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Some factors affecting the results of soil-geogrid direct shear test

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ABSTRACT: This paper attempts to propose an appropriate technique for precisely estimating in-soil shearing resistance of geogrids based on the test results by using two types of direct shear box apparatus. A series of drained direct shear tests changing the configurations of soil and geogrid, roughness of dummy material on which the geogrid is glued, and the distance between the surface of geogrid and the shear plane was performed. Based on the test results, appropriate type of direct shear box apparatus and appropriate method of testing soil-geogrid direct shear test are proposed.

1 INTRODUCTION

For practical use of geotextile as a soil reinforcement material, suitability of the material should be checked by evaluating not only mechanical properties of itself but also soil-geotextile interaction properties. With the development of soil reinforcement technique, soil-geotextile interaction testing have been much performed. To say about a direct shear test, which is one of the method for obtaining frictional properties between soil and geotextile, different methods are used by different institutions. In this paper, factors affecting the results of soil-geogrid direct shear test is discussed by using two types of direct shear box apparatus and by changing testing methods. Based on the test results, proper method for precise estimation of in-soil shearing resistance of geogrids is proposed.

2 SOIL, GEOGRIDS AND TESTING APPARATUSES USED

Yufutsu Sand, mean diameter and uniformity coefficient of which is 0.29mm and 2.8 respectively, was prepared in a large scale direct shear box by multiple sieve pluviation method so as to have the relative density (Dr) of the sand to be 85%. Two kinds of geogrids, polymer grid SR2 and fiber geogrid CG-8, which are much different in shape with each other (Fig. 1) were used. Their properties are listed in Table 1.

Two types of direct shear test apparatus were

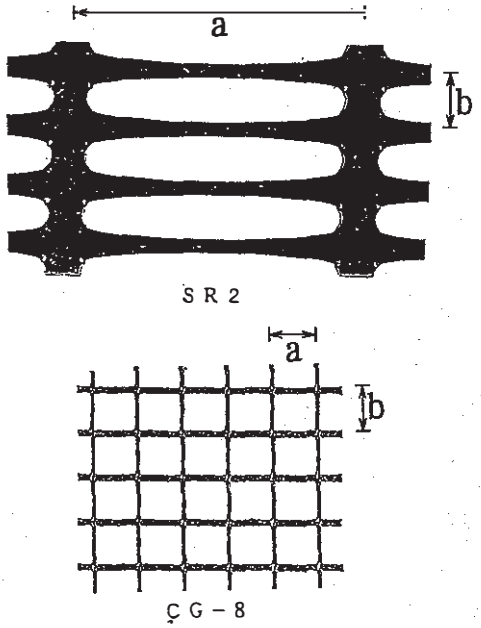


Fig. 1 Geogrids used for tests

Table 1. Properties of geogrids

grid	size (mm) a	b	tensile strength (kN/m)
SR2	110	22	80
CG-8	17	17	80

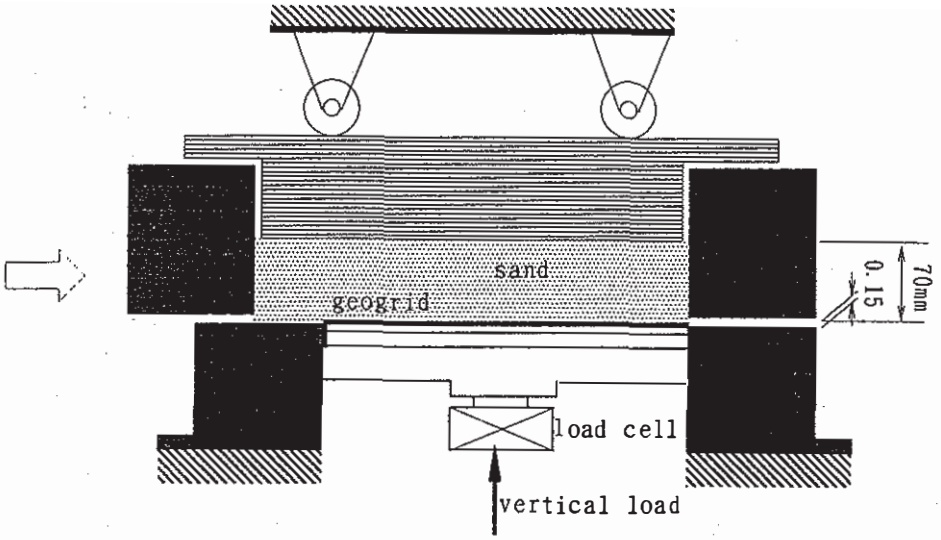


Fig. 2(a) Apparatus (a)

