International Geotechnical Symposium on Theory and Practice of Earth Reinforcement / Fukuoka Japan / 5-7 October 1988
© 1988 Balkema, Rotterdam. ISBN 90 6191 820 0

Field pull-out test of polymer grid in embankment

H.Ochiai, S.Hayashi, J.Otani & T.Umezaki
Kyushu University, Fukuoka, Japan

E.Ogisako
Shimizu Corporation, Fukuoka, Japan

ABSTRACT: In order to examine the pull-out behavior of polymer grids in soils, a series of full scale field tests was performed in the way of pulling the polymer grids laid in a test embankment of 5.0m in height. Displacement of polymer grid in soil and pull-out resistance mobilized on grid junctions were discussed on the basis of a concept that the pull-out resistance concentrates and acts on each grid junction proposed by authors. As a result, it was concluded that the characteristic of pull-out resistance in actual size are basically very similar to the results from the laboratory model test.

1 INTRODUCTION

Most of the design method currently being employed for reinforced soil structures are based on the perfect plasticity theory which takes no account of displacement and deformation of reinforcing material in soil(Netlon Ltd. 1984). However, for some types of earth reinforcement such as polymer grid reinforced soil structures where the soil on upper and lower sides of the polymer grid is partially continuous, a pull-out resistance of the polymer grid in soil may be attributed to an interaction between reinforcing material and soil, thus depending on the displacement of polymer grid in soil. To make clear the mechanism, authors have conducted experimental studies in laboratory using a pull-out shear box apparatus and have emphasized the important role of grid junctions in the pull-out resistance(Hayashi et al. 1985, Ochiai et al. 1988).

In this paper, the results obtained from a full scale field pull-out test in an embankment of 5.0m in height are discussed in relation with the basic concept of pull-out resistance mechanism from the laboratory studies.

2 BASIC CONCEPT OF PULL-OUT RESISTANCE MECHANISM

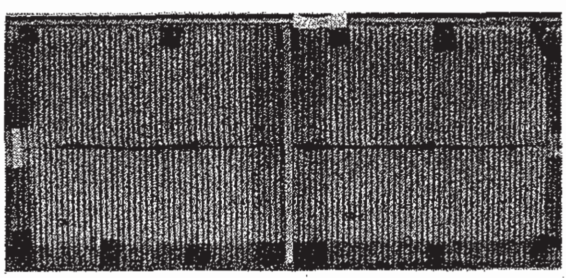
When the polymer grid in soil is subjected to a pulling force, the polymer grid is pulled out in the soil as the grid itself deforms, and thus the pull-out resistance is mobilized on both grid junction and rib of the polymer grid. In the case of the polymer grid which the soil on either side of the reinforcing material is partially continuous, the resistance effect of the rib at right angle with the direction of pulling is assumed to be transferred to the grid junctions in a concentrated manner . Thus the resistance mobilized on each of grid junction plays a greater role than that mobilized on each rib. It is therefore considered that the pull-out resistance concentrate and act on each of grid junctions.

This behavior was observed visually by using a soil box with transparent plastic plate. To make clear the grid displacement in the observation, the plastic plate was marked by vertical red lines, and the marker rubber membrane strips were pasted with silicone grease on the plate. Applying constant confining pressure, the grid was pulled out with constant speed.

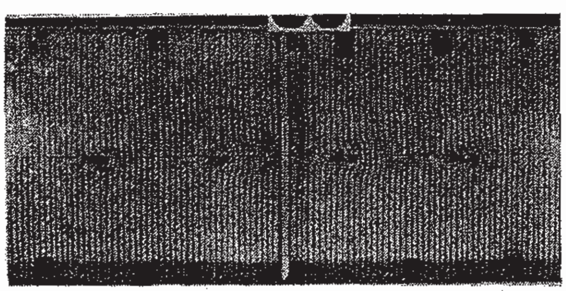
The results of observation are shown in Photo. 1 for two different displacement levels. It can be realized from these photographs that the grid junction plays very important role in the mechanism of mobilization of pull-out resistance. An elliptic slip field is formed in front of each grid junction and expanded with increasing the displacement level of grid junction. When the displacement reaches some large value, adjacent slip fields interact each other so that the pull-out resistance acting on each junction decreases and reaches the residual state. These results substanciate the validity of the concept which attaches importance to the role of grid junctions in the mobilization of pull-out resistance.

