The confinement effect of different geogrids

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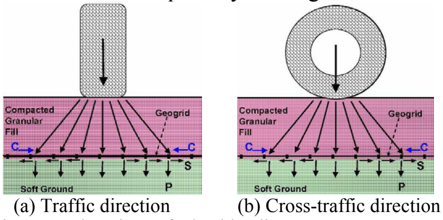
ABSTRACT: It is now well accepted that the primary fill stabilisation mechanism of geogrids is confinement of the fill by the geogrid. To gauge the potential for this and to compare products, index properties such as the load at 2% strain in each of the two primary directions have been used in the past. This approach has had some merit whilst all geogrids available were square or rectangular structures. Now, however, the introduction of innovative products to the market has rendered this comparison ineffective. To overcome this, the option of doing tensile tests in more directions than just along the two primary axes has been proposed and used. However, this also is ineffective as it still fails to model the omni-directional confinement required to stabilise fill under a wheel load. In a paper presented at the EuroGeo4 Conference in 2008 it was shown that from index tests on the elements of a geogrid and a simple calculation, the confinement potential of different products can be readily determined and compared. The paper also showed that simply using tensile testing in different directions is inappropriate for this purpose. This concept of confinement potential can be defined as: Confinement Load: The load that a circle of geogrid can provide at a specified strain to confine a layer of soil placed upon it.The present paper takes this concept forward by describing the measurement of the properties of a number of geogrids, both rectangular and non-rectangular. From this the Confinement Load available from each geogrid is calculated. Also described is work towards developing an index test that could measure this property directly.

1 BACKGROUND

When a wheel load is applied to a geogrid-reinforced road-bed this is conventionally illustrated by elevations such as Figure 1(a). Also, the road deformation from repeated passes a linear rut. This led to a belief that the primary loading from the wheel



(a) Traffic direction (b) Cross-traffic direction

Figure 1: Elevations of wheel loading

on the ground is stresses transverse to the direction of travel. In fact, this is not the case. Figure 1(b) is equally valid. The wheel applies a point load to the ground. Stresses at the interface are as shown in the plan view of Figure 2 with omni-directional radial shear stress S being generated by the wheel load. This is resisted by an omni-directional confinement load C within the reinforcing geogrid.

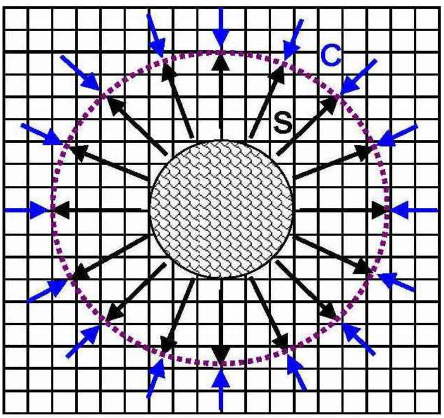


Figure 2: Stresses at Reinforced Interface

In Wrigley & Zheng, 2008, it was shown that conventional tensile testing in accordance with ISO 10319 is not capable of predicting the confinement load C that geogrids can generate, particularly for the novel geogrids that are now on the market with apertures that are triangular. However, it was shown in that paper that the confinement load C could be calculated readily from the properties of the individual sets of ribs in the geogrid.

At the time of writing Wrigley & Zheng, 2008 large-scale samples of non-square geogrids were not available for testing. Therefore, the concept proposed was purely theoretical.

Now that suitable samples have become available that work has been taken forward practically. In this current paper tests of the properties of the ribs of both square- and triangular-aperture geogrids are described, results given and the potential confinement load for each product calculated. Then this work is taken a step further and this paper reports initial results of a method of omniaxial loading of geogrid samples. This is potentially the basis of an index test for the direct determination of the confinement load that a geogrid can generate.

2 RIB PROPERTY TESTING

For geogrids with square apertures, standard ISO 10319 wide-width tests in each direction on samples as illustrated in Figure 3(a) are direct measurements of the rib properties in the direction of test.