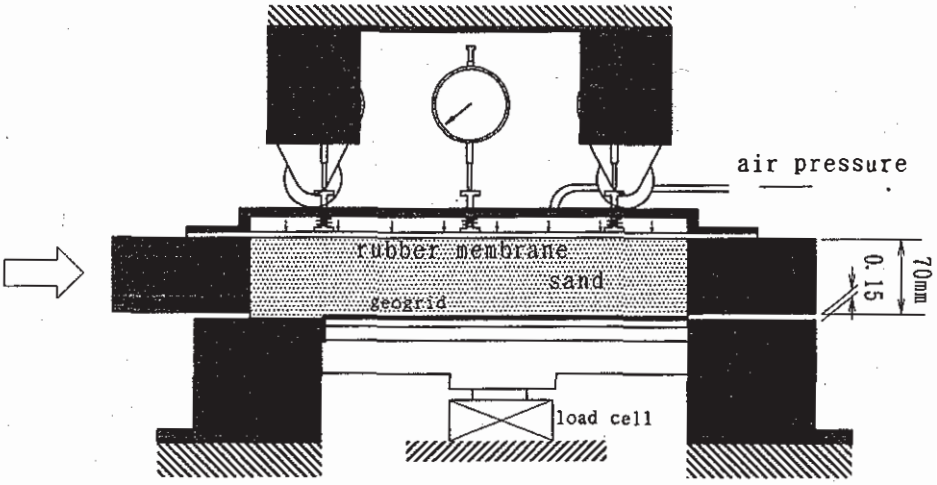
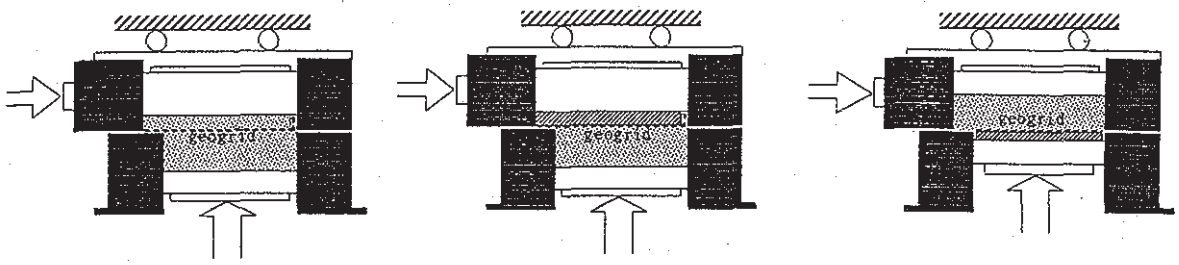


Fig. 2(b) Apparatus (b)

used to investigate the factors affecting the results of soil–geogrid direct shear test.

The first type (Apparatus (a), shown in Fig. 2(a)) is the apparatus in which vertical load is applied in the upper direction from the bottom of the lower box, and the vertical load is measured by a load cell installed at the same side. The displacement of the loading plate is measured as the vertical displacement of the test specimen. The second type (Apparatus (b), shown in Fig. 2(b)) is the apparatus in which vertical load is applied in the lower direction from the top of the upper box over a rubber membrane by air pressure, and measured by a load cell installed at the bottom of the lower box. Both apparatuses have 410mm * 50mm size upper box and 350mm * 350mm size lower box.



method 1)
geogrid installed between sand layers

method 2)
geogrid glued on the plate

method 3)
geogrid glued on the plate

Fig. 3 Test methods

3 TEST RESULTS

3.1 Influence of the relative position of the geogrid against the soil layer

To investigate the influence of the relative position of the geogrid against the soil layer on the test results, a series of drained direct shear tests on dry sand have been carried out with three methods by using Apparatus(a). In the method 1), the geogrid is installed initially at the position of potential shear plane in a sand layer. In the method 2) and 3), geogrid glued on the perspex plate is installed at the interface, where the geogrid locates over or under the sand layer, respectively.