3 OUTLINE OF FIELD PULL-OUT TEST

A series of field pull-out tests was conducted in the way of pulling the polymer grids laid in a test embankment of 5.0m in height. The embankment was built whole of sand and part of decomposed granite(Masa soil) as shown in Fig.1. The steel sheet piles and H-section steel columns with penetration depth of about 1.0m were used for constructing the vertical embankment, and the steel columns of both sides were connected to each other by tie-rods. As shown in the figures, the polymer grids, which were 0.5m in width



(a) Displacement level=5.0mm



(b) Displacement level=30.0mm
Photo 1. Visual observation of mobilizing process in pull-out test.

and 2.0m and 4.0m in length for SR-2 type and 1.0m in width and 3.0m in length for SS-2 type, were laid at the depth of 1.0m, 2.5m and 4.0m from the top of embankment, respectively.

In the tests, the buried polymer grids were pulled at a constant pulling speed of 1.0mm/min by means of a center-hole type of oil pressure jack, and measurements were made of the pulling force at the forefront of the polymer grid and the displacement of each of grid junctions in soil. For the measurement of the displacement of grid junctions, thin stainless steel wires were attached to the grid junctions at the positions shown in Fig.3 and connected to dial gauges set up outside of the embankment. The wires were passed through vinyl tube to avoid friction against the soil.

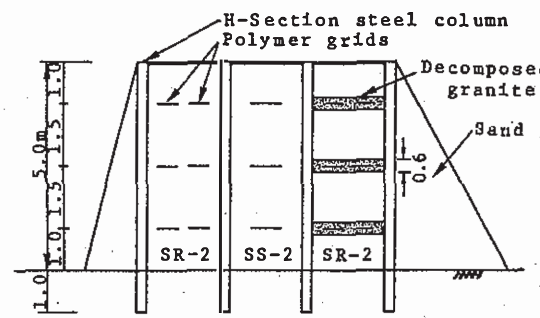


Fig.1 Test embankment (Front view).

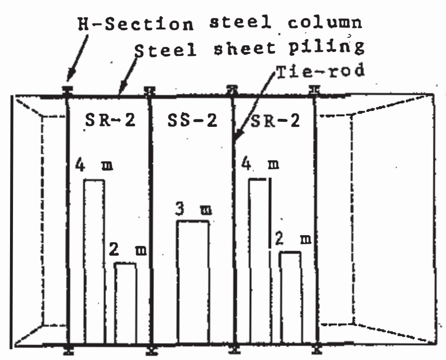


Fig.2 Test embankment (Plane view).

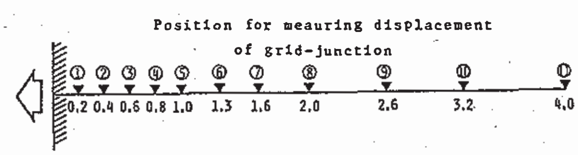


Fig.3 Position of measurement of displacement.

4 TEST RESULTS AND DISCUSSIONS

4.1 Displacement of polymer grid in soils

Examples of the actual measurements made of pulling force(Ft) and displacement of the grid junctions(Xi) during the tests are shown in Fig.4 and Fig.5. In the results, the SR-type of grid for reinforcing materials and sand and decomposed granite(Masa soil) for fill materials were used and the overburden pressure(σ_v) was $1.7tf/m^2$.

