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Large scale plate load testing of biaxial geogrids with integral junctions

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ABSTRACT: To gain a better understanding of the behaviour of biaxial geogrids with integral junctions under concentrated loading normal to the plane of the geogrid, a series of large scale plate loading tests were undertaken. Tests were conducted at constant rates of deformation and under sustained loading. In this paper, the properties of the biaxial geogrids tested are detailed, the apparatus and test procedures are described and test data obtained are presented. It is shown that the biaxial geogrids responded to plate loading in a complex manner. Areas close to the loaded plate edges act uniaxially in two orthogonal directions, but away from the loaded area, biaxial behaviour was observed. Thus, the operational stiffnesses of these geogrids varied over the test area. A means of dealing analytically with this variation of uniaxial and biaxial stiffness in designs and back-analyses of operational performance is detailed.

1 INTRODUCTION

Recent research has shown that biaxial geogrids with integral or welded junctions, tested under biaxial loading conditions, exhibit significantly higher stiffness than when tested under uniaxial loading conditions. This applies both to constant rate of strain and sustained loading test conditions (McGown and Kupec 2004, Kupec and McGown 2004).

Thus, the choice of design input parameters must consider these differences. It is suggested here that under plane strain operational conditions, such as in long walls, slopes and embankments, the uniaxial stiffness should be used. However, during construction of such structures, biaxial loading and so biaxial stiffnesses of geogrid reinforcements may be mobilised, e.g. as a result of compaction stresses. For applications such as road pavements and load transfer platforms, it is likely that the operational loading in the geogrids is principally biaxial, hence biaxial stiffness will generally apply. Nevertheless it should be noted that operational biaxial loading may not always be equal in both directions, (isotropic), rather it may be unequal, (anisotropic) and the operational stiffness may therefore lie somewhere between the uniaxial and biaxial stiffness values.

Thus, in order to establish the response of biaxial geogrids with integral junctions to loading normal to the plane of the geogrid, whilst it is restrained laterally, a large-scale plunger load test methodology was developed and used to test a number of biaxial geogrids with integral junctions.

2 TEST APPARATUS

The apparatus employed for the plate load testing consisted of two main parts, Fig. 1.

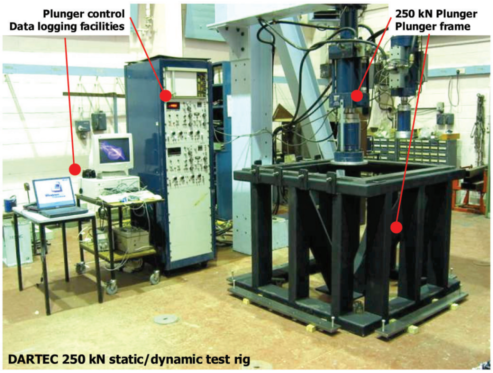


Figure 1. Test apparatus.

The first part was a 250 kN capacity hydraulically operated loading ram electronically controlled so that it could apply loads at a constant rate of vertical displacement, at a constant rate of load increment or at a constant load level. On the end of the ram, rigid platens of various diameters were attached. In the reported test series, platens of 300, 400 and 500 mm diameters were employed.

The second part of the apparatus was a very rigid 1 m square support frame fixed to a structural rigid floor. The centre of the frame was exactly beneath the centre of the loading ram. On the top of the support frame there were four 1 m long profiled clamps. Two clamps were fixed and two were adjustable so that the biaxial geogrids could be slightly pre-stretched prior to loading by the platen attached to the ram.

In order to measure the load-strain behaviour of the geogrid under normal loading the applied hydraulic load in the ram was measured electronically. The vertical displacement of the platen was measured by a Linear Variable Differential Transformer (LVDT) remotely clamped to the support frame. Numerous other LVDTs were attached to the geogrid sample to measure the deformations generated at selected points. Additionally, a fixed camera was placed on the structural floor beneath the support frame to take detailed photographs of the deformations generated in the geogrid sample, the relative movement beneath the loading platen and to record the mode of failure. All the electronic loading and displacement data were captured and analyzed using a remote Personal Computer operating specially developed software.

3 TEST METHOD

Geogrid samples were cut carefully to size, (1.1 m × 1.1 m) and the four edges cast in 20 × 12 mm Ostalloy for the purposes of clamping (Ostalloy is a fusible alloy with a low melting temperature of approximately 65°C). The prepared sample was left in a flat position for at least 24 hours next to the test apparatus in the test laboratory to ensure the material was at the control temperature, (20 ± 2°C).

