Long-term pull-out tests of polymergrids in sand

K.Kutara & N.Aoyama
Public Works Research Institute, Ministry of Construction, Tsukuba, Japan

H.Yasunaga & T.Kato
Technical Research Institute, Hazama Gumi Ltd, Yono, Japan

ABSTRACT: In order to establish the rational design methods for geotextile reinforced structures, it is necessary to clarify the long-term friction/adhesion characteristics between soil and geotextiles. Therefore, both the displacement-controlled short-term pull-out tests and load-controlled long-term pull-out tests were conducted respectively for the polymergrids embedded in sand. From the test results, it was found that, with a constant pull-out force applied to the polymergrid embedded in sand, each bar of the polymergrid is displaced with time but its free end is hardly displaced with time and that the increase with time in the deformation of polymergrid in sand is smaller than the increase obtained from the results of tensile tests.

1 INTRODUCTION

High tensile strength geotextiles are being utilized as reinforcing materials for steep slopes and reinforced earth structures. High effectiveness of the geotextiles is widely recognized, but the present design methods are unable to fully utilize their effectiveness. Particularly with respect to the friction/adhesion characteristics between soils and geotextiles, there are still many items which have not been clarified. Because of this, the current design methods require high strength and large lengths of geotextiles. Thus, for establishing a rational design method for geotextile reinforced structures, it is necessary to clarify the friction/adhesion characteristics between soils and geotextiles.

Generally, for examining the friction/adhesion characteristics between soils and geotextiles, pull-out tests or direct shear tests have been carried out. According to the researches conducted up to now, it was found that considerable deformation and displacement of geotextiles occur when pulling geotextiles embedded in soils, by which the tensile strains are mobilized in them. However, these tests were conducted by the displacement-controlled methods and were short-term tests, and long-term friction/adhesion characteristics between soils and geotextiles were hardly studied.

Therefore, by using polymergrids embedded in sand, displacement-controlled short-term pull-out tests and load-controlled long-term pull-out tests were performed. Based on the test results, the short-term and long-term friction/adhesion between sand and polymergrids (including the long-term deformation characteristics of polymergrids in sand) were examined.

2 TEST PROCEDURE

Two series of pull-out tests were performed, which were displacement-controlled tests and load-controlled tests. Through both tests, air-dried Toyoura sand (G_s=2.64, G_{50}=0.16mm, U_c=1.46, e_{max}=0.96, e_{min}=0.64) and polymergrids were used. An example of the polymergrids is indicated in Fig. 1. Both

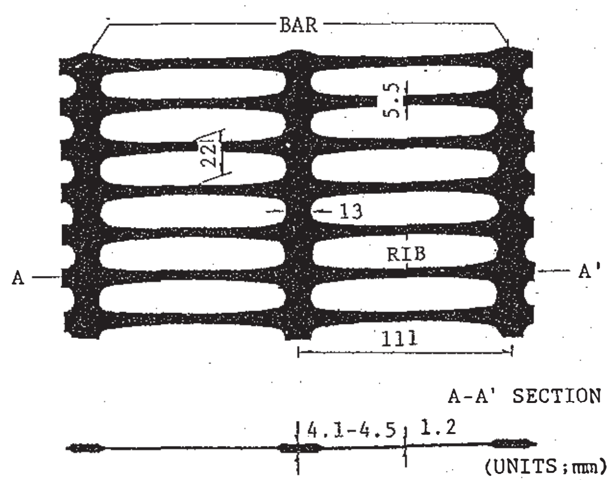

Fig. 1 An example of polymergrids

series of the tests were conducted under two conditions of the relative density, 20% and 65%, and under three conditions of the confining pressure, 2.0, 4.0, and 8.0tf/m^2. Each test piece of the polymergrids was 400mm wide and 700mm long in sand, and it had seven bars in sand. Each bar was named the survey point No.1-No.7(the bar closest to pull-out side was No.1 and the farthest bar was No.7). The pull-out force and the displacement of each bar were measured by means of load cells and displacement transducers.