When a pull-out force is applied to the forefront of polymer grid in soil, the force is transmitted from forefront to back part, thereby the corresponding displacement of grid junction being caused. This behavior is the same as that observed in the laboratory test(Hayashi et al. 1985 Ochiai et al. 1988). For a design strength of polymer grid, the value of 40% of the tensile strength(Tf) is usually used as a non-creep stress level(Yamanouchi et al. 1985). At the condition of stress ratio Rf=Ft/Tf=0.4, distributions of displacement of grid junctions are summerized in Fig.6 and Fig.7 under taking note of effects of

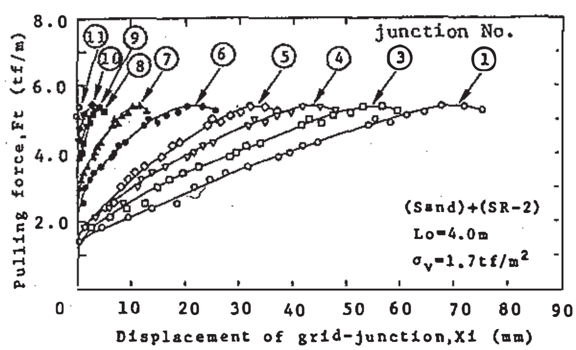


Fig.4 Force-displacement relation of each grid junction (sand)

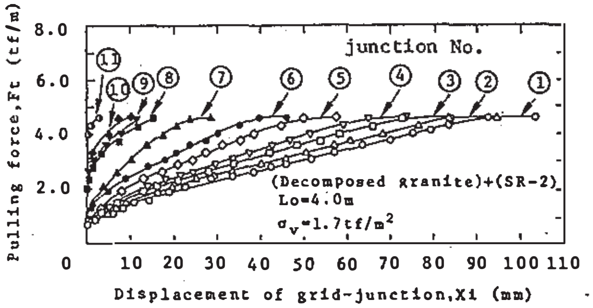


Fig.5 Force-displacement relation of each grid junction (decomposed granite)

overburden pressure (σ_v) and fill material. The results for the grid length of 4.0m is shown in Fig.6 and that of 2.0m is shown in Fig.7, respectively. Comparing both results, the more the grid length is long, the more the difference of fill materials under each overburden pressures is crucial. In the case of the grid length of 4.0m, the value of displacement of grid junction and the strained range of polymer grid in decomposed granite is larger than that in sand under the same overburden pressure. At the overburden pressure of $\sigma_v=1.7tf/m^2$ in both sand and decomposed granite, there exists the non-strained range in the grids of 4.0m in length, while the grids of 2.0m in length is strained in the whole length of the grids.

The effects of grid length and overburden pressure on the displacement distributions of polymer grid in soils are summarized in Fig.8 as a relation between the stress ratio Rf=Ft/Tf and the

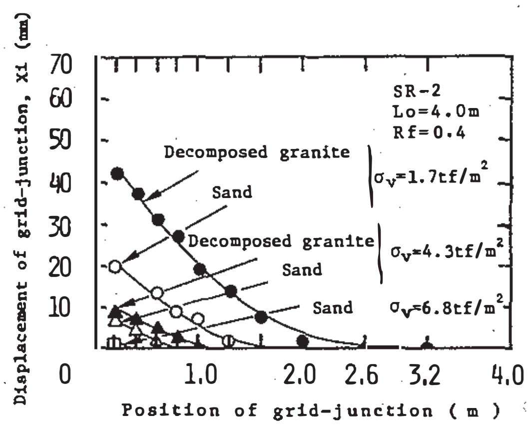


Fig.6 Distribution of displacement of polymer grid (grid length Lo=4.0m)

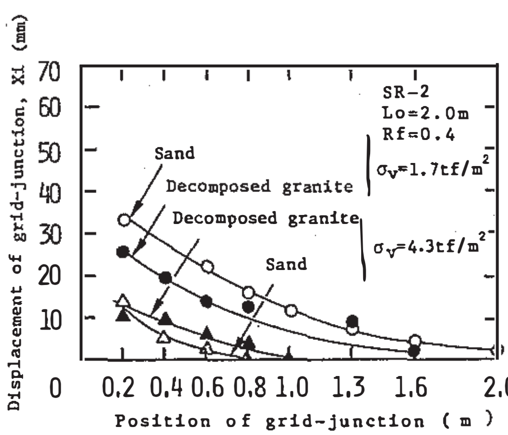


Fig.7 Distribution of displacement of polymer grid (grid length Lo=2.0m)

