Engineering Properties of Five Major Geogrids in Japan

T. Akagi
Toyo University, Kawagoe City, Saitama, Japan

T. Higuchi
Regional Environment Development Consultants, Minatoku, Tokyo, Japan

S. Chida
Public Works Research Center, Kohtohku, Tokyo, Japan

ABSTRACT: Five major geogrids in Japan were tested for their engineering properties approximately under the same conditions; 1)tensile strength, 2)creep characteristics, 3)pull-out test results, etc. Since each brand has several grades having various strengths, the properties of the five geogrids having approximately the same nominal strength of 50 kN/m were compared. While the ultimate tensile strengths exceeded the nominal strengths, the strains at failure varied widely between about 2 and 15%, with each brand always exhibiting a consistent rigidity. Creep tests were conducted under constant loads ranging from 10 to 90% of the nominal strength for more than 1000 hours, leading to a conclusion that the design strength should be reduced to 60 to 65% of the nominal strength. The pull-out test results indicated that the apparent friction angle between the geogrids and sand ranged from roughly 15 to 30 degrees being considerably smaller than the angle of internal friction of the sand.

1 INTRODUCTION

In recent years various types of geogrids have been developed and utilized mainly to reinforce embankments and backfills. A total of 3.5 million m^2 of geogrids is used annually in Japan according to a recent survey conducted by the Japan Chapter of IGS. The Public Works Research Center (PWRC) recently made a study on the engineering properties of five major geogrids in extensive use in Japan. PWRC is a non-profit organization having a task to examine and review new products for civil engineering use to assure the quality and performance and to grant certificates to manufacturers producing good quality engineering materials.

Geosynthetic materials show in general considerably different properties depending upon test conditions. Since the five different geogrids were tested approximately under the same conditions specified by PWRC (PWRC, 1993), it was possible to make a reasonable comparison to indicate a range of properties of the products tested. Since each brand has several grades having various strengths, the properties of the five different geogrids having approximately the same nominal strength of the order of 50 kN/m were compared.

These geogrids were tested for 1)tensile strength characteristics, 2)creep characteristics, 3)friction between geogrids and sand by means of pull-out tests, 4)junction strengths, 5)degrees of damages due to impacts and 6)degrees of deterioration due to artificially accelerated climatic changes, temperature changes and chemical environments. Also, 7)manufacturing processes and 8)field performance records were examined before the certificates were granted.

This paper discusses only the first three items 1) through 3) and will not refer to the last five items, other than the fact that PWRC found the qualities of the 5 geogrids related to 4) through 8) quite satisfactory and acceptable.

2 GEOGRIDS TESTED

The five geogrids tested, each produced by a different manufacturer, consist of 1)Geogrid A made of an FRP consisting of

Table 1 Five geogrids compared

Geogrid	A	B	C	D	E
Opening size(mm)	100x30	50x50	26x28	23x23	116x22
Unit mass(g/m^2)	260	620	1400	380	510
Contrrol strength(kN/m)	6.0	7.0	6.0	5.4	5.75
Nominal strength (kN/m)	5.0	5.5	4.8	5.0	5.0

glass fibers soaked in vinyl ester plastics, 2)Geogrid B of superdrawn polyoxymethylene coated with ethylene-vinyl acetate polymer, 3)Geogrid C of HDPE reinforced by alamid fibers, 4)Geogrid D of polyester fibers of polyethylene terephthalate coated with PVC and 5)Geogrid E of uniaxially drawn HDPE.

Table 1 shows the opening size, the unit mass, the control strength and the nominal strength. The control strength is the tensile strength of a strand subjected to a strain ranging from 1% to 50% per minute principally for the purpose of quality control during production, while the nominal strength is the standardized tensile strength guaranteed when a specimen of geogrid, at least 200 mm wide, is tested under the condition set out in Table 2 and is intended to be a basic design strength.

3 TENSILE STRENGTH TESTS

All the tension tests were conducted in accordance with the test condition specified by PWRC, Table 2. Five specimens of each brand were tested for tensile strength and were found to exhibit very similar results when plotted in terms of the relationship between the tensile load applied and the strain developed. A representative curve of each brand was selected and given in Fig. 1. The nominal strengths of the five geogrids fall between 48 and 55 kN/m as indicated by a horizontal shaded zone marked as "Nominal strengths." Fig. 1 demonstrates that each curve has its ultimate strength exceeding its nominal strength. It is to be noted, however, that the slopes of the curves, i.e., the values of rigidity, vary widely and the strains at failure range between roughly 2% and as much as 15% or greater.