2.1 Displacement-controlled pull-out tests

The apparatus of displacement-controlled tests is indicated in Fig. 2. It consists essentially of a steel box, 1200mm long, 600mm wide, and 600mm deep. The confining pressure was applied using rubber bags, with the same plan dimensions as the box, filled with air at the required pressure. The tests were performed by pulling the test piece of polymergrids out with a screw jack. The pull-out speed was adjusted to 1mm/minute.

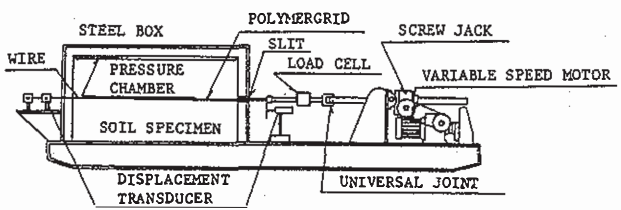

Fig. 2 Displacement-controlled pull-out test apparatus

2.2 Load-controlled long-term pull-out tests

The apparatus of load-controlled tests is indicated in Fig. 3. It consists essentially of a steel box, 1000mm long, 800mm wide, and 500mm deep. The confining pressure was applied by the same method as displacement-controlled tests. The tests were carried out by pulling the test piece of polymergrids out with a constant pull-out force. The pull-out force was to be applied in stages of 0.5tf/m each up. Each pull-out force stage had to be maintained for about twelve hours.

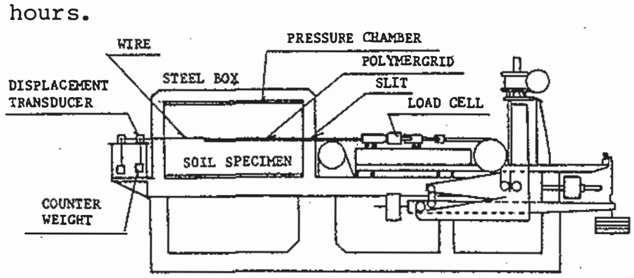

Fig. 3 Load-controlled pull-out test apparatus

3 TEST RESULTS

3.1 Tensile test results

Before pull-out tests, to review the stress and deformation characteristics of polymergrids alone, tensile tests were performed for the polymergrids by means of displacement control and load control.

As the test results, obtained were tensile force-strain relation shown in Fig. 4 and elongation-time relation by load-controlled long-term tensile tests shown in Fig. 5. By comparing two tests in Fig. 4, it is recognized that the strain in displacement-controlled test well coincided with the

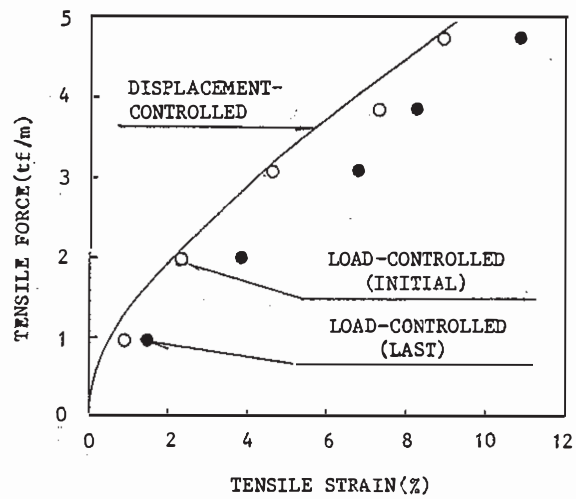

Fig. 4 Tensile test results: relation between tensile force and strain

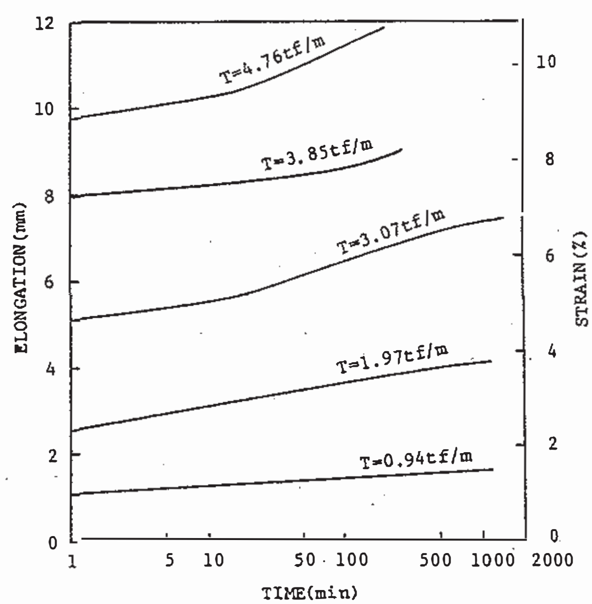

Fig. 5 Tensile test results: load-controlled long-term tensile tests

strain immediately after loading of the load-controlled test.