Shear stress vs. horizontal displacement and vertical displacement vs. horizontal displacement relationships in direct shear test results on polymer grid SR2 by three methods mentioned above are shown in Fig. 4. In the case of method 3), marked positive dilatancy is developed during shear, and peak shear stress becomes as large as that of the test results with sand only. As the shear progresses, shear stress decreases toward the residual value in method 1) and method 2). In the case of method 2), as the geogrid SR2 has flat and wide ribs, apertures of geogrid are not filled with sand particles in the initial stage of shear. As the shear progresses, apertures of geogrid gradually become to be filled with sand particles and stresses are fully transmitted to the sand particles in the apertures. Paying attention to the residual shear stress, test results by three methods are close to one another, even though there appears some differences due to the difference of resisting mechanism, and as a whole, test results by method 1) is plotted in the middle of others. In the method 1), since there is a possibility in which

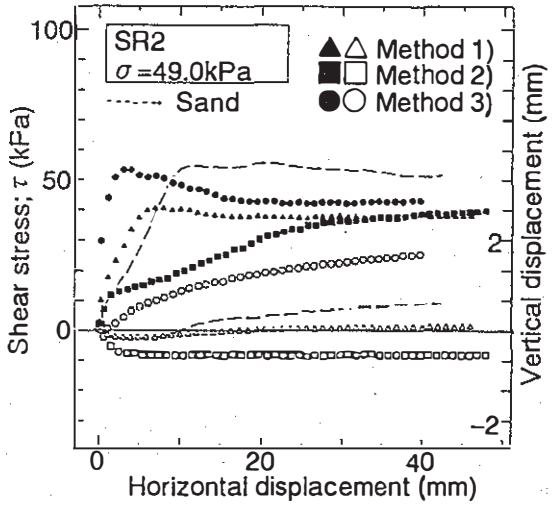


Fig. 4 Shear stress vs. horizontal displacement and vertical displacement vs. horizontal displacement relationships (Apparatus (a))

a thick shear plane is developed by the movement of the shear plane due to dilatancy during shear, shear resistance not between sand and geogrid but between sand particles could be measured. As described above, the authors recommend the test method 3) as a best one. But in this method, it is necessary to make correction on a test results relating with dilatancy. The influence of surface roughness of dummy plate on which geogrid glued and the influence of the vertical displacement of geogrid due to consolidation or dilation during shear are described later.

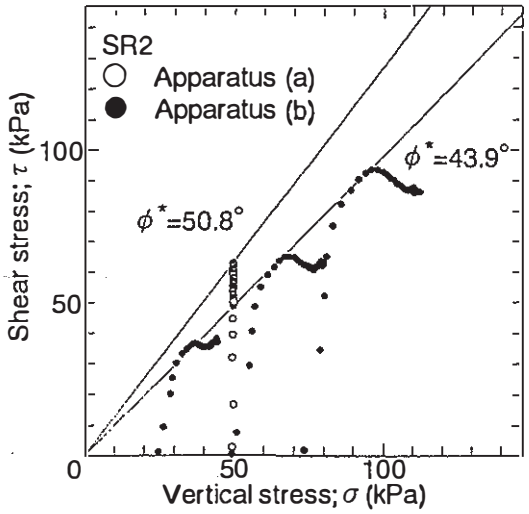


Fig. 5 Test results using Apparatus (a) & (b)

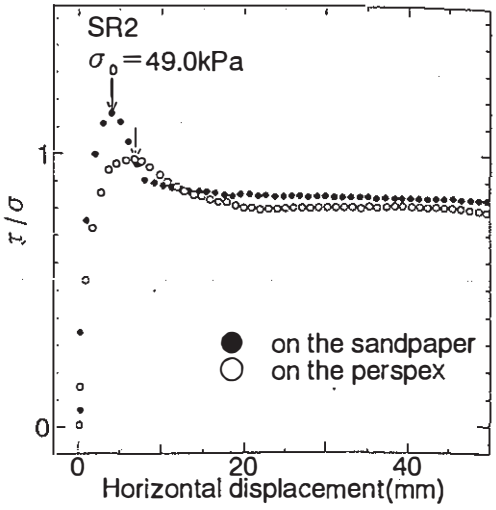


Fig. 7 Test results using Apparatus (b) with changing material of the dummy plate