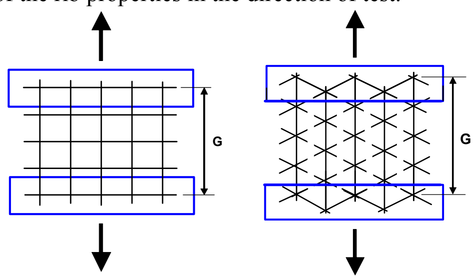


Figure 3: (a) Square Aperture (b) Triangular Aperture

For geogrids with triangular apertures it is necessary to cut all ribs angled to the direction of test, as illustrated in Figure 3(b), in order to measure the properties of a set of ribs. Also, as standard knurled jaws grip only on the junctions of an integral geogrid, it is necessary to cut the overall shape of each sample of triangular-aperture grid in the form shown in Figure 3(b) to ensure that the gauge length G of each rib is the same

Tests in accordance with the principles of ISO 10319 (20%/min speed and temperature of 20 ± 2^0C) were carried out on 5 different geogrids: 3 grades of square-aperture grid from a manufacturer's stock, and 2 grades of triangular-aperture grid obtained in the UK market. Results of conventional ISO 10319 tests and rib strength tests are summarised in Table 1. In this table, Products S1-3 are biaxially-stretched geogrids with square apertures. Products T1,2 are biaxially-stretched geogrids with triangular apertures. All these products are as close as manufacturing technology allows to being isotropic, but there are small differences in rib strength from one direction to another in them all. The figures for Rib Strength given in Table 1 are the averages for each product. Results for products S1-3 are from the manufacturer's QC data. Results for products T1,2 are from testing in an independent laboratory.

3 CALCULATION OF CONFINEMENT LOAD

In Wrigley & Zheng, 2008 fomulae for the calculation of confinement load for isotropic geogrids were determined to be:

$$C_{2Square} = F_{R2}/p \text{ N/m} \quad (1)$$

And

$$C_{2Triangular} = 1.5F_{R2}/p \text{ N/m} \quad (2)$$

Where

C_2 = The Confinement Load at 2% Strain

F_{R2} = Rib Load at 2% Strain (N)

p = Rib Pitch (m)

Based on Formulae (1) and (2) the Confinement Load at 2% Strain was calculated for each product tested. The results are shown in Table 1.

Table 1: Tensile Test results

Product		T1		S1		T2		S2		S3	
Test Direction		MD	CMD	MD	CMD	MD	CMD	MD	CMD	MD	CMD
Ultimate Strength	kN/m	26.7	18.3	22.5	24.4	32.4	22.5	31.4	34.5	42.2	47.5
Strain at Ultimate	%	9.0	10.3	11.4	8.6	8.8	8.4	14.0	9.1	14.0	9.8
Load at 2% Strain	kN/m	8.9	6.8	10.3	11.3	10.5	9.5	13.6	15.1	16.5	20
Average Rib Load at 2%	N	249		470		323		605		700	
Average Rib Pitch	mm	38.6		42.7		38.4		41.6		37.7	
Weight	g/m^2	251		251		308		347		536	
Calculated Confinement Load at 2% Strain	kN/m	9.7		10.8		12.6		14.3		18.2	

Note: S denotes a square-aperture sample and T triangular

4 DISCUSSION OF THE CALCULATED CONFINEMENT LOADS AT 2% STRAIN.

The figures in Table 1 show that the Confinement Load at 2% Strain is closely related to the weight/m2 of the different products, with no significant difference between square and triangular apertures. This is not surprising. In the square-aperture products there are 2 sets of ribs, whilst in the triangular-aperture products there are 3 sets. Therefore, if two products have the same weight per square metre the ribs of a square-aperture product are approximately 50% heavier and stronger than the ribs of a triangular-aperture product if both are oriented to similar levels.

