Investigation of Pull-out Resistance of Geogrids

R. -H. Chen & C. -C. Chen
National Taiwan University, Taipei, Taiwan

ABSTRACT: The pull-out resistance of geogrids is investigated by performing pull-out tests for three geogrids embeded in sands and gravelly sands. It is found that the contribution from the friction between soil and geogrid is more important than the passive resistance of soil. The ultimate pull-out resistance is higher for rigid geogrid than soft geogrid. Besides, the theoretical bearing stress ratio F_q is not suitable for soft geogrids for predicting the passive resistance.

1 INTRODUCTION

It has now been well known that the pull-out resistance of geogrids embedded in soil is mainly composed of two parts, namely, the friction between soil and geogrid, and the passive resistance of soil acting against the transverse ribs of geogrid (Koerner, 1990; Jewell, 1991; Cowell and Sprague, 1993). However, quantitative study on the contribution of each part is rare.

This study aims to look into the pull-out resistance of geogrids by performing pull-out tests for three geogrids embedded in two soils. Hence, the frictional force and the passive resistance are obtained. In addition, theoretical equation for passive soil resistance will be examined.

2 MATERIAL PROPERTIES

Two kinds of soils are poorly-graded sands (called soil S) and poorly-graded sands with gravels (called SG). They are both classified as SP in the Unified Soil Classification System. However, soil S ($d_{50} = 1.2\,mm$) contains only 3% (by weight) of gravels, but soil SG ($d_{50} = 1.7\,mm$) contains 33% of gravels ($d_{\max} = 0.75\,in.$). The strength parameters ($D_r = 80\%$) obtained from direct shear tests are $c = 0.5\,kPa$, $\phi = 38.7°$ for soil S and $c = 18\,kPa$, $\phi = 41.4°$ for soil SG, respectively.

Material properties of geogrids is shown in Table 1. Geogrid A is made of HDPE and has elliptic open shape. Its opening is formed by punching and stretching. Geogrids B and C are both made of polyester and have rectangular openings. The junctions of the ribs of geogrid B are formed by heat-bonded. The junctions of geogrid C are formed by knitting.

Table 1 Properties of geogrids

	A	B	C
Mass per unit area (g/m^2)	1100	480	500
Dimension of the opening ($mm \times mm$)	160 × 16	125 × 50	20 × 18
Thickness of transverse rib (mm)	5.5	2.0	1.5
Percent open area (%)	43	45	37
Tensile strength (kN/m)	110	100	100
Junction strength (%)	90	7-50	–
Strain at failure (%)	12	15	15

3 PULL-OUT TEST

The box for pull-out tests is $40\,cm \times 25\,cm$ (length × width). Geogrids of $30\,cm \times 20\,cm$ are embedded in soil and clamped at the pull-out end by a wedge type clamp. Besides, to ensure the contact area between soil and geogrid remaining constant during the test, two aluminum sheets are put between the clamp and the geogrid. Hence, the frictional force at the interface of soil and aluminum sheet has to be measured and subtracted from the total pull-out force.

The pull-out tests for geogrids without transverse ribs are performed firstly. Hence, the maximum force is expressed as follow:

$$F_m = F_{al} + F_{\ell r} \tag{1}$$

where F_{al} = the frictional force between soil and aluminum sheet.
$F_{\ell r}$ = the frictional force between soil and longitudinal ribs.

Then, the pull-out tests for geogrids with both the longitudinal and transverse ribs are performed. The maximum pull-out force is expressed as:

$$F_{mt} = F_{al} + F_{\ell r} + F_{tr} + P_p \tag{2}$$

where F_{tr} = the frictional force along the transverse ribs.
P_p = the passive resistance of soil

F_{tr} is obtained from eq. (3), assuming the same coefficient of friction,

$$F_{tr} = \frac{A_{tr}}{A_{\ell r}} \times F_{\ell r} \tag{3}$$

where $A_{tr}, A_{\ell r}$ = the area of the transverse ribs and longitudinal ribs, respectively.

The pull speed for all the tests is $1\,cm/min$.

