Sandy soil-geogrid interface behavior under changes of water content

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ABSTRACT: Heavy rainfall is considered to be the main cause of the slope failures that lead to collapse catastrophically without prior warning. Even in the geogrid reinforced soil structures, the possibility of collapse caused by rainfall remains. The infiltration induced by rainfall might weaken the reinforced strength and the stability potential. In order to investigate the effect of rainfall on the stability of geogrid reinforced soil structures, this paper presents the results from a series of pullout tests investigating interface behavior between soil and geogrid paying attention to the rainfall infiltration.. It is shown that the water presence dominate the behaviors of soil-geogrid interface and soil mass around it. This study also provides a basis for further research the strength loss of reinforced soil structures induced by heavy rainfall.

1 INTRODUCTION

The geogrid-reinforced soil structures play important roles in the reinforcement applications since 1980s. However, the soil-geogrid interaction behavior paying attention to the rainfall infiltration is not directly considered in engineering practice. Instead, the interaction strength is conservatively represented by the consolidated drained strength of soil. As a result, reinforced soil structures remain the possibility to failure caused by rainfall even totally following design code. Shibuya et al. (2007) presented a case history study of reinforced retaining wall collapse caused by rainfall, although the retaining wall fully satisfy the request of Japanese design code.

Therefore, soil-geogrid interaction behavior need to be directly investigated considering the rainfall infiltration. Abu-Farsakh et al. (2007) surveyed the soil-geogrid interaction through large-scale direct shear tests considering the moisture content. And with the help of improved pullout test device, Zhang and Yasufuku (2008) investigated pullout behavior paying attention to the influence of water presence. It was pointed out that the increase in water content could significantly reduce the reinforcement resistance due to the reduction of the soils' suction with the increase in moisture content and the possible development of excess pore water pressure in near saturated clays, which reduced the effective stresses and the shear resistance.

In this research, improved pullout tests simulating in-suit rainfall infiltration are conducted. In order to survey the infiltration effect on interaction behavior, the pullout behavior of infiltrated soil samples are compared with the pullout behaviors of dry soil sample and soil sample with optimum water content. And the soil samples in pullout tests are prepared in different degree of compaction for investigating the compaction effect. Moreover, direct shear tests are performed to investigate the mechanism how the rainfall infiltration affects the interface behaviors.

2 TEST PROGRAMS

2.1 Materials tested

Cohesionless soils are considered as insusceptible to water in earth-reinforced soil structures due to their relative good drainage. As a result, the impact of water presence on sandy soil-geogrid interaction is investigated here. As typical standard silica sand in Japan, Toyoura sand is selected to be surveyed in this study. Meanwhile, as widely used geogrid in engineering practice, the biaxial geogrid SS2 is investigated in this research. The physical properties of tested soil and geogrid are presented by Zhang and Yasufuku (2008).

2.2 Pullout test

In order to simulate the rainfall infiltration, the pullout test device is improved. The details of improved pullout test device are introduced by Zhang and Yasufuku (2008).

Palmeira and Milligan (1989) reported that the wall roughness dramatically increased the bond resistance between soil and reinforcement in pullout test. Ochiai et al. (1996) lubricated interfaces between soil and inside walls with greased rubber membranes in order to diminish boundary frictions. Such method is also utilized in this research.

Three kinds of pullout tests are performed here, dry test, unsaturated test and infiltrated test.

The pullout tests for dry samples are carried out as follows: (1) the soil was poured into the pullout chamber in 8 layers and is suitably compacted. The density is controlled by means of changing weight of soil specimen; (2) the geogrid is placed in sand between layer 4 and layer 5, with the displacement measurements; (3) the air bag is applied on top of the soil to provide uniform vertical stress at the top of pullout chamber. The geogrid is pulled out of the soil sample after the air pressure achieves the target value; (4) the pullout tests are carried out under a constant speed of 1mm/min through a screw jack. The length of geogrid inside the pullout chamber is maintaining constant during pullout process.

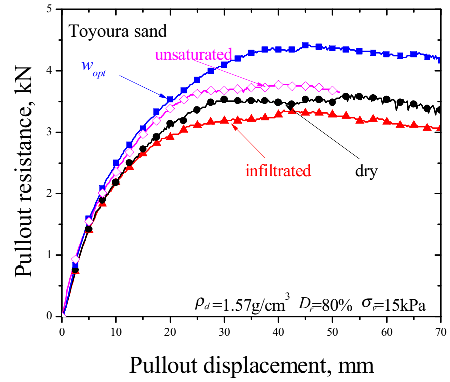
The pullout force measured by tension load cell and displacements measured by displacement sensors and measured soil stress on bottom are recorded by the data acquisition system (TD-303).

For unsaturated and infiltrated test, the test procedures are basically the same as that of dry test. The soil samples for unsaturated and infiltration are prepared with same optimum water content in (1). Other procedures of unsaturated tests are the same with that of dry tests. For infiltrated tests, a water bearing layer is set up before air bag pressure to provide water infiltrating into the soil sample under overburden pressure. The tension meters, soil moisture sensors and vertical displacement on the top of soil sample are monitored so as to determine whether the infiltration procedure is finish. When the records from these sensors remain stable, the infiltration procedure could be regarded as completed. After finishing infiltration process, the pullout method follows the procedures of dry tests.

