Influence of Water Content on Pullout Behaviour of Geogrid

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Abstract. The interaction between geogrid and soil is fundamental and crucial factor on safety and stability of geogrid-reinforced earth structure. Therefore, the interface index between geogrid and soil is of vital importance in the design of reinforced earth structures. The pullout behaviour of geogrid in soil is studied, an experimental investigation is conducted using geogrid in four groups of soil with 20%, 24%, 28%, 32% water contents, which correspond to normal stresses of 50, 100, 200 and 300 kPa respectively. The results indicate that the geogrid embedded in soil mainly represents pullout failure, and the ultimate pullout force is sensitive to water content. It decreases with the increase of the water content firstly. Besides, the water content influences the process of the pullout behaviour. The increase of water content leads to the ultimate pullout force soon.

1. Introduction

Geogrid is commonly used in many works such as soil reinforced walls, soft ground improvement, roads and railway embankments, slope stabilizations and bridge abutments constructed also in seismic areas. In all previous applications the main function of geogrid is reported to be the soil reinforcement and the high tensile resistance, and the long-term efficient tensile behaviour of these materials makes possible this function. Wilson [1-2] studied of the short-term and long-term pullout characteristics in detail, a set of methods for predicting the pullout resistance of geogrid in sand soil was obtained. Sugimoto M [3-4] used the stress and strain equation of the pull-out test to simulate the pullout characteristics of the whole geogrid and achieved good results fruit. Farsakh [5] studied the pullout behaviour of geogrid in clay and obtained the formula for calculating the pullout resistance. Yang Guang-qing [6] studied the interface characteristics of geogrid in clay and sand soil, the results show that the shear strength is high in sand soil. Shi You-zhi [7] studied the pullout process of geogrid in the soil and divided the test into 4 stages. Ma Cun-ming [8] and Zhang Bo [9] studied on interface friction of plastic geogrid reinforce earth At present, the studies about water content influences the pullout behaviour were relatively less, so this study was particularly important. This paper carried out a series of pullout tests for geogrid reinforcement soil, testing the relationship between the ultimate pullout capacity and normal pressure under the different water content.

2. Pullout test

2.1. Fill material

Soil used in pullout test is taken from the library construction site of Northeast Electric Power University in the northeast province of Jilin, China. The buried depth of undisturbed soil sample is about 1.5 m. It has well-graded, non-uniform grain size and less impurities. Soil samples after drying, crushed, grinding treatment is shown in figure 1. The conventional tests were conducted including the grain size distribution analysis, specific gravity test, liquid plastic limit test, compaction test. The soil...
properties are shown in table 1. Based on the grain size distribution analysis and plastic index, the soil is named as silty clay.

Table 1. Properties of test soil

| Property                   | Value |
|----------------------------|-------|
| Specific gravity, $G_s$    | 2.72  |
| Plastic limit, $w_p$       | 25.27%|
| Liquid limit, $w_l$        | 36.58%|
| The maximum dry unit weight, $\rho_{d,\text{max}}$ | 1.74g/cm |
| Optimum moisture content, $w_{op}$ | 16.5% |

2.2. Geogrid

One geogrid, identified as TGSG3030, was used in this investigation. Specifically, the geogrid products were biaxial geogrid that was made of PP. It is manufactured by BOSTD Geosynthetics Qingdao Ltd. in China. The geometric features and main indexes of the geogrid were shown in figure 2 and table 2.

Table 2. The main indexes of the geogrid in test

| Property                             | Value  |
|--------------------------------------|--------|
| Transverse value of aperture, $A_T$ (mm) | 32.08  |
| Longitudinal value of aperture, $A_L$ (mm) | 36.12  |
| Width of longitudinal ribs, $F_{WL}$ (mm) | 2.38   |
| Width of transverse ribs, $B_{WT}$ (mm) | 2.14   |
| Thickness of transverse ribs, $t_{B}$ (mm) | 2.25   |
| Thickness of longitudinal ribs, $t_F$ (mm) | 1.23   |
| Tensile strength (at 2% strain) (kN/m) | 13.6   |
| Tensile strength (at 5% strain) (kN/m) | 24.9   |
2.3. Pullout test device
The integrated test system about geosynthetics was used in this investigation, which could do most conventional test about geogrid. The picture about device was shown in figure 3. The length, width and height of soil-bin are 210 mm, 200 mm and 115 mm. The normal pressure was accurately applied by airbag, and the pullout load was applied using a universal load frame, capable of recording the pullout load and the front displacement.

![Figure 3. Integrated test system about geosynthetics](image)

2.4. Experimental Method
The soil used in the pullout test program was placed at the lower shear box. The soil was compacted in three layers. The geogrid specimen was then positioned on top of the lower shear box and subsequently clamped on the front edge of the lower shear box. The pullout tests were conducted using normal stresses of 50, 100, 200 and 300 kPa respectively. Consistent with the test device, a pullout rate of 2.2 mm/min was used during testing. When the peak of the pullout forces appeared, continued the pullout test until pullout forces became stable, then stopped the experiment. Besides, The tests were terminated when the displacement reached approximately 30 mm, which corresponds to the maximum travel allowed in the equipment. The test program was shown in table 3.