It should also be noted that these calculations are based on the assumption that uniaxial rib tests are representative of product behaviour under omniaxial loading. The work described below suggests that this is not necessarily the case.

5 AN INDEX TEST FOR CONFINEMENT LOAD

5.1 *Background*

In order to check the assumption that uniaxial testing can predict omniaxial performance a test is needed in which a sample is loaded omniaxially at a suitable scale. The simplest way to do this is to carry out some form of burst test of a circular sample clamped around its edge. There are many such tests available and in particular DIN 61551, 2008 which includes the testing of samples up to 1m in diameter – a very similar scale to what is believed to be the loaded area of a geogrid under a wheel load. Equipment for this testing at 1m diameter was available at SKZ, Würzburg, Germany and arrangements were made to test the types of integral geogrid shown in Table 1.

5.2 *Test Method*

The equipment required for testing in accordance with DIN 61551 is shown in Figure 4.

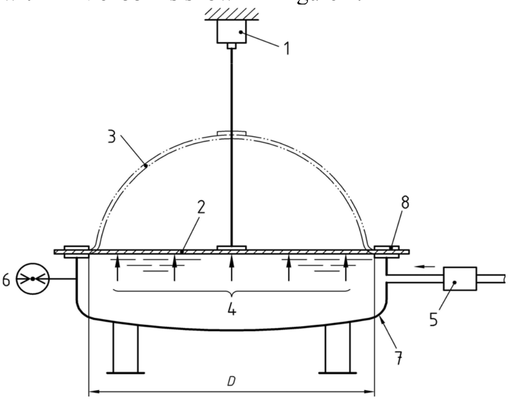


Figure 4: DIN 61551 Apparatus (© Deutches Institut für Normung)

In the standard test a circular sample, 2, generally a geomembrane, is clamped across a base, 7, by clamps, 8,and subjected to water pressure, 4. This inflates the sample to position 3, or further, as required. During testing the water pressure and sample deflection are logged. For a 1m diameter sample the relationship between deflection and omniaxial strain in the sample are shown in Figure 5.

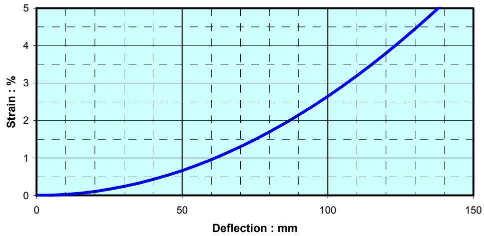


Figure 5: Relationship of Strain to Deflection for a sample of 1m diameter.

Clearly this requires an impervious sample. Therefore, to test a geogrid a combination of geogrid and impervious membrane was need for the test method to function. For the tests described below a flexible PVC membrane was used under each geogrid. Tests were also carried out of the membrane alone so that the net load in the geogrid alone could be determined. In the region of the clamp, 8, of Figure 4 the arrangement used for the testing of the combined materials is shown in Figure 6.

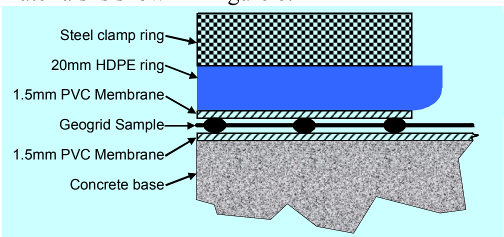


Figure 6: Clamping of Geogrid and Membrane together

In DIN 61551 there are 2 options for running tests: controlled pressure and controlled inlet water flow rate. As the computer software for the apparatus was set up for the controlled pressure method, this was employed for these tests, even though the controlled rate method would be more suitable for geogrids for comparison with other tensile test data.