From Fig. 5, for the tensile force lower than 2tf/m, the strain increases almost in proportion to the time logarithmically indicated. When the tensile force further increases, the initial strain also increases and the increment of strain also increases with time. From this, when considering the long-term deformation, it is recognized to be necessary to review the long-term deformation characteristics of polymergrids alone.

3.2 Relation between pull-out force and pull-out displacement

When a pull-out force was applied to polymergrids embedded in sand, considerable displacement and deformation occurred. Typical examples of distribution of pull-out displacement are shown in Fig. 6 for displacement-controlled pull-out tests and in Fig. 7 for load-controlled pull-out tests. Even in the test under the same pull-

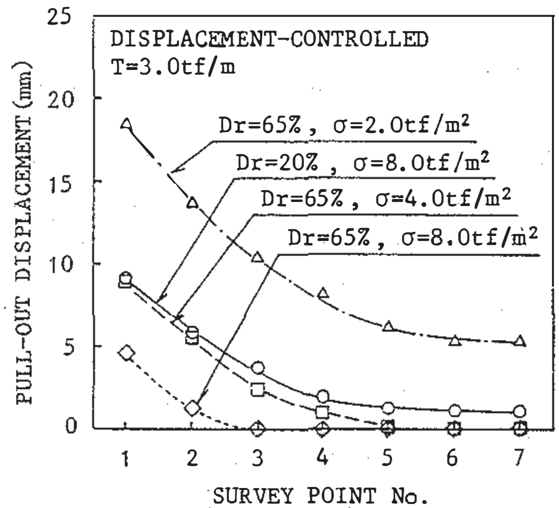

Fig. 6 Displacement-controlled pull-out test results: pull-out displacement distribution

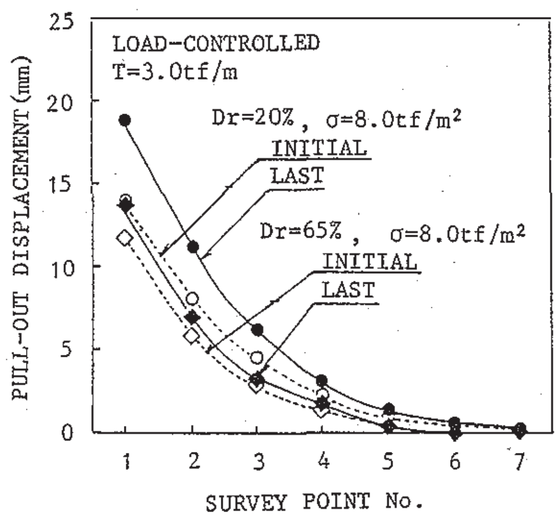

Fig. 7 Load-controlled pull-out test results: pull-out displacement distribution

Table 1. Legend in Figs. 8-11

Confining pressure (tf/m^2)	Displacement-controlled	Load-controlled Initial	Load-controlled Last
2.0	———————	○	●
4.0	——— - ———	△	▲
8.0	—— —— ——	□	■