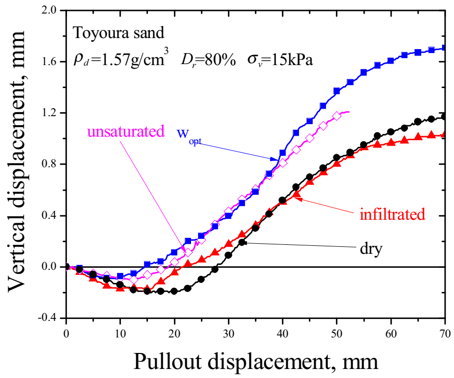
2.3 Direct shear test

The pullout strength mobilized between geogrid and soil might be regarded as stress transferred from bearing resistance on the transverse members and the shear stress mobilization on the top and bottom surface of the geogrid. Therefore, direct shear test pay attention to the effect of infiltration on soil shear strength are performed so as to investigate the mechanism of infiltration influence on interaction behavior between soil and geogrid.

The automatic direct shear test apparatus applied here for unsaturated soil is able to implement monodirectional shear test and cyclic shear test on unsaturated soil. The sheared soil sample is 60mm in diameter and 20mm high. The maximum overburden pressure in direct shear cell is 500kPa. Meanwhile, the minimum overburden pressure is 2kPa considering that most infiltration occur in shallow layer of soil structures. The control system is capable of controlling either shear speed or shear force in test. The direct shear speed is able be chosen from 0.001mm/min to 10mm/min, and the direct shear force could maintain constant within 5kN.

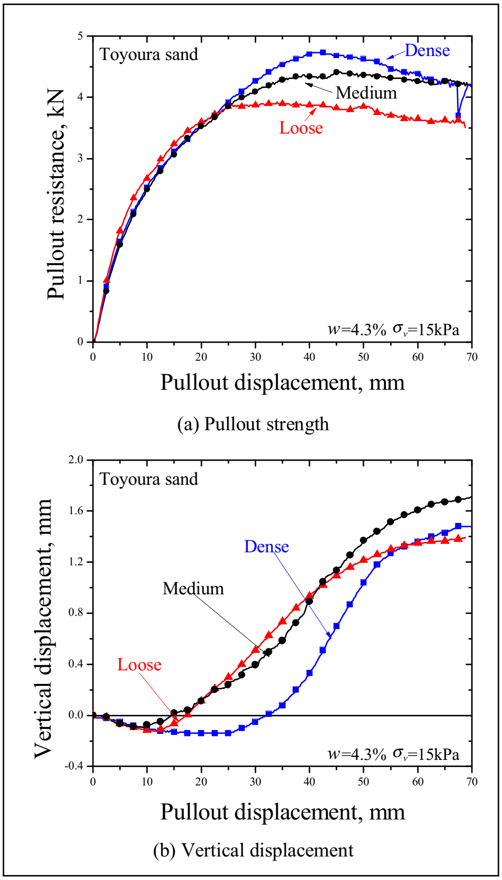


(a) Pullout strength



(b) Vertical displacement

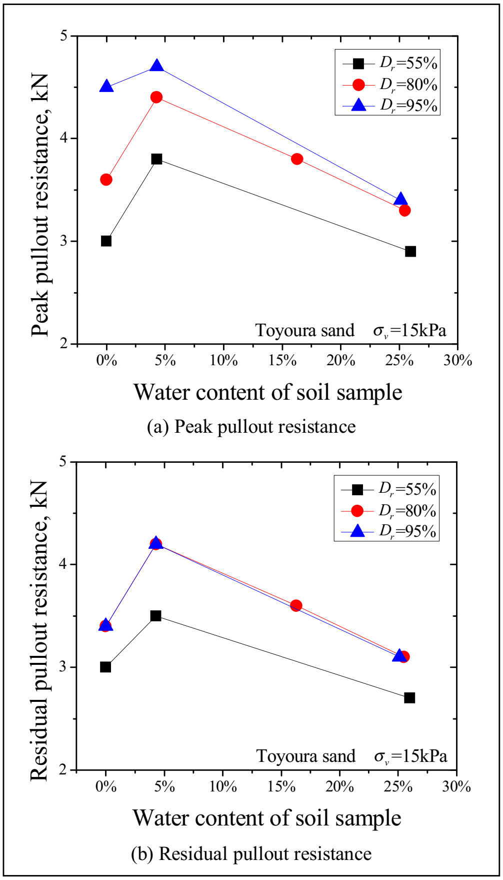
Figure 1 Pullout behaviors of medium Toyoura sand under σ_v =15kPa considering infiltration



(a) Pullout strength

(b) Vertical displacement

Figure 2 Pullout behaviors of unsaturated Toyoura sample under σ_v =15kPa



(a) Peak pullout resistance

(b) Residual pullout resistance

Figure 3 Schematic view of pullout resistance considering infiltration under σ_v =15kPa

3 PULLOUT TEST RESULTS AND ANALYSIS

According to the compaction curve of tested soils by Zhang and Yasufuku (2008), the maximum dry density from standard compaction test is 1.51 g/cm^3 for Toyoura sand. It is noted that the dry density of Toyoura sand varies fractionally for different degree of compaction under the compaction energy of standard compaction test. Therefore, the density of Toyoura sand tested is controlled by relative density instead of compaction degree. The denser Toyoura soil samples are obtained by enhance compaction energy compared to standard compaction test (JGS 0771-2000).

