Geosynthetics Asia'97, 26–29 November, Bangalore, India

BEARING CAPACITY OF GEOSYNTHETIC REINFORCED GROUND WITH DIFFERENT RELATIVE DENSITIES

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ABSTRACT : This study was performed to investigate the effects of the relative density on the geosynthetics reinforced sandy ground with horizontally one-layer reinforcement. A series of plane strain model tests on the sandy ground were performed with three different relative densities (Dr=49%, 68% and 86%). Values of 0.7B and 4B as the depth and length of one-layer reinforcement were used, where B is the loading plate width. Geosynthetics such as geonet, tensar grid and fortrac grid were used as reinforcing materials, and the standard sand of Korea, which is called 'Jumunjin sand', was used as a soil of model ground. From the test results it was shown that the effect of relative density was very great on the increase of the ultimate bearing capacity. However, BCR, which is the ratio of the unreinforced ground to the peak bearing capacity of reinforced one, was inclined to be almost constant in spite of the difference of relative density. And BCR_s which is defined as the bearing capcity ratio of the unreinforced ground to the reinforced one, at the same settlement, was smallest at Dr=68% among them.

1. INTRODUCTION

With relation to the increase of the bearing capacity in the foundation structures, the use of geosynthetics can be said to be an effective method. In case of reinforcement of sandy soils under the strip footing, there are several factors having an effect on the increase of the bearing capacity under the strip footing. Of them dominat factors are the reinforcing method, the kind of reinforcing material, and the friction between geosynthetics and soil. Also the friction characteristic has important relations with the density of subsoil.

The object of the study is to investigate the effects in the ultimate bearing capacity of geosynthetics reinforced sandy ground according to the variation of a relative density (49%,68%, and 86%). Here geosynthetics such as geonet and geogrid were used as reinforcing materials and Korea standard sand was used as a soil of model ground.

For the experimental results, the following items were investigated ;

1) load-settlement behavior according to relative densities, 2) failure shape of reinforced ground according to relative densities, 3) ultimate bearing capacity according to relative densities, 4) the effects of relative densities on the BCR, and BCRs.

2. EXPERIMENT

2-1. Model ground

The multiple sieving pluviation method was used in producing three model grounds with different relative densities. The production conditions of each model ground are shown in Table-1.

Table-1. Production conditions of model ground

Dr(%) / conditions	49	68	86
Number of sieve used	5	5	5
Size of sieve mesh(mm)	3	5.3	5.3
Falling height(cm)	50	70	70
Hopper diameter(mm)	40	40	10
Production time required	30 min	40 min	6 hours
Sand	Korea Standard Sand		

2-2. Test apparatus

The size of model test apparatus is 1200mm wide, 300mm long, and 700mm deep. The side wall of bin consists of transparent plastic plates, and rubber membrane. Silicon grease was used on both side plates of the bin to reduce the side friction. The force is applied on the ground surface by motor screw jack under the condition of 1mm/min of displacement speed.

2-3. Experimental conditions

One layer of geosynthetics is placed at the depth of 7cm from the surface, and 40 cm-length of geosynthetics was used. Experimental conditions are shown in Table-2.

Table-2. Experimental conditions

Relative Density (%)	Reinforcing Material		Maximum tensile strength (tonf/m)	Maximum tensile strain (%)	Grid size (mm)
49%	Unreinforced		-	-	-
	Rein-forced	Geonet-1	0.2	41.0	8×6
68%		Geonet-2	0.76	20.2	8×6
		tensar grid	1.2×1.7	15.0	29×38
86%		fortrac grid	5.5	12.5	20×20

3. EXPERIMENTAL RESULTS

3-1. Load-settlement on the unreinforced ground

Fig.3-1 below shows that bearing capacity is increased with the increase of relative density on the unreinforced model ground. From the relation between load and settlement of Fig.3-1, it was shown that clear peak appeared in the case of 86% relative density and slow peak in the case of 49% and 68% relative density.
That is to say, 86%-model ground is considered as general shear failure, while 49% or 68%-model ground as local shear failure.

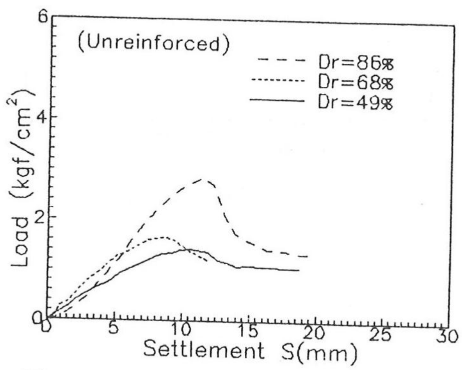


Figure.3-1 Load and Settlements

3-2. Load-settlement curve on the reinforced ground

Fig.3-2 shows the load-settlement curve according to relative density about 4 kinds of geosynthetics(a,b,c,d). From the figure, though the reinforcing effect was great, we can know that the shape of load-settlement curve is similar to that of the unreinforced. Accordingly we can know that the shape of load-settlement curve depends on the relative density, not on the existence of a reinforcing material.