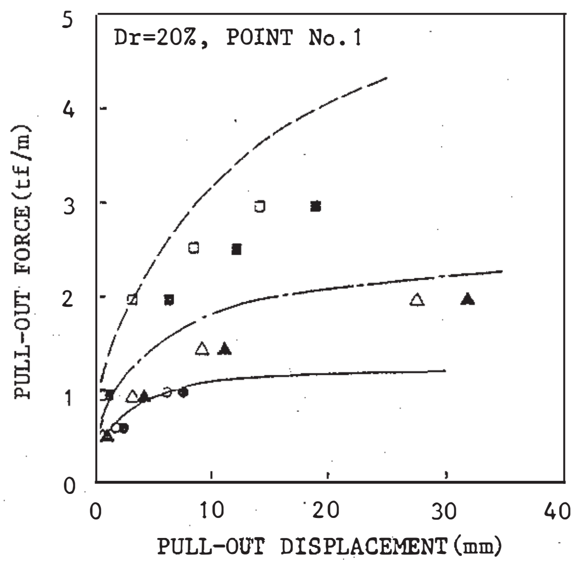

Fig. 8 Relation between pull-out force and displacement: Dr=20%, Point No.1

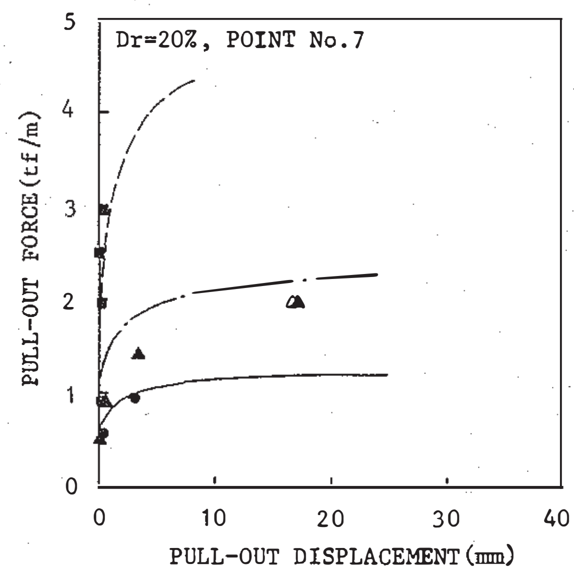

Fig. 9 Relation between pull-out force and displacement: Dr=20%, Point No.7

out force (T=3.0tf/m), the distribution of pull-out displacement varies between both the tests. However in both the tests, the displacement is large at the survey points near the pull-out side and decreases as the survey points become far from the pull-out side. Also, the pull-out displacement increases in the cases where the confining pressure decreases. It is also affected by the density of sand, and the pull-out displacement became larger as the relative density decreased even under the same confining pressure. From the above results, it was clarified that, when pulling out the polymergrids embedded in sand, the pull-out displacement of polymergrids was affected