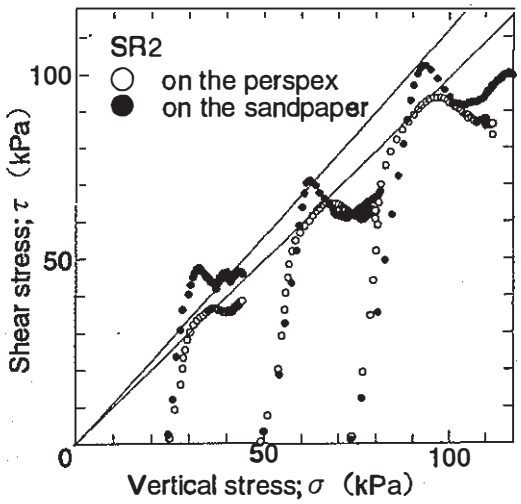


Fig. 6 Test results using Apparatus (b) with changing material of the dummy plate

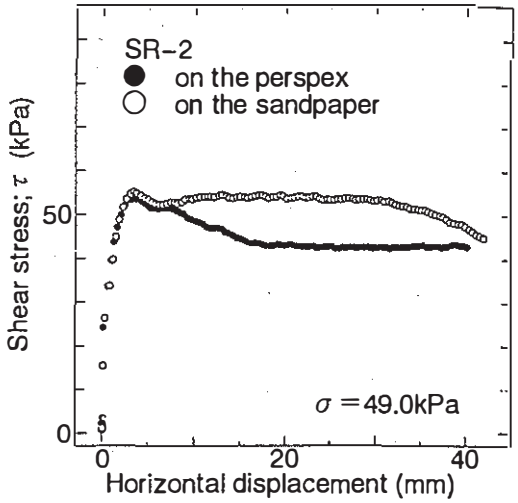


Fig. 8 Test results using Apparatus (a) with changing material of the dummy plate

3.2 Influence of the different method of controlling and measuring normal stress

Shear stress vs. normal stress relationship obtained by direct shear test on sand–polymer grid SR2 using Apparatus (a) and (b) are shown in Fig. 5. As the normal force for Apparatus (a) is applied and measured at the same side, the measured normal stress shows prescribed constant value. In contrast to this, the normal stress measured by Apparatus (b), in which the load cell is installed at the opposite side of the normal pressure loading system, changes due to the dilation of sand particles in the vicinity of the shear plane during shear though the applied normal pressure is kept constant. Accordingly, it is necessary to measure a correct normal stress at the shear plane where geogrid is installed, because the normal stress at the shear plane may change during shear even in the nominal vertical load constant direct shear test.

Fig. 5 also shows that the angle of shear resistance ϕ^* obtained by Apparatus (a) could be apparently evaluated larger than ϕ^* obtained by Apparatus (b).

3.3 Influence of surface roughness of the dummy plate on which geogrid glued

Test results using Apparatus (b) with changing material of the dummy plate, perspex plate and sandpaper, on which geogrid glued are shown in Fig. 6. According to stress paths in Fig. 6, the peak shear stress obtained by the test using sand paper is

larger than that by using perspex plate, but the increment of normal stress is not so much compared with the results of perspex plate. Shear stress vs. horizontal displacement relationship from the same test results are shown in Fig. 7. It is shown that the shear stress in the case using sand paper reaches peak stress earlier than the case using perspex plate. According to the results shown above, in the case using the material with a rough surface like a sand paper as a dummy plate, the large shear stress is exerted on the test specimen from the initial stage of shear due to the interlocking between sand particles and rough surface of the plate in the apertures of geogrid. On the other hand, in the case using the material with a smooth surface like a perspex plate, sand particles in the apertures of geogrid are pushed out of the apertures from the initial stage of shear. As a result, sand packing in the vicinity of the geogrid becomes looser than that at the initial state.