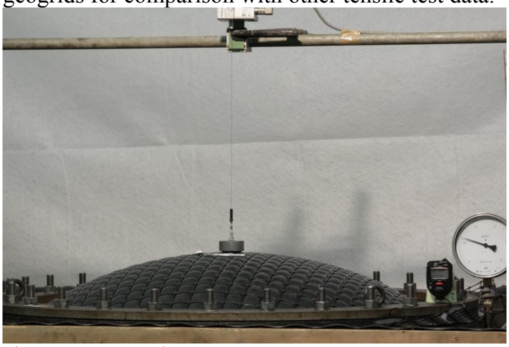


Figure 7: Test S2-2 in progress

5.3 *Test Results*

For each geogrid 2 samples were tested. One of these tests in progress is shown in Figure 7. Then 3 samples of membrane alone were tested. The average results of the membrane tests were deducted from the results of each combined product test, even though they represented less than 6% of the combined product loads, to leave data giving the relationship between deflection and water pressure for each geogrid sample. These data were then converted to omniaxial strain and tension based on formulae given in DIN 61551.

These data are plotted in figures 8 and 9. Figure 8 compares the results for the two lightest geogrids, Figure 9 compares the 2 medium-weight geogrids.

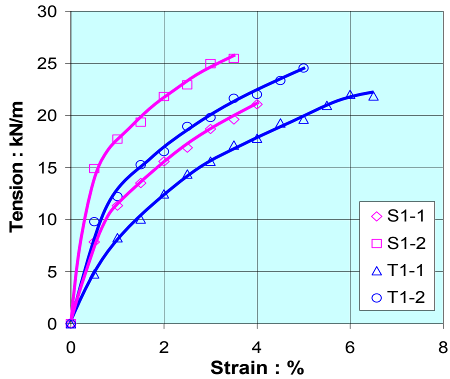


Figure 8: Comparison of light-weight geogrids

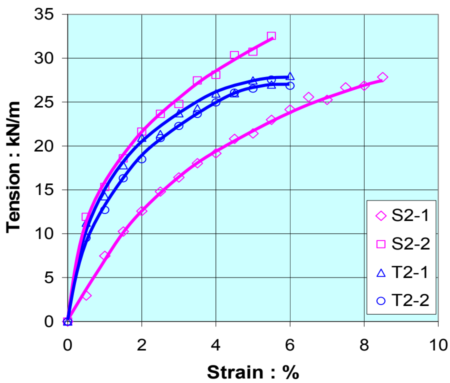


Figure 9: Comparison of medium-weight geogrids

5.4 *Discussion of results:*

In both Figures 8 and 9 three things can be seen:

- There is a large scatter between samples
- The tensions at 2% strain are higher than the calculated confinement loads from Section 4 above.
- As suggested in section 4 there does not seem to be any significant difference in performance between square- and triangular-aperture products.

The first of these observations is probably due to the test method. This test was developed for large-strain testing of membranes and it has not been optimized yet for low-strain testing of geogrids. This has then probably been exaggerated by the resilient clamping of the samples giving additional apparent strain.

The second of these observations suggests that the integral geogrids tested all behave with greater stiffness under omniaxial loading than under uniaxial loading. This is probably due to the junction regions being loaded by all ribs rather than just one pair of ribs in-line. If this observation is confirmed by further work it would play a part in explaining the occurrence of differences in the field performance of different geogrids, e.g. Jenner et al, 2002.

Before these observations can be finally confirmed more work is required to optimise the test method for low strain testing of geogrids. In particular:

- The sample clamping needs to be improved to ensure there is no resilience.
- The test should be conducted at a constant rate of inflation..

6 CONCLUSIONS

- As in Wrigley & Zheng, 2008, it is concluded that omniaxial tension, or "Confinement Load" at 2% strain should be adopted as an index measure of the performance potential of a geogrid to enable the comparison of different forms of geogrid
- When the test method of DIN 61551 has been optimised for measurements of the performance of geogrids at low strain it will be a suitable index test for the Confinement Load at 2% strain of geogrids.
- The increased stiffness of response of integral geogrids to omniaxial loading compared to uniaxial loading should be studied further. This may give an explanation of the differences in field performance of these products compared to other forms of geogrid.

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