The test sample was carefully lifted into position and fixed into the four clamps on top of the support frame. The two adjustable clamps were carefully pulled out horizontally in order to exert a small, equal pre-tension load to the test sample in the two orthogonal directions.

Circular platens were used. However, preliminary testing was undertaken and showed that under operational strains there was no significant difference in the behaviour of the geogrid loaded with square or circular platens (Kupec 2004).

With the test sample in position and pre-tensioned, the loading ram with the chosen platen fixed to the end was gradually lowered onto the surface of the geogrid. As the platen was made from smooth aluminium a sheet of coarse double-sided sandpaper was inserted between the platen and the geogrid to ensure that no relative slippage over the loaded area occurs during testing. This was confirmed by the photographic record of the relative movements of numerous points on the geogrid sample beneath the loading platen.

The vertical LVDT was fixed to the loading platen and various other LVDTs were attached to the geogrid at selected points. At the first indication of load resistance, the vertical LVDT and all the LVDTs attached to the geogrid, were zeroed.

The loading ram was then set to move vertically downwards at a constant rate of deformation or exert a sustained loading after an initial and predetermined deformation. The rate of deformation chosen was varied with the relative proportion of the loaded area to the full restrained area, such that the average rate of strain in the geogrid between the edge of the platen and the restrained edge was always 10% strain in 100 minutes, (0.1% per minute). At the start of loading, the loads and LVDT readings were continuously recorded and photographs of the geogrid deformations taken every 3 minutes.

4 MATERIALS TESTED

Three isotropic biaxial geogrids were tested, geogrids E, F and G, Table 1. On the basis of an extensive series of uniaxial and biaxial short-term and long-term testing isochronous load-strain curves were developed (McGown et al 2004, Kupec 2004).

Table 1. Geogrid properties.

Isotropic Biaxial Geogrid with Integral Junctions	Mass Per Unit Area [g/m^2]	Polymer	Nominal Strength° MD/XMD [kN/m]
E	660	PP	40/40
F	470	PP	30/30
G	260	PP	20/20

Note: °According to manufacturer specification

5 TEST PROGRAMME AND TEST DATA

The likely distribution of uniaxial and biaxial stresses within the test samples, was initially analysed using simple FEM analysis. These data were used to determine the size and shape of the test specimens.

A series of constant rate of deformation and sustained loading tests were carried out on three isotropic biaxial geogrids (Kupec 2004). The applied plunger loads were re-plotted as the normalised loads carried by the geogrid in the two orthogonal directions against the measured average strains in the geogrids and the normalised vertical platen displacement, Fig. 2. The test results from sustained loading tests were plotted geogrids loads against logarithmic time, Fig. 3.

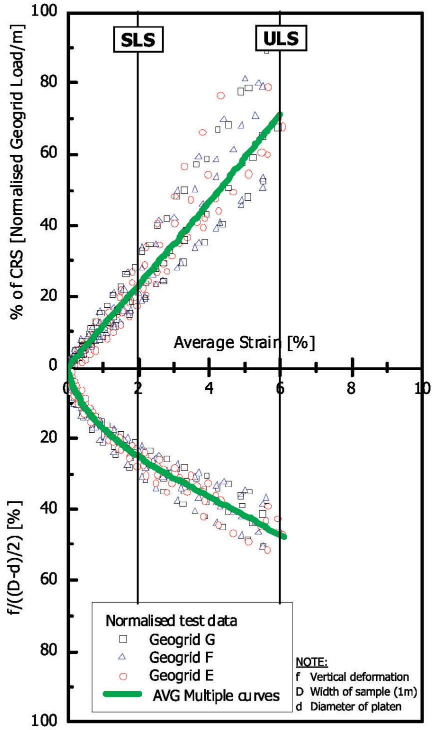


Figure 2. Range of normalised constant rate of deformation test results with representative averaged multiple curves.

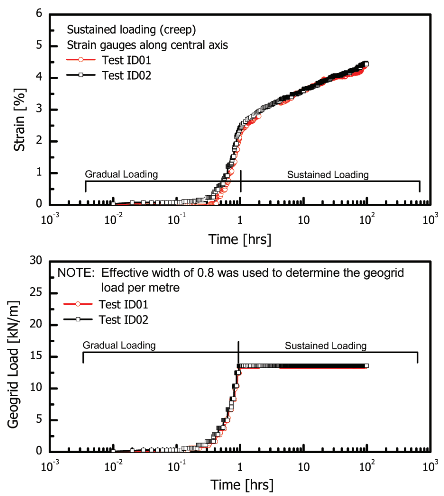
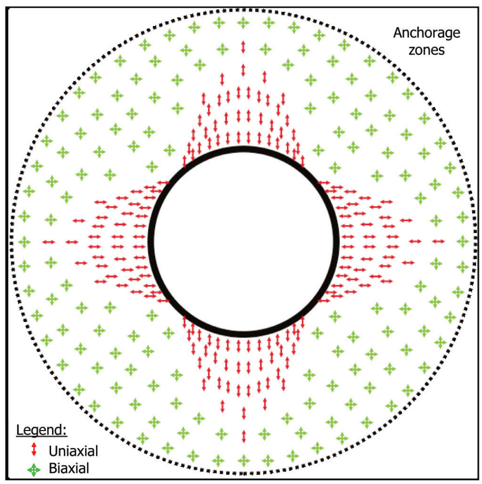