Test results using Apparatus (a) are shown in Fig. 8. It appears from the figure that the surface roughness of the dummy doesn't affect the shear stress from the initial stage of shear to the peak stress, but affects the stress change from the peak to the residual state. The difference of the test results obtained by two types of apparatus depends on the way to apply the normal stress. In other wards, when dense sand is put between solid plates, the normal stress is not transmitted to the sand particles in the apertures of geogrid especially in the initial stage of shear. As the shear progresses and reaching to the residual state, the normal stress fully transmitted to the sand particles in the apertures of geogrid and the frictional resistance is exerted between sand particles and dummy plate. In the case of Apparatus (b) whose test results are shown in Figs. 6 and 7, since the normal stress is applied over the flexible rubber membrane and the normal stress is measured at the opposite side, it is possible to evaluate both the normal and shear stresses between sand and dummy plate precisely from the initial stage of shear.

3.4 Influence of the vertical movement of geogrid during shear

From a series of direct shear test with two types of geogrid (CG-8 and SR2) glued on a perspex plate fixed at the four different vertical positions by using apparatus (b), τ / σ vs. vertical distance between the perspex plate and shear plane (d: in Fig. 10) relationships are shown in Fig. 9. For comparison, a series of test using plain perspex plate was also performed.

Fig. 9 shows that τ / σ takes minimum value when the surface of the plain perspex plate is

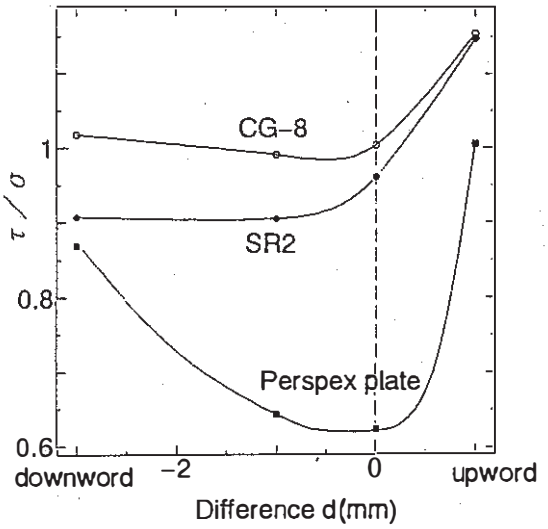


Fig. 9 τ / σ vs. vertical distance between the perspex plate and shear plane (d: in Fig. 10) relationships

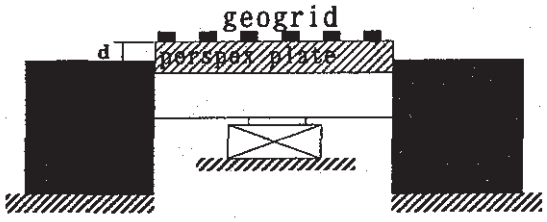


Fig. 10 Vertical distance between the perspex plate and shear plane

arranged at the same position of the potential shear plane (d=0). In the case using a geogrid glued on a perspex plate, τ / σ takes minimum value when the upper surface of the perspex plate is installed a little lower than the potential shear plane. The suitable position depends on the thickness and the surface roughness of the geogrid. τ / σ increases markedly when the geogrid glued on a plate is installed higher than the shear plane when comparing with the case mentioned above. This means that the test using Apparatus (a) overestimate the frictional resistance of soil-geogrid when the loading plate moves upward due to consolidation or dilation of loose sand during shear.

4 CONCLUSIONS

Based on a series of test results by using two types of direct shear box apparatus and by changing the factors affecting the test results, the authors

recommend the followings as the appropriate testing method:

1)A type of apparatus as shown in Fig. 2(b) should be used, in which the normal stress can be applied over a flexible boundary and be measured at the opposite side.

2)Test specimen of the geogrid glued on the dummy plate should be placed under the sand layer and the surface of dummy plate should be arranged a little lower than the potential shear plane. The suitable position depends on the thickness and the surface roughness of the geogrid.

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