Table 2 Conditions specified for a tensile test

Test device	Strain-controlled
Temperature	23 ± 2 ℃
Humidity	50 ± 20 %
Adjusting Time	> 16 hours
Strain rate	1 %/min.
Specimen width	> 200 mm
No. of specimens to be tested	> 5

It is clearly shown in Fig. 1 that Geogrid A is a highly rigid material as compared with Geogrids B and C having a medium rigidity and Geogrids D and E having a relatively low rigidity. However, A is so rigid it may break relatively easily when bent too sharply; hence it should be folded in a diameter no less than 30 to 50 mm. Both B and C consist of high strength core fibers mantled by plastic cover and as is noted in Table 1, greater differences exist between the control strength and the nominal strength. While D and E appear to exhibit rather irregular, non-linear curves on Fig. 1, their results are always very consistent, falling in a narrow range showing the same pattern.

Generally, when the strain rate was increased, the strength of all the geogrids tended to increase and the strain at failure to decrease. The strength per unit width was always the greatest when a single strand was tested and decreased with increasing width of test specimens. Grabbing a geogrid specimen at its ends for a satisfactory tension test required special care and ingenuity depending upon the rigidity of the geogrid. It is to be understood that for testing each brand of the geogrid in its manufacturer's laboratory, the testing machine and the device to grab specimens were different. This might have some minor bearing on the test results, although the test condition specified in Table 2 was always strictly adhered to.

4 CREEP TESTS

Creep tests were conducted for specimens consisting of two or more strands up to a width of 200 mm which were subjected to a constant load for a period up to more than 1000 hours. To test each brand 5 different loads were applied ranging from 10 to 90% of the nominal strength. The