3-3. Failure factors

There are two kinds of failure factors in destroying reinforced ground. The first is the breaking of geosynthetics due to the lack of tensile strength. The second is the pullout of geosynthetics due to the lack of pullout resistance. In this study the failure factor was observed after each model test for the confirmation of failure mechanisim. Table-3 shows the failure factor after each test according to various conditions.

Table-3. Failure factor

Geosynthetics / Dr	Geonet-1	Geonet-2	Tensar grid	Fortrac grid	Remarks
49 %	◎	◎	◎	◎	◎ : pullout failure × : breaking failure
68 %	◎	◎	◎	◎	
86 %	×	×	◎	◎	

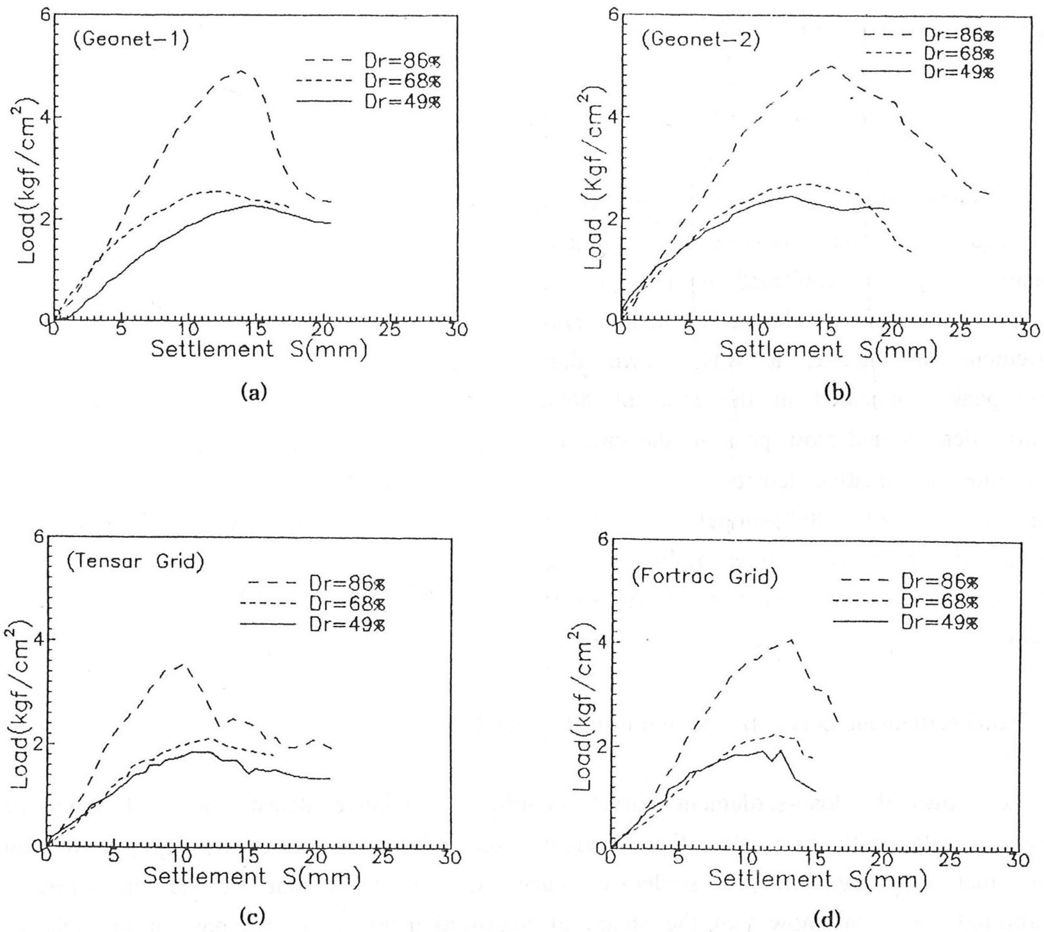


Fig.3-2 Load-settlement with relative densities

In Dr=86% the breaking failure happened in the test using geonet-1 and geonet-2 which have the weak tensile strength, while in case of the fortrac-grid and the tensar grid which have the stronger tensile strength showed the pullout failure. Fig.3-3 shows the broken shape of geosynthetics after test. From the figure we could confirm that the greatest tensile strength acts on the center of reinforcing material. Also, It shows that the relative density has an important effect on the failure factor. That is to say, if the relative density increases, the friction between soil and geosynthetics also increases. Accordingly in case of reinforced ground having high density and low strength, the ground will have much possibility to be failed due to the breaking of the geosynthetics, while in other case of reinforced ground having low density and high strength, the ground will have much possibility to be failed due to the pullout of the geosynthetics.