3.1 Infiltration effect on pullout resistance

Figure 1 presents typical pullout behavior for Toyoura sand considering infiltration. All the pullout tests here are carried out under overburden pressure σ_v =15kPa. The dry density ρ_d in Figure 1 is 1.57 g/cm^3, and relative density D_r is equal to 80%. The pullout strength behaviors are shown as pullout strength in pullout jack against pullout displacement in pullout jack. In the vertical displacement figures, negative denotes the compression of soil sample, and the positive denote the dilatancy of the soil sample. It is clear that the pullout resistance is greatest in the state of optimum water content. And the pullout resistance decreases as the increase of the water content of soil sample. The pullout resistance of soil after infiltration is least. It demonstrated that the geogrid pullout strength embedded in soil decreased by rainfall infiltration.

3.2 Compaction effect on pullout resistance

The degree of compaction is very important state parameter for soil engineering behavior. Typical

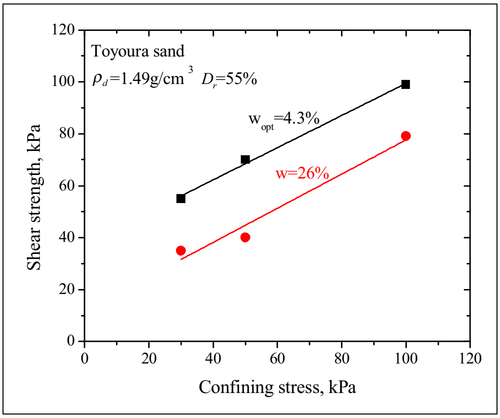


Figure 4 Soil strength of loose Toyoura sand

pullout behaviors considering compaction effect are presented in Figure 2. The pullout behaviors are compared in varied density linked with degree of compaction. The degree of compaction here is indicated by the relative density. The reason is that the density range of Toyoura sand is narrow under standard compaction test.

Compaction effect is well accepted that it could enhance the mechanical properties of soil in engineering practice. The same behaviors are obtained here. Better compacted soil sample reveals better pullout strength. The enhancement of compaction in peak pullout strength is distinct. However, there is limitation enhancing residual pullout resistance by compaction (shown in Figure 3).

3.3 Mechanism of rainfall infiltration

The pullout resistance of geogrid is close linked with the strength indexes of soil around the geogrid. Therefore, direct shear test is helpful to understand the interaction behavior between geogrid and soil. Figure 4 presents the test results from consolidated drained direct shear test for loose Toyoura sand. Soil sample with optimum water content and infiltrated soil sample are investigated respectively. The average water content of infiltrated soil sample is 26%, which is checked right after the pullout test.

It could be seen obviously that the suction in soil sample with optimum water content provides cohesion between soil particles, increasing the soil strength. The suction is the distinct factor enhancing the pullout resistance.

In the other hand, the fitting frictions angles for unsaturated soil sample and infiltrated soil sample $\phi = 31.8^{\circ} \pm 1.7^{\circ}$ and $\phi = 33.4^{\circ} \pm 4.7^{\circ}$ respectively. Considering the scatter of experimental results, they are close. It indicates that the frictional behavior of Toyoura sand is not influenced by infiltration. As a result, the interface frictional resistance between geogrid and soil is not obviously affected by infiltration.

At the same time, the cohesion of infiltrated soil sample which is near saturated is 11.9 ± 7.9 kPa. It indicates that the strength indexes of infiltrated Toyoura sand is close to the strength index of dry Toyoura sand. However, the pullout strength of infiltrated soil sample is also smaller than dry soil sample's (as shown in Figure 1) even though the strengths of soils in front of transversal ribs are close. The reason for such reduction of pullout strength might be that the generation of excess pore water pressure. The excess pore water pressure generated as the pullout resistance mobilization even the permeability of Toyoura sand is good.

4 CONCLUSIONS

Study on the pullout resistance of geogrid-Toyoura sand interface with the presence of infiltration is carried out. The following remarks could be drawn:

- The improved pullout test device is able to simulate the field infiltration process induced by rainfall.
- The effect of suction on the pullout resistance is distinct for Toyoura sand.
- Compaction could increase the peak pullout resistance, however, it could not enhance the residual pullout strength effectively.
- Both suction decreases and excess pore water generation are the main mechanism induced by rainfall infiltration to reduce the interaction resistance between soil and geogrid.

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