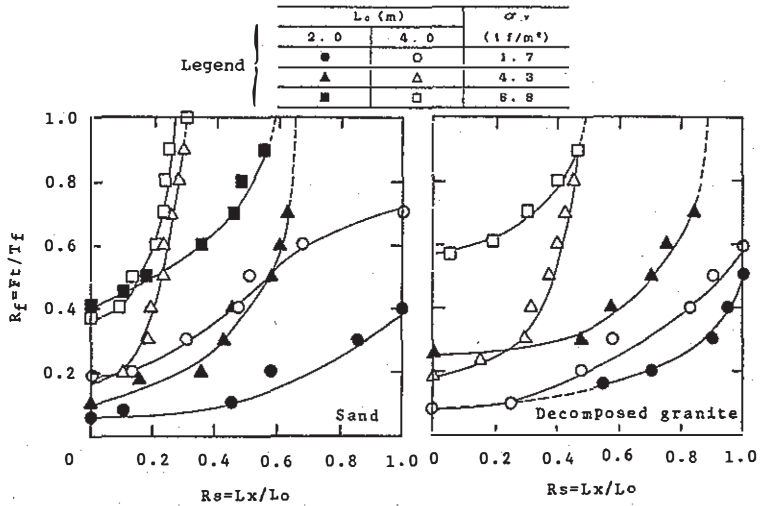


Fig. 8 Relation between ratios Rf=Ft/Tf and Rs=Lx/Lo for sand and decomposed granite.

displacement ratio Rs=Lx/Lo, in which Lo is the original length of polymer grid and Lx is the length of strained range measured from the forefront of the grid. Pull-out behavior can be easily recognized from the figure. When both values of overburden pressure and grid length are small, the ratio Rs increases gradually with increasing the ratio Rf, and the curve finally reaches the line of Rs=1.0. This means that the grid is pulled out without non-strained range. On the other hand, when the value of overburden pressure increases, the trend of graphs shown in Fig.8 is quickly raised and the ratio Rf reaches 1.0. This means that even if the tensile strength(Tf) of polymer grid is applied, there is the non-strained range in back part of the grid. The tendency of rising of the curve for sand is more distinguished than that for decomposed granite because of the difference of the interlocking effect between soil and polymer grid.

According to these results, when the polymer grid is used as a tensile reinforcing material in an embankment on the expectation of mobilizing the interlocking effect, it is very important to decide the grid length with considering the properties of fill material. On the other hand, when it is expected to maintain the stability of embankment by the anchoring effect of polymer grid, the grid length has to be decided under considering the overburden pressure and the properties of fill material. Therefore, when the overburden pressure is relatively small, the grid length has to be long enough, and on the contrary, the short length of grids may be used for the case of large value of overburden pressure.

4.2 Pull-out resistance mobilized on grid junctions

As described in Chap.2, the pull-out resistance of polymer grid in soil concentrates and acts on each grid junction. The resistance forces(Ti) mobilized on grid junctions are calculated by the analytical procedure using Ft-Xi curve as shown in Fig.4 and Fig.5(Ochiai et al.,1988). Fig.9 and Fig.10 show the relation between the resistance(Ti) and the displacement(Xi) at the grid junction for the case of Lo=4.0m and σ_v =1.7tf/m^2 without the non-strained range. At each grid junction, there exists a value of displacement which corresponds to a maximum value of mobilized resistance. And as the locations of grid junction is the back of grid, the value of the displacement decreases and that of the maximum resistance increases, thus the curve with a sharp peak being obtained.

However, when the polymer grid is pulled out without the non-strained range, a maximum value of the resistance is mobilized at a grid junction which is located at about half of total length of the grid in this example, and values of the resistances mobilized at grid junctions behind the location decrease.