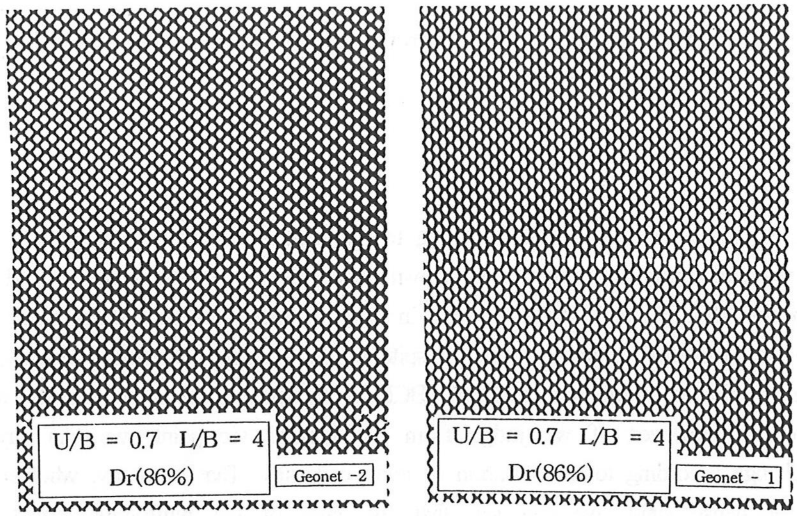


Fig.3-3 The broken shape of geosynthetics

3-4. Ultimate bearing capacity according to relative densities

Fig.3-4 shows the change of ultimate bearing capacity accodring to Dr about four kinds of geosynthetics and one unreinforced. When Dr changes from 49% to 68%, the increasing rate of ultimate bearing capacity averages about 13%. However, if Dr changes from 68% to 86%, the increasing rate of ultimate bearing capacity reaches 90%. And it shows that unreinforced one has also similar inclinations. From the result, it can be known that the relationship between Dr and the ultimate bearing capacity is not linear and the effect of Dr-difference under high density is very great.

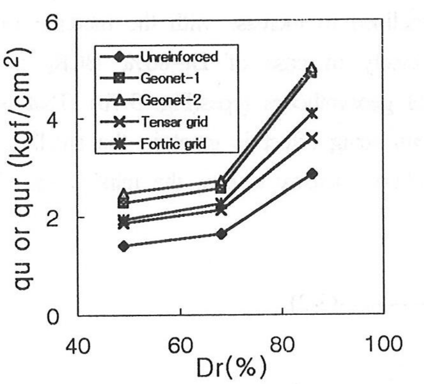


Fig. 3-4 Dr - the ultimate bearing capacity

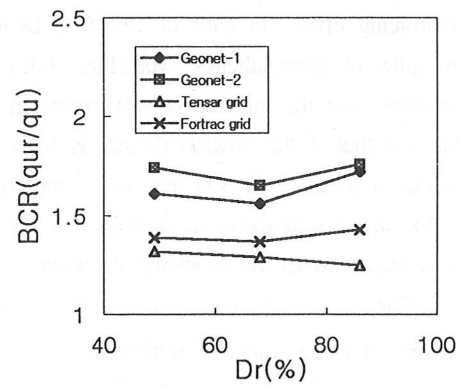


Fig.3-5 Dr - BCR

3-5. Bearing capcity ratio according to relative densities

Bearing capacity ratio is here defined as two kinds of concepts. One is called BCR defined as the ratio of the unreinforced ground to the peak bearing capacity of reinforced one, and the other is called "BCRs" defined as the bearing capcity ratio of the unreinforced ground to the reinforced one at the same settlement.

1) BCR

Fig. 3-5 shows the variation of BCR according to the relative density. When geonet-1 and geonet-2 were used as reinforcing materials, it is shown that BCR in Dr=68% has a little lower value compared to the Dr=49% and Dr=86%. And in case of using fortrac-grid as reinforcing material, BCR shows the inclination nearly constant in spite of the variation of relative density. Also in case of using tensar-grid as reinforcing material, BCR is inclined to decrease slightly as the relative density increases. However, if we judge from the general viewpoint, we can say there is no remarkable change according to the variation of relative density. That is to say, whether the ground is loose sand or dense sand, we can say that the ratio of the reinforcing effect reinforced by geosynthetics is nearly constant. The relation is expressed as the following equation.

$$BCR(Dr=49\%) \fallingdotseq BCR(Dr=68\%) \fallingdotseq BCR(Dr=86\%) \quad \text{———} \quad (3\text{-}1)$$