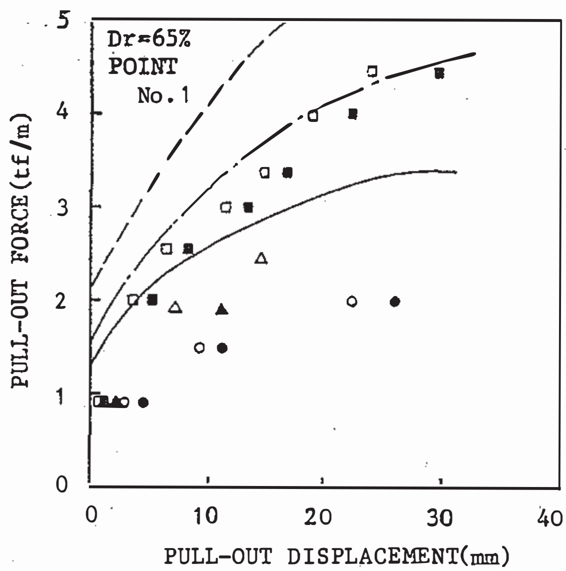

Fig. 10 Relation between pull-out force and displacement: Dr=65%, Point No.1

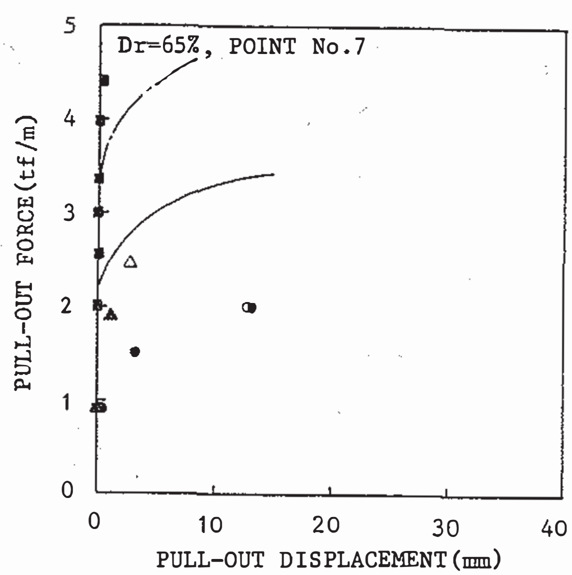

Fig. 11 Relation between pull-out force and displacement: Dr=65%, Point No.7

not only by the magnitude of the pull-out force but also by the density and confining pressure of sand.

Typical examples of relation between pull-out force and pull-out displacement are shown in Figs. 8 to 11. It was found that if the pull-out displacement of the free end (the survey point No.7) increases to a certain degree (about 10mm in the present experiment), then the pull-out force becomes almost constant.

Now making comparison between the displacement controlled tests and the load-controlled tests, it was found that in the case of loosely compacted sand, the results of both the displacement-controlled and load-controlled tests are almost the same regardless of confining pressure and pull-out force. In the case of densely compacted sand, the displacement by load control is larger than by displacement control when comparing based on the time of application of the same pull-out force.

3.3 Long-term friction/adhesion characteristics between sand and polymergrids

From the results of load-controlled long-term pull-out tests, it was found that the pull-out displacement increases with time. Typical examples of the relations between pull-out displacement and time are shown in Figs. 12 to 14. In each case, at the survey point where the pull-out displacement is large, the increase in displacement with time was recognized to be also large, and the pull-out displacement at the free end (No.7) of polymergrids hardly increased with time. That is, it was found that region where the pull-out displacement increased with time is limited. This increase in displacement seems to be caused by the long-term deformation characteristics of the polymergrids itself in sand rather

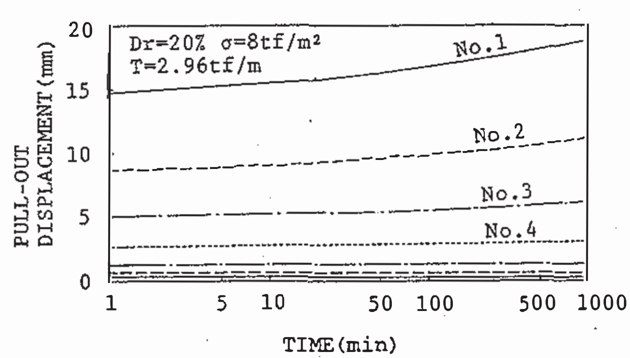

Fig. 12 Relation between pull-out displacement and time: Dr=20%, σ=8tf/m^2, T=2.96tf/m

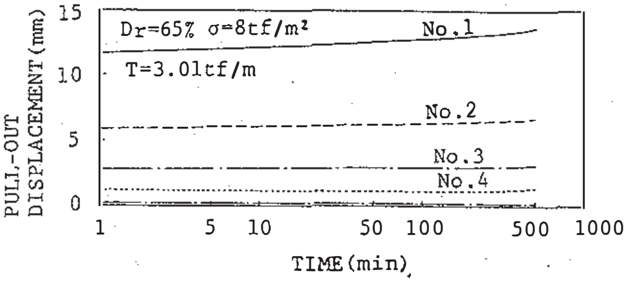

Fig. 13 Relation between pull-out displacement and time: Dr=65%, σ=8tf/m^2, T=3.01tf/m

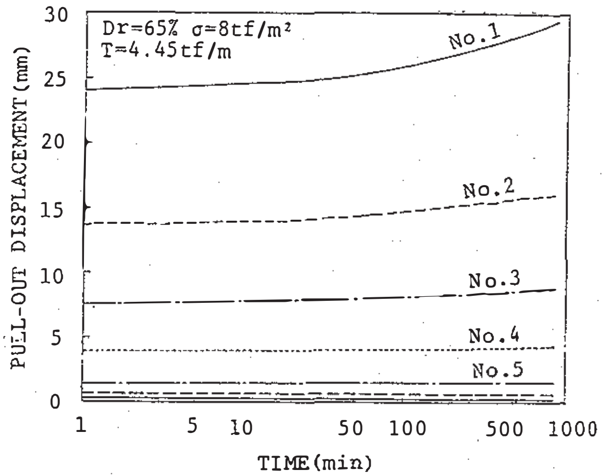

Fig. 14 Relation between pull-out displacement and time: Dr=65%, σ=8tf/m^2, T=4.45tf/m

than by the long-term characteristics of shear resistance acting between sand and polymergrids. Thus, when a pull-out force acts to polymergrids embedded in sand and the polymergrids are stable in short term, then the long-term stability may be also maintained.