4 TEST RESULTS

The force-displacement curves for geogrids with/without transverse ribs generally show ductile behavior as shown in Figs. 1~2. However, for geogrids B and C, samples after testing show significant deformation near the pull-out end and some failure at junctions. But, for geogrid A, no significant deformation or junction failure can be detected.

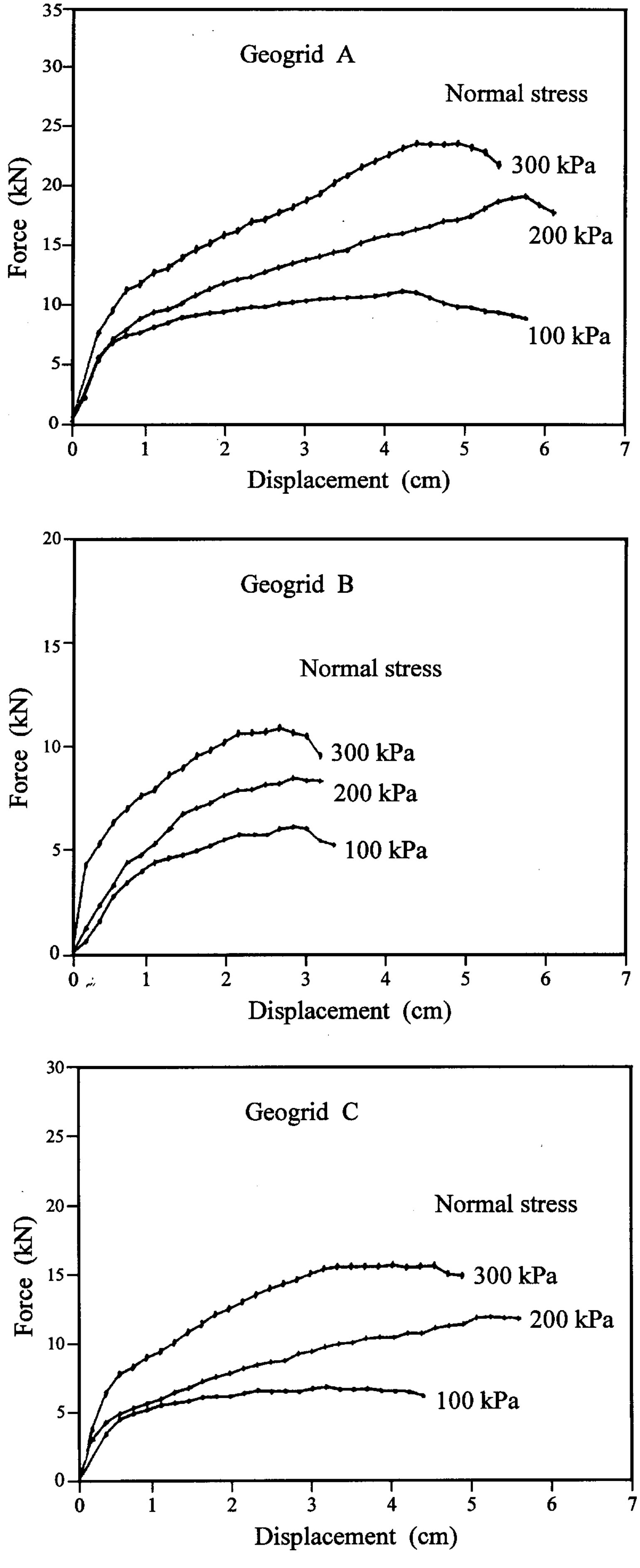

