using higher stiffness reinforcement, both limit proportion load and ultimate load became large measure. Ultimate load in FE18 is about second times as FE03. In every case, placed reinforcements did not brake in ultimate condition. Therefore, this difference of resistance behavior in loading is due to the reinforcement stiffness.

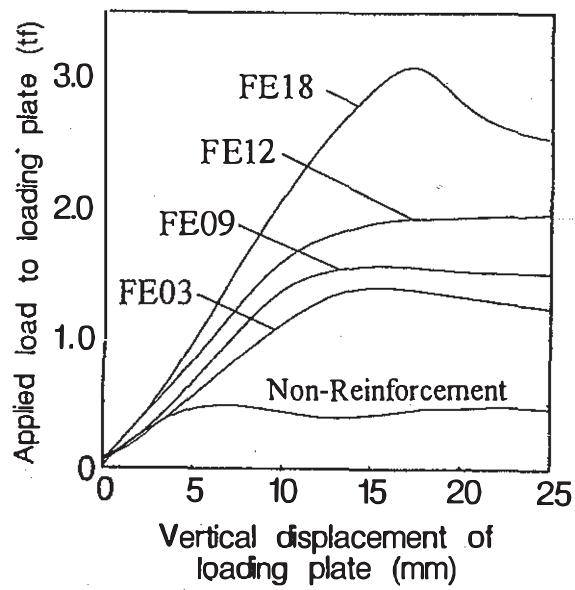
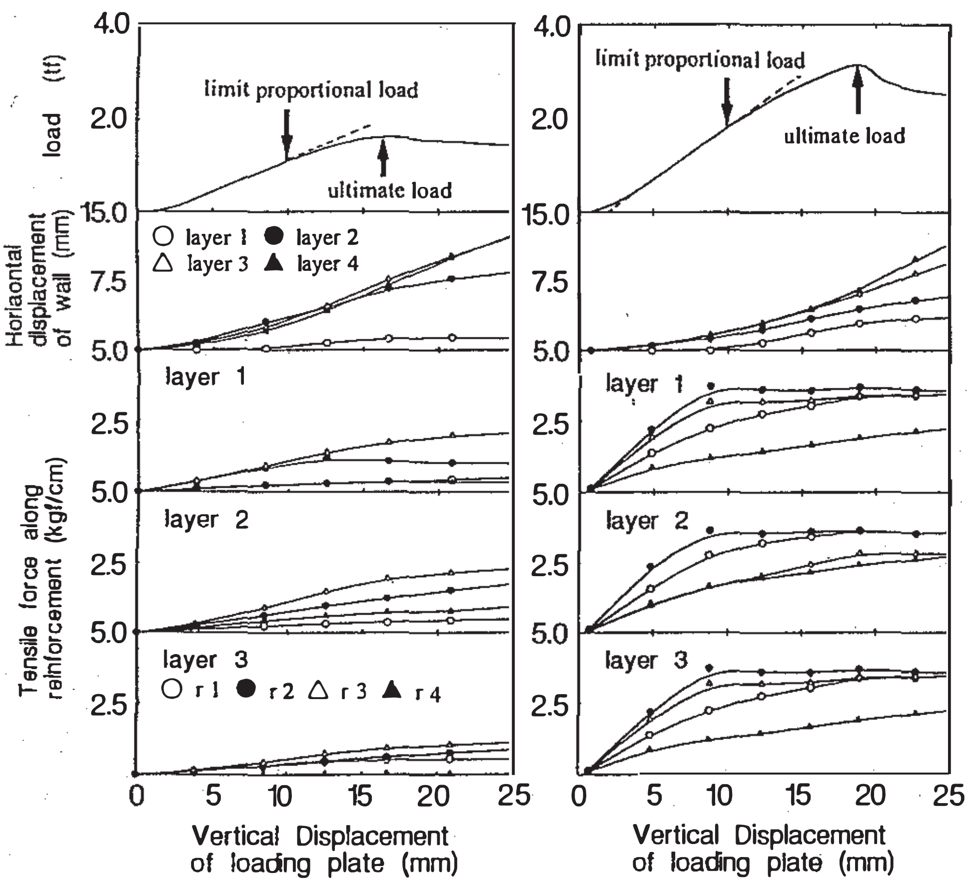


Fig. 3 The relationships between the loading plate displacement and applied load for loading plate