3.4 Characteristics of the long-term deformation of polymergrids in sand

Based on the results of load-controlled long-term pull-out tests, the long-term deformation characteristics of polymergrids in sand were reviewed. When a pull-out force was applied to the polymergrids embedded in sand, the polymergrids were deformed and tensile strains were mobilized between the bars. Mode of change with time in the tensile strain under a constant pull-out force was investigated as the long-term deformation characteristics of the polymer-grids in sand.

Typical examples of relation between strain and time are shown in Figs. 15 to 18. In consequence, it was found that, as the initial strain becomes larger, the strain

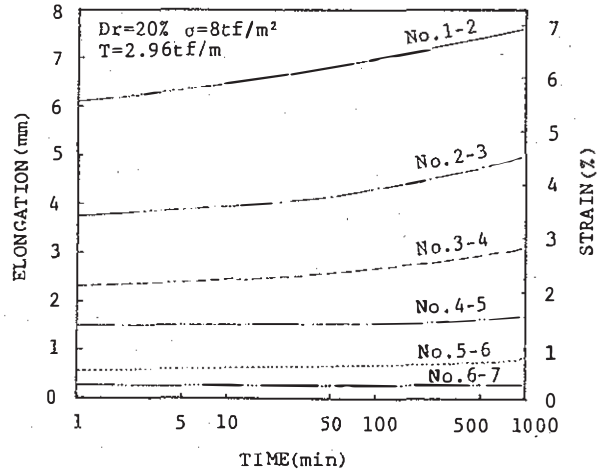

Fig. 15 Relation between elongation and time: Dr=20%, σ=8tf/m^2, T=2.96tf/m

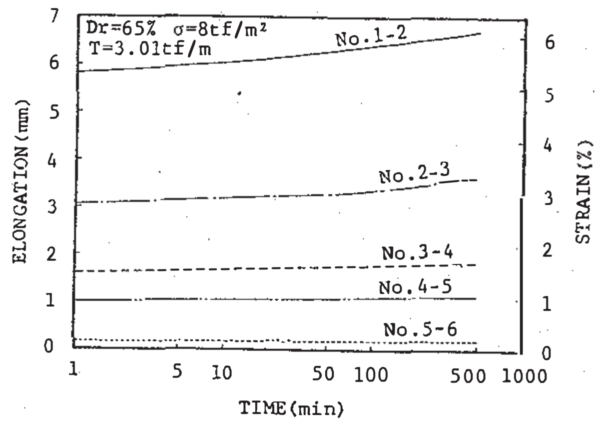

Fig. 16 Relation between elongation and time: Dr=20%, σ=8tf/m^2, T=3.01tf/m

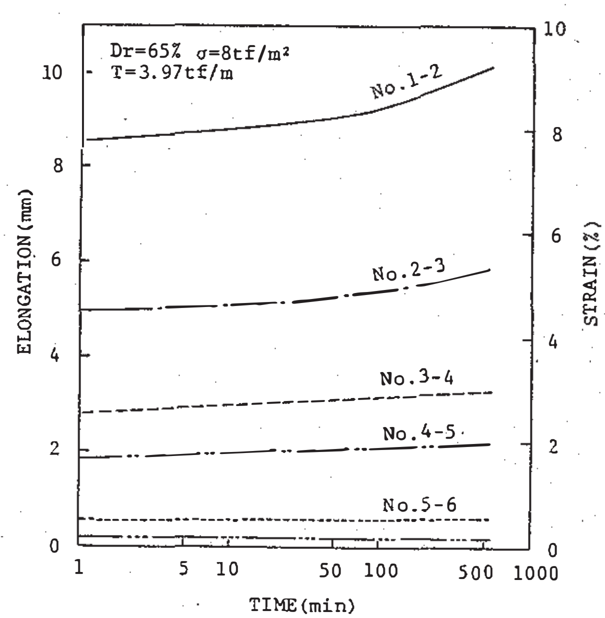

Fig. 17 Relation between elongation and time: Dr=65%, σ=8tf/m^2, T=3.96tf/m

increases more thereafter. Also, by making a comparison based on the same initial strain, it was found that the increase in strain thereafter becomes smaller as the confining pressure increases. For instance, the increment in strain between the survey point No.2 and No.3 in Fig. 15 is larger than the increment in strain between the survey point No.3 and No.4 in Fig. 17.

Fig. 18 shows the comparison between tensile test results and pull-out test results. By making a comparison based on the same initial strain, the increase in strain is smaller in the pull-out tests than in the tensile tests. This was probably caused because the polymergerids were confined by sand and thus were not easily deformed.

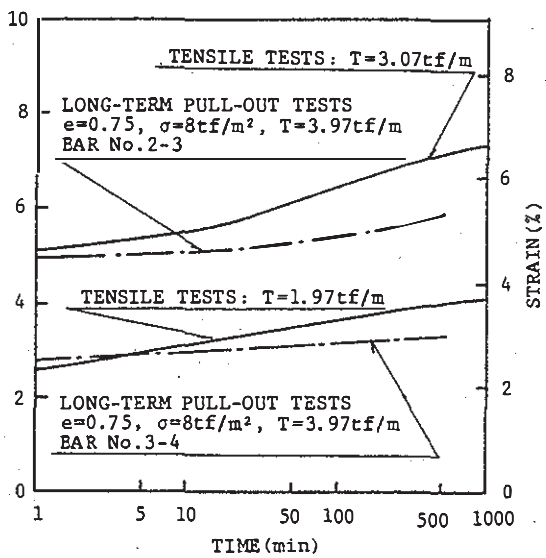

Fig. 18 Comparison between tensile test results and pull-out test results

4 CONCLUSIONS

The following conclusions can be drawn from the results of tests stated above:

1. When a pull-out force is applied to a polymergrid embedded in sand, considerable displacement and deformation occur. Also, the displacement and deformation vary depending on not only the density of sand, the confining pressure and the pull-out force but also the testing methods.

2. In the case of loosely compacted sand, the initial pull-out displacement immediately after loading by load-controlled pull-out tests well coincides with displacement-controlled pull-out displacement. On the other hand, in the case of densely compacted sand, the former is greater than the latter.

3. When polymergrids embedded in sand are pulled out with a constant force, the pull-out displacement increases with time. However the displacement at the free end of polymergrids hardly increases with time. Thus, long-term stability can be maintained for the friction/adhesion between sand and polymergrids as long as they can provide short-term stability.

4. Cause of the long-term characteristics of the friction/adhesion between sand and polymergrids is the long-term deformation of polymergrids itself in sand rather than long-term shear deformation between sand and polymergrids.

5. The deformation of polymergrids embedded in sand increases with time in response to the initial strain occurred between each bar. And this increase varies depending on the density of sand.

6. When making a comparison based on the same initial strain, the increase with time in the deformation of polymergrids in pull-out tests is smaller than that in the tensile tests (see Fig. 19).

REFERENCES

Bergado, D.T. 1987. Laboratory pull-out tests using bamboo and polymer geogrids including a case study. Geotextiles and Geomembranes. Vol.5 No.3, pp. 153-189.

Ingold, T.S. 1983. Laboratory pull-out testing of grid reinforcements in sand. Geotechnical Testing Journal. Vol.6. No.3, pp. 101-111.

Jewell, R.A. 1985. Material properties for the design of geotextile reinforced slopes. Geotextiles and Geomembranes. Vol.2. No.2, pp. 83-109.

McGown, A., Andrawes, K.Z., Yeo, K.C., & DuBis, D. The load-strain-time behaviour of Tensar geogrids. 1984. Proceeding of Symposium on Polymer Grid Reinforcement in Civil Engineering. London.