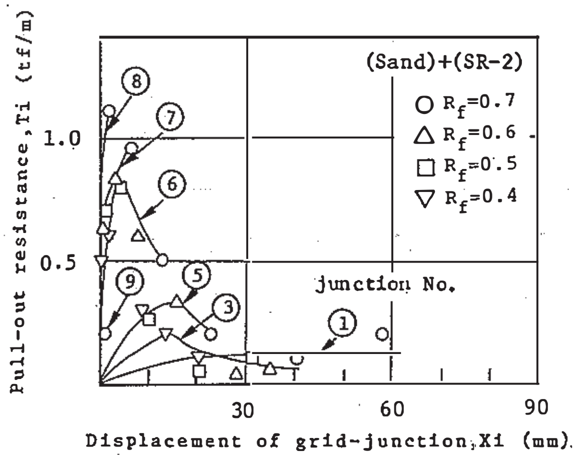


Fig.9 Relation between pull-out resistance (Ti) and displacement (Xi) of each grid junction (sand)

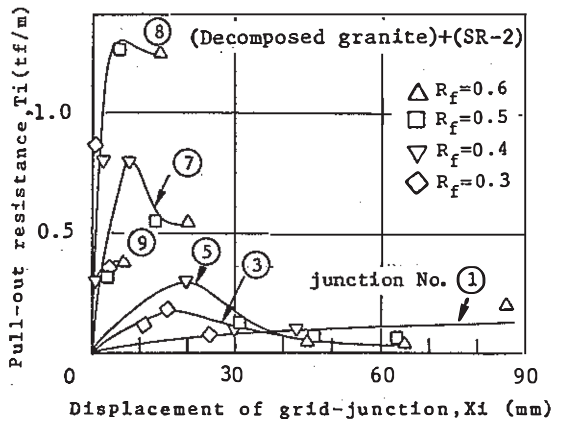


Fig.10 Relation between pull-out resistance (Ti) and displacement (Xi) of each grid junction (decomposed granite)

The reason why the resistance mobilized on each grid junction has a peak value at some displacement and decreases is that an elliptic slip field is formed in front of each grid junction and adjacent slip fields are affected each other as described in Chap.2.

It is also recognized from the comparisons of the results for sand and decomposed granite that the resistance curve mobilized on each grid junction depends on the properties of fill materials. The resistance curve with a sharp peak is obtained for fill material having a stress-strain relation with a peak value at relatively small strain range such as dense sand, while the curve with a flat peak corresponds to a stress-strain relation without a peak value as observed on decomposed granite.

All of discussions about the characteristics of pull-out resistance here are basically very similar to the results from the laboratory tests(Hayashi et al.1985, Ochiai et al.1988).

5 CONCLUSIONS

Results of field pull-out test using an embankment of 5.0m in height were examined to understand the pull-out mechanism of polymer grid in soil. The main conclusions aresummalized as follows :

1) The grid junctions play very important role in the pull-out resistance of polymer grid in soil. The resistance is considered to be mobilized at each grid junction in a concentrated manner.
2) When the polymer grids are used in soil as a tensile reinforcing material, it is important to decide the length of grid under considerations of the mechanical properties of soil and the magnitude of overburden pressure.
3) The pull-out resistance acting on the grid is not always uniform even at the same level of overburden pressure but varies with the displacement of grid junctions in soil.
4) The characteristics of pull-out resistance obtained from full scale field test are basically very similar to the results from the laboratory model test discussed in the previous paper.

REFERENCES

Hayashi, S. et al. 1985. Mechanism of pull-out resistance of polymer grids in soils, Tsuchi-to-Kiso, JSSMFE,Vol.33, No.5, pp21-26 (in Japanese).

Netlon Ltd. 1984. Guidelines for the design and construction of reinforced soil retaining walls using tensar geogrids.

Ochiai, H. et al. 1988. Pull-out behavior of polymer grid in soils and its analytical method, Memoirs of the Faculty of Eng., Kyushu Univ., Vol.48, No.2.

Yamanouchi, T. et al 1985. Tests for estimating of design strength of polymer grid, Proc. 30th. Symp. JSSMFE (in japanese).