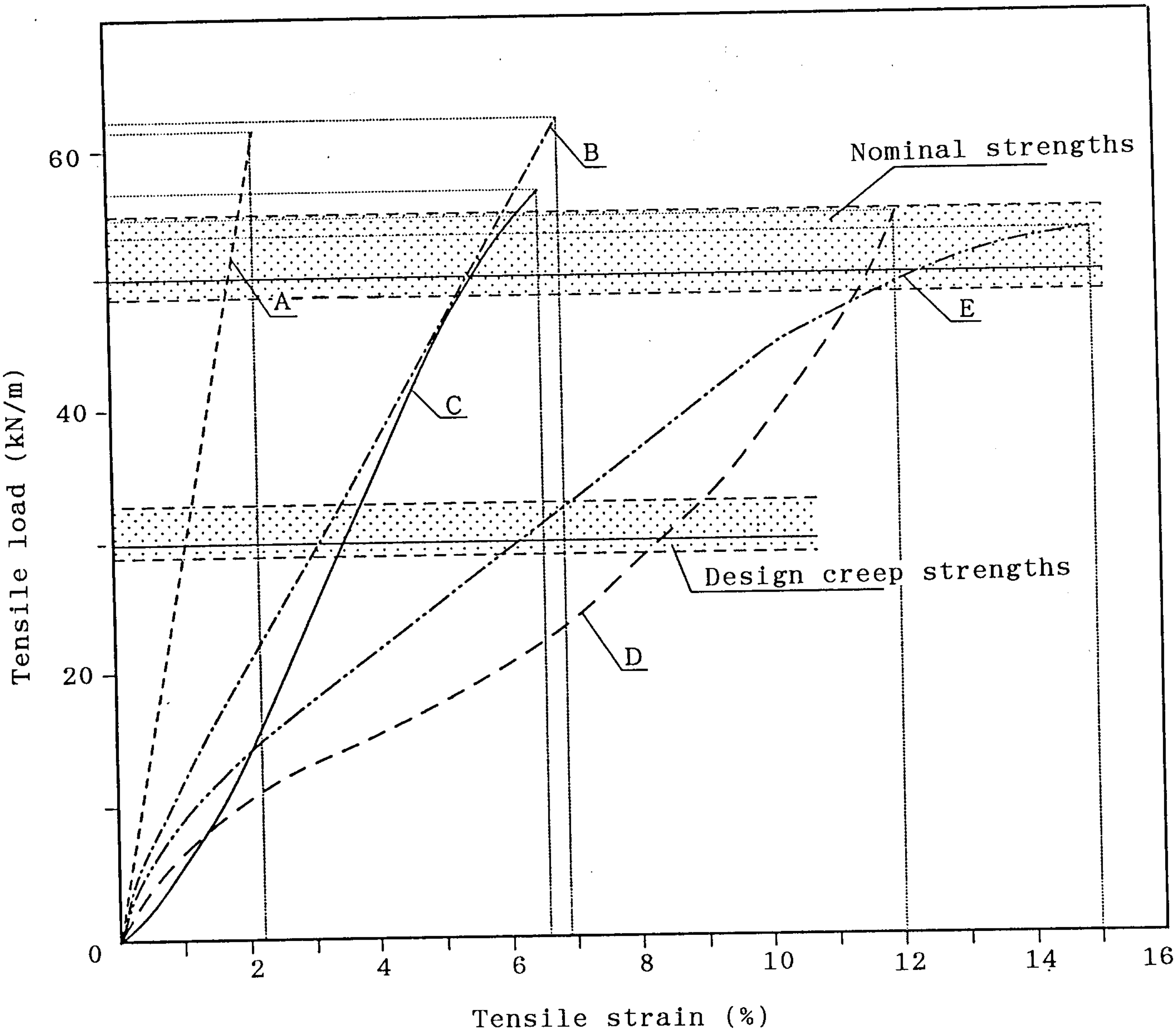

Fig. 1 Typical tensile strength test results

requirements for temperature and humidity during the test are the same as those specified in Table 2.

Geogrids A, C and D were brought to failure under a constant load greater than 90% of their respective nominal strengths in less than 1000 hours. Geogrids B and E, however, ruptured when subjected to a sustained load exceeding only 70% of their respective nominal strengths in less than 1000 hours. While A and E indicated rapidly increasing strains as failure approached, B, C and D appeared to have reached failure rather abruptly. Strains at failure observed during creep tests of the five geogrids were roughly of the same magnitude as those at failure during the short-term strength tests.

Fig. 2 summarizes the relationship between creep strengths and time of loading required for creep failure in which each curve is extended by a short-dotted line for extrapolation. Based on the results extrapolated for the 100 year creep strength, thus, it was concluded that the design strength should be reduced to 60% of the nominal strength for all the geogrids except Geogrid D that should be decreased to 65%. These "Design creep strengths" are indicated on Fig. 1 also by a horizontal shaded zone ranging from 28.8 to 33.0 kN/m.

5 PULL-OUT TESTS

Pull-out tests were carried out using the Toyoura Standard sand under three different normal stresses ranging from 20 to 90 kPa. Geogrid specimens were pulled out of a sand box at a pulling rate of 1 mm/min. Unfortunately the relative density of the sand varied widely(A:90%, B:44%, C:40%, D:60%, E:80%) and also the test device differed for each brand of the geogrid tested.