(a)FE03 (b)FE18

Fig. 4 Non-linear behavior of embankment

The relationships of loading plate displacement and applied load for loading plate, horizontal displacement, reinforcement force in the test case FE03 and FE18 are as shown in Fig. 4. In both case, when walls started moving, the relationship of load and loading displacement change non-linear from linear. In FE18 which show higher resistance behavior to over load, larger reinforcement force than FE03 mobilize on all over reinforcement. And in FE18, when increase of reinforcement force in the position r2 (see Fig. 1) stopped, the relationships of loading plate displacement and load changed non-linear from linear. At this moment, the local slippage between soil and reinforcement is suggest to be in the position. The other side, in FE03, the above mentioned behavior can not be seen. In this case, it can be suggested that soil did not deform reinforcement because of its shear failure, and that resistance behavior of embankment leaded to ultimate condition by accumulation of local soil shear deformation. It is investigated that relationship between stability of reinforced embankment and behavior of soil or reinforcement is closely related respectively.

Fig. 5 shows distribution of reinforcement force at ultimate load. In higher stiffness geogrid, higher tensile force mobilize along geogrid. In using higher stiffness reinforcement, magnitude of tension near the wall can not to be ignored. Therefore, the rapped around wall system stabilized the active zone in reinforced area. H.Miki et. al.(1992) discussed the effect based on analysis results of field test.

Fig. 6 is illustration show formed slip line in each test case. This is observed from side acryle panel of the testing box after loading test. From comparison of 4 reinforced cases and non-reinforced case, it can be seen that the slip line moving into the inner part because of reinforcement, but, there is no difference in reinforced cases .

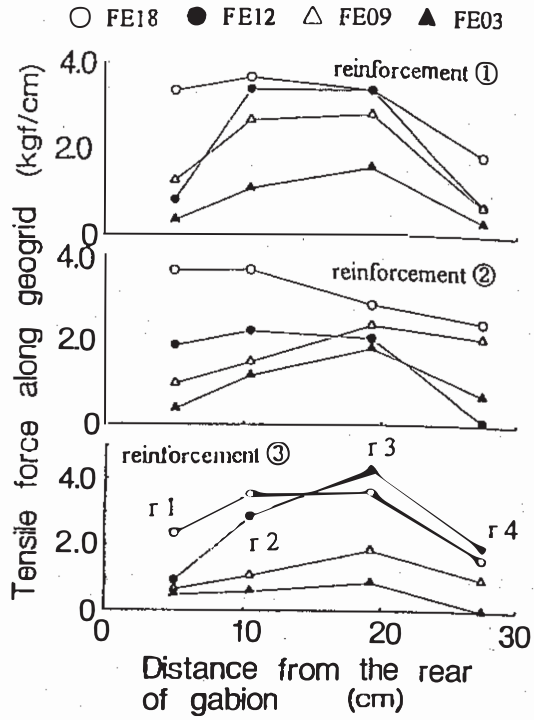


Fig. 5 Distribution of reinforcement force at ultimate load

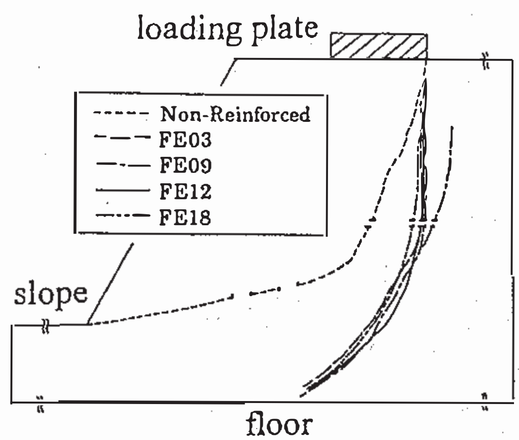


Fig. 6 Failure mechanism

5 CONCLUSIONS

Test results are summarized as follows.

(1)In the both of the two type tests, slip line in reinforced case arises more inner part in embankment than non-reinforced case.

(2)Reinforced using higher stiffness reinforcement, embankment resistance to the higher surcharge.

(3)A cause that reinforced embankment behavior in loading change from linear to non-linear is different in according to reinforcement stiffness.

(4)Rapped around wall system using high stiffness reinforcement stabilize the active zone in reinforced area.

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