2) BCRs

Fig.3-6 shows the BCR_S according to the relative density and geosynthetics-type when the settlement is precribed as 5mm, 8mm, and 10mm. From the figure it is shows that with the exception of geonet-1, the other three kinds of geosynthetics had the same inclination. That is to say, BCRs shows the lowest value without exception in Dr=68%. However, we can know that as the settlement increases, the effect of relative density decreases. The friction between soil and geosynthetics happens with tensile strain of geosynthetics. Therefore there need some settlements in order to show the reinforcing effect. In case of Dr=68%, BCR_S is inclined to increase with the increase of settlements in spite of geosynthetics types(Fig. 3-7a). Conversely in case of Dr=86%, BCR_S is inclined to decrease with the increase of settlements in spite of geosynthetics types(Fig. 3-7b). That is to say, we can see that if the relative density is high, the reinforcing effect is great in the small settlements as is shown in fig 3-7b. On the other hand, if the relative density is low, the reinforcing effect is great in the larger settlements as is shown in Fig 3-7a.

It is expressed as the following equation.

$$BCR_s = ax + b \ (x = settlement) \quad \text{————} (3\text{-}2)$$

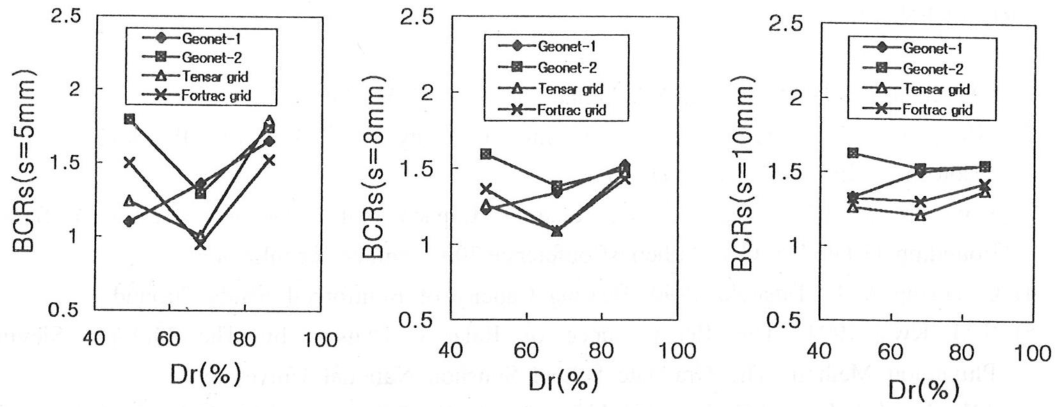
where , x is the value of settlement.

a >0 in case of Dr=49%

a <0 in case of Dr=86%

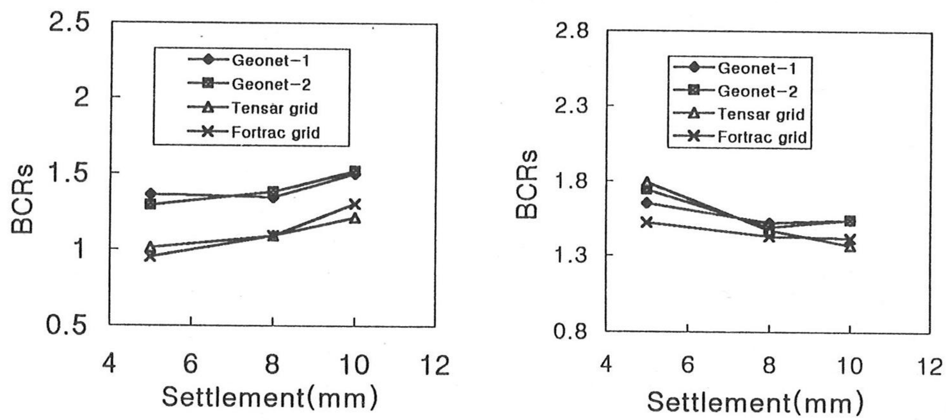
4. CONCLUSIONS

Model grounds with relative densities of 49%, 68%, and 86% for each were produced, and plane strain model tests on the ground reinforced by geosynthetics such as geonet, tensar grid, and fortrac grid were performed.



(a) (b) (c)

Fig.3-6 Dr -BCR_S



(a) (b)

Fig.3-7 Settlement - BCRs

From the results we could know that the shape of load-settlement curve depended on the relative density, not on the existence of a reinforcing material. We could know that in case of reinforced ground with high density and low tensile strength, the ground had much possibility to be failed due to the breaking of the geosynthetics, while in the other case of reinforced ground with low density and high tensile strength, the ground had much possibility to be failed due to the pullout of the geosynthetics. And there seemed no remarkable changes on the variation of BCR, regardless of whether the ground is loose sand or dense sand. In case of BCRs, we could see that if the relative density is high, the reinforcing effect is great in the small settlements, while if the relative density is low, the reinforcing effect is great in the larger settlements.

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