Fig. 1 The results of pull-out tests for geogrids embedded in gravelly sands

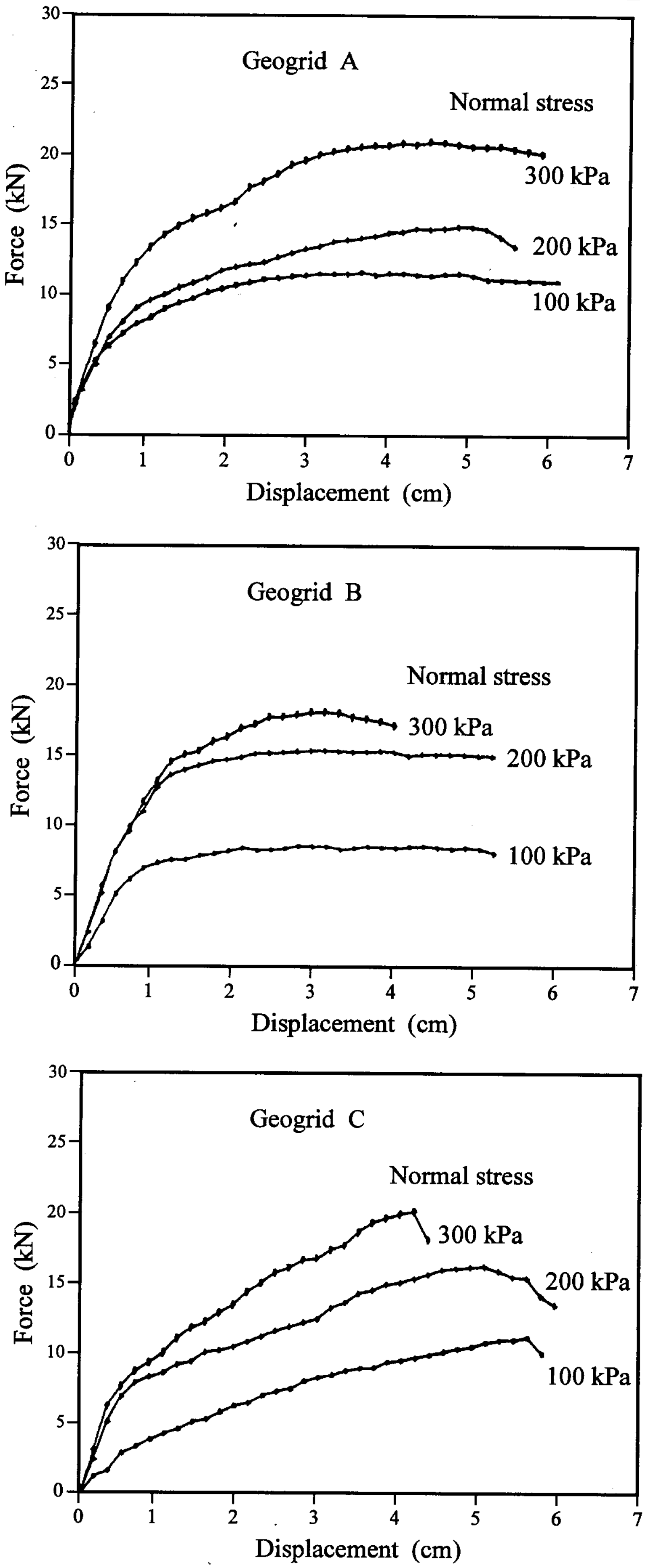

Fig. 2 The results of pull-out tests for geogrids embedded in sands

The results of the pull-out tests for aluminum sheet are shown in Fig. 3. It can be seen that the ultimate frictional stress remains about constant as the displacement increases for constant normal stress, but increases about linearly with the normal stress.