### Table 3. Pullout test program

| Influence factor | Test No | Water content (%) | Normal pressure (kPa) |
|------------------|---------|-------------------|-----------------------|
| Water content    | A1      | 20                | 50, 100, 200, 300     |
|                  | A2      | 24                |                       |
|                  | A3      | 28                |                       |
|                  | A4      | 32                |                       |

3. Experimental results and analysis
The pullout test results are analyzed in order to evaluate the influence on the peak pullout resistance and on the interface pullout friction coefficient of different water content investigated in the research. According to the formula (1) and (2), the pullout friction strength between the geogrid and soil as well as the pullout friction coefficient of the geogrid could be calculated. That is

\[
\tau_p = \frac{T_p}{2LB}
\]

\[
f = \frac{\tau_p}{\sigma}
\]

Where \(\tau_p\) = pullout friction strength; \(T_p\) = ultimate pullout force; \(L\) = the length of geogrid buried in the soil; \(B\) = the width of geogrid buried in the soil; \(f\) = the pullout friction coefficient; \(\sigma\) = the normal pressure.

The load- displacement curves obtained from the pullout tests conducted on silty clay, the curves were shown in figure 4. The curves indicated that the pullout friction strength increased with the increase of
displacement when the normal stress was 50kPa and 100kPa, the pullout friction strength achieved the limit value and remains stable when the pullout displacement continued to increase. The tests were terminated when the displacement reached approximately 30 mm. The geogrid broken in the process of pullout test when the pullout friction strength was greater than the tensile strength of geogrid, the $2\tau_p$ didn’t reach the limit value under this condition. From (a) to (d) of figure 4, when the normal stress was 300kPa, the $2\tau_p$ was nearly 200 kPa at 20% water content, the $2\tau_p$ was nearly 130 kPa at 32% water content, so the $2\tau_p$ decreased with the increase of water content under different normal stress.

![Figure 4](image1.png)

**Figure 4.** Relation load-displacement curves of pullout test under different water content

![Figure 5](image2.png)

**Figure 5.** Relation between pullout friction coefficient and water content

On the basis of these formulas the friction coefficient under different water content and normal stresses can be achieved, the curve was shown in figure 5. When the normal stress was 50kPa, the $f$ was nearly 2 at 20% water content, the $f$ was nearly 0.8 at 32% water content, the $f$ had a great decrease. It indicated that the pullout friction coefficient between the geogrid and soil would decrease with the increase of water content. It had charged effect on the surface of the clay particles, which adsorbed water molecules and formed water membranes. With the increase of the water content, the water membranes became thin gradually.
Therefore, the friction force between the soil and geogrid decreased gradually, in this case, the pullout friction coefficient would decrease with the increase of soil moisture content.

4. Conclusion
A series of pullout tests were conducted to evaluate the influence of water content on pullout behaviour of geogrid. The main conclusions that can be drawn from this investigation are as follows:

- The pullout friction strength of geogrid decreased with the increase of water content under different normal stress. The geogrid broken in the process of pullout test when the pullout friction strength was greater than the tensile strength of geogrid.
- The test results show that the influence of water content within the range of this experiment (20%~32%) seems to be significant, the friction coefficient between the geogrid and soil would greatly reduce with the increase of moisture content in soil.

5. Acknowledgement
This financial is supported by the National Natural Science Foundation of China (Grant No. 51409045) and the Science and Technology Development Project of Jilin Province (Grant No. 20170520105JH).

6. Reference
[1] Wilson Fahmyr F, Koerner R M and Sansone L J 1994 Experimental behaviour of polymeric geogrids in pullout Journal of Geotechnical Engineering 120(4) pp 661–677
[2] Wilson Fahmyr F, Koerner R M and Harpur W A 1995 Long-term pullout behavior of polymeric geogrids Journal of Geotechnical Engineering 121(10) pp 723–728
[3] Sugimoto M and Alagiyawanna A M N 2003 Pullout behavior of geogrid by test and numerical analysis Journal of Geotechnical and Geoenvironmental Engineering 129(4) pp 361–371
[4] Sugimoto M, Bueno B S and Zornberg J G 2007 Pullout resistance of individual longitudinal and transverse geogrid ribs Journal of Geotechnical and Geoenvironmental Engineering 133(1) pp 37–50
[5] Farsakh M, Farrag K and Almohd I 2005 Bearing and frictional contributions to the pullout capacity of geogrid reinfor-cements in cohesive backfill Proceedings of the Geo-frontiers Congress pp 1-11
[6] Yang Guang-qing, Li Guang-xin, Zhang Bao-xian 2006 Experiment studies on interface friction characteristics of geogrids Chinese Journal of Geotechnical Engineering 28(8) pp 948-952
[7] Shi You-zhi, Ma Shi-dong 2003 Test for interface characteristics of geogrids Rock and Soil Mechanics 24(2) pp 296-299
[8] Ma Cun-ming, Zhou Yi-tang, Liao Hai-ni, et al 2004 Experimental study on interface friction of plastic geogrid reinforce earth Chinese Railway Science 25(3) pp 36-39
[9] Zhang Bo, Shi Ming-lei 2005 Research on direct shear test and pullout test between clay and geotextile Rock and Soil Mechanics 26(5) pp 61-64