Fig. 3 gives relationships obtained be-

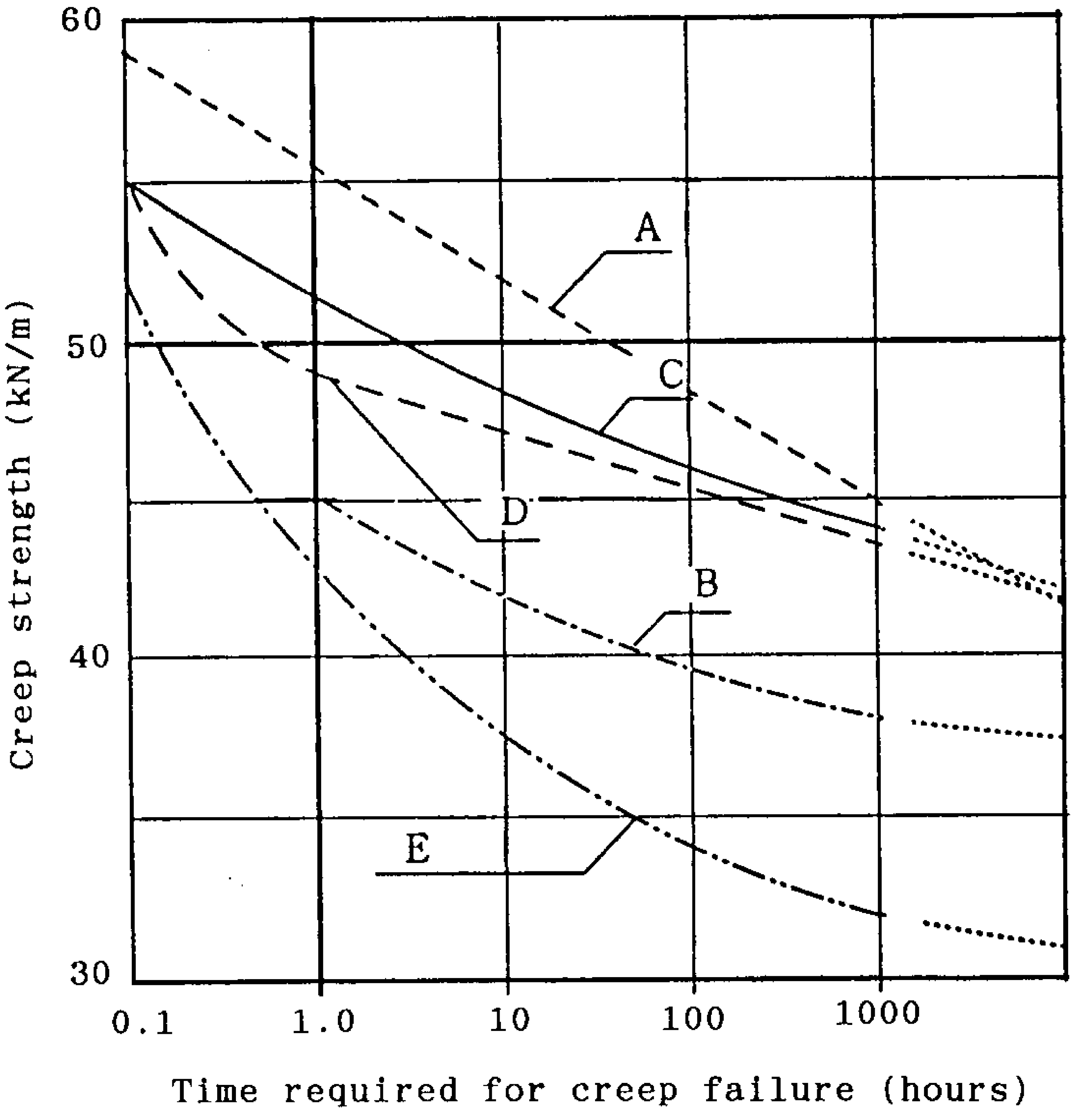

Fig. 2 Results of creep tests

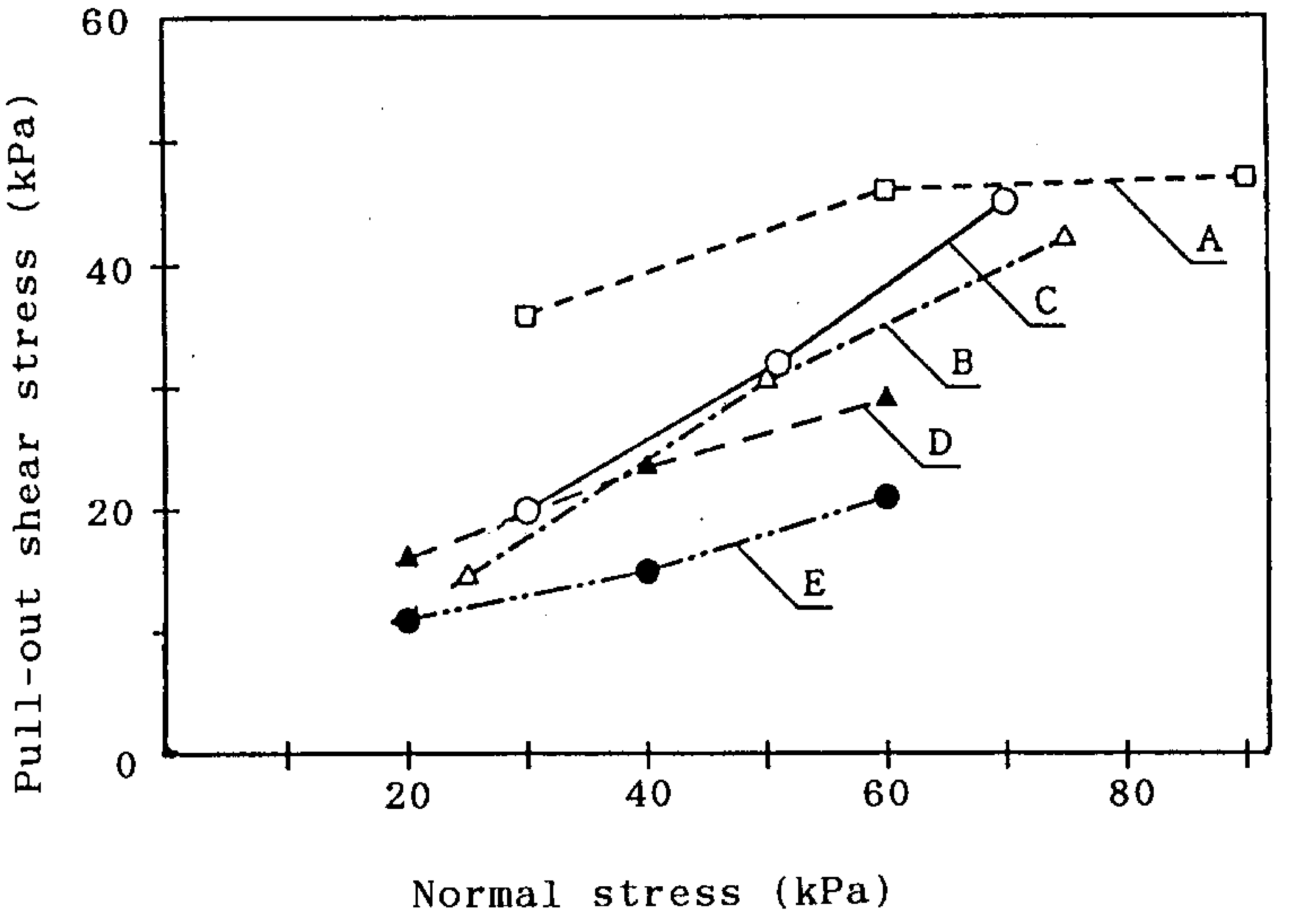

Fig. 3 Results of pull-out tests

tween the maximum pull-out shear stress (frictional resistance) between the gross surface area of the geogrid and the sand, and the normal stress applied through the sand. The maximum shear stresses measured were the highest when Geogrid A was pulled out of the sand with a high relative density of 90%, whereas the lowest resistance was recorded for Geogrid E in spite of the fact that it was placed in the sand having a relative density as high as 80%. Although Geogrids B and C were pulled out of the sand with relative densities as low as 44% and 40%, respectively, their pull-out shear stresses measured were somewhat greater than those obtained for Geogrid D buried in the sand having a higher relative density of 60%.

The foregoing results appear to suggest that each brand possesses a significantly different pull-out resistance and that conventional pull-out tests are influenced not by the density of sand alone, but perhaps by such factors as details of the test device and testing procedure.

Since each test result is represented by only 3 points as shown on Fig. 3, it is difficult to determine the angle of friction and the cohesion intercept. However, the apparent friction angle between the gross surface area of the geogrids and the sand seems to range from about 15° to 30° being considerably smaller than the angle of internal friction of the sand employed for all the tests.

6 CONCLUSIONS

1)Geogrids having the same nominal strength may have considerably different rigidity, i.e., the strain at failure may vary roughly from 2 to 15% or greater. 2)The design long-term strength should be reduced to 60 to 65% of the nominal strength and it is to be noted that the rupture strain is about the same magnitude as that observed for the short-term strength test. 3)Further details of the pull-out test should be standardized in order to evaluate correctly and reliably the frictional resistance of the geogrid installed in soils. 4)Strains at failure should be taken into account more carefully when the design strength of a geogrid is selected for reinforcement purposes.

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REFERENCE

Public Works Research Center (1993) Design and construction manual for soil structures reinforced by geotextiles, 288p., PWRC, Tokyo (in Japanese).