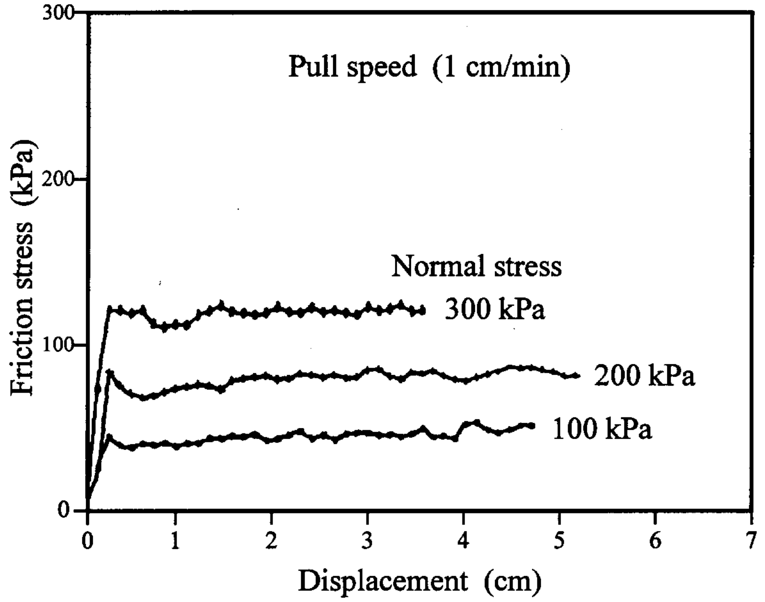

Fig. 3 Friction stress versus displacement for aluminum sheet embedded in gravelly sands

The ultimate pull-out force for each geogrid embedded in two soils is shown in Table 2. It can be seen that, in general, more rigid geogrid such as geogrid A has higher pull-out resistance than soft geogrids, especially when embedded in gravelly sands. Besides, from Table 3, the passive resistance is also higher for gravelly sands than sands and becomes more important as the normal stress increases. However, the passive resistance contributes

Table 2 The ultimate pull-out force ($kN/0.2\,m$)

Geogrid	Soil	Normal Stress (kPa)		
		100	200	300
A	SG	10.23	15.69	22.01
	S	10.95	13.74	18.63
B	SG	4.92	7.59	9.76
	S	6.50	11.46	14.76
C	SG	6.08	11.20	13.56
	S	9.84	15.20	19.01

only 34% of the total resistance at most as shown in Table 4.

Table 3 The passive resistance ($kN/0.2\,m$)

Geogrid	Soil	Normal Stress (kPa) 100	200	300
A	SG	1.81	3.30	6.33
	S	1.25	2.30	4.69
B	SG	0.28	1.12	1.88
	S	0.36	0.74	1.21
C	SG	0.50	3.48	4.66
	S	1.03	1.68	2.30

Table 4 The percentage of friction and passive force

Geogrid	Soil	Normal Stress (kPa) 100		200		300	
		F^a	B^b	F	B	F	B
A	SG	82	18	79	21	71	29
	S	88	12	83	17	75	25
B	SG	94	6	85	15	81	19
	S	94	6	94	6	92	8
C	SG	92	8	69	31	66	34
	S	90	10	89	11	88	12

[a] F = friction
[b] B = passive resistance

Finally, the bearing stress ratio is defined as:

$$F_q = \frac{\sigma_b}{\sigma_n} = \frac{\text{passive stress}}{\text{normal stress}} \tag{4}$$

Then, in gravelly sands, the F_q values for geogrids A, B, C are 8.6, 5.2, and 2.4, respectively . In sands, the F_q values are 6.1, 5.0, and 1.7, for geogrids A, B, C, respectively. The theoretical F_q values using eq. (5) are 13.0 for $\phi = 38.7°$ and 17.0 for $\phi = 42.4°$.

$$\frac{\sigma_b}{\sigma_n} = \tan\left(45° + \frac{\phi}{2}\right) e^{(\frac{\pi}{2}+\phi)\tan\phi} \tag{5}$$

It may be concluded that the theoretical equation of bearing capacity for rigid members is not suitable for soft geogrids.

5 CONCLUSIONS

The frictional part of the pull-out resistance plays a more important role than the passive resistance of three geogrids tested. However, the passive resistance gets more important as normal stress increases. In addition, theoretical bearing capacity equation for soft geogrids needs to be further studied.

REFERENCES

Cowell, M. J. and Sprague, C. J. (1993) Comparison of pull-out performance of geogrids and geotextiles, *Proc. Geosynthetics*, Vancouver, 2: 579–592.

Jewell, R. A. (1991) Application of revised designed charts for steep reinforced slopes, *J. of Geotextiles and Geomembranes*, 10: 203–233.

Koerner, R. M. (1990) *Designing with Geosynthetics*, Prentice-Hall, New Jersey.