Figure 3. Test results from sustained loading.

6 INTERPRETATION OF TEST DATA

6.1 *The development of uniaxial and biaxial strains in the geogrid*

Analysis of the photographic record of the geogrid as it was strained under load, together with the LVDT deformation data at selected points, showed that the geogrid developed both uniaxial and biaxial strain patterns at various areas between the loading platen and the edge restraints, Fig. 4. Close to the platen the strain behaviour was uniaxial in two orthogonal directions but away from the platen these very quickly changed to biaxial strains. Thus close to the platen the load strain behaviour of the geogrid would be that identified in uniaxial testing in two orthogonal directions, but away from the platen it would be biaxial. This was observed to significantly influence the deflection pattern of the geogrid under these localised normal loading conditions.



Note: Results from large scale plate loading constant rate of deformation and sustained loading indicated similar results

Figure 4. Representation of the load transfer mechanisms within a centrally loaded geogrid sample (1 m × 1 m).

6.2 *Representing the load strain behaviour of the geogrids under plate loading*

Biaxial load strain test data for biaxial geogrids is not widely available, therefore it is generally necessary to predict or interpret the behaviour of biaxial geogrids using uniaxial load strain test data. Thus, in order to interpret the plate loading test data this approach was taken.

Firstly, normalised load-strain curves for the three isotropic biaxial geogrids were produced using the

1-hour, uniaxial creep test isochronous load-strain data divided by their nominal uniaxial CRS strengths. Secondly, the plunger loading test data were adjusted using different effective widths of the geogrid as a proportion of the plunger diameter (w*). Next correlations between the 1-hour plunger loading test data and the 1-hour normalised load-strain at operational strains were established.

Limiting strains commonly applied for Serviceability Limit State (SLS) and Ultimate Limit State (ULS) were plotted. Although some national and international standards suggest a SLS strain of 4%, operational conditions generally relate to lower strain levels. ULS strain of approximately 6% is commonly employed to limit the associated vertical deformations.

For the 1-hour test duration and for other times it was shown that an effective width of the geogrid as a proportion of the plunger diameter (w*) of 0.8 was appropriate for correlations of test data from the plate loading test data and uniaxial test data, Fig. 5.

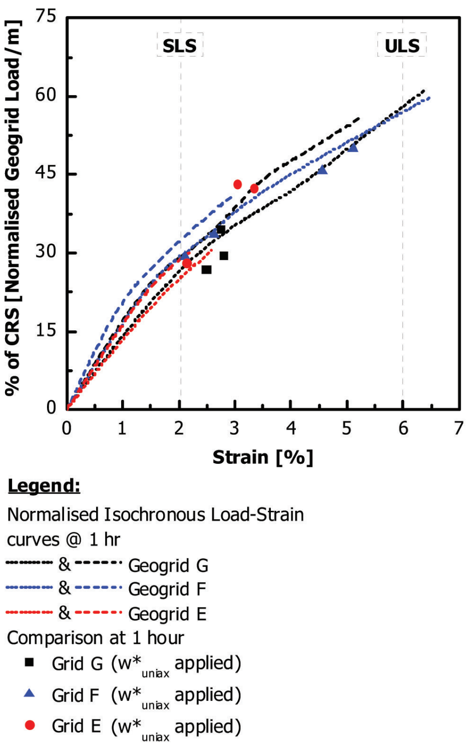


Figure 5. 1 hour isochronous load-strain curves from large scale plate loading tests, with w* applied, in comparison with 1 hour uniaxial isochronous load-strain curves.

7 DISCUSSION

The large scale plate loading test apparatus and test methodology described in this paper has provided a better understanding of the behaviour of biaxial geogrids under localised normal loading. It has shown for three isotropic biaxial geogrids with integral junctions that they behave very similarly.

Both orthogonal uniaxial load strain behaviour and biaxial load strain behaviour were observed to develop in different areas of these geogrids, depending on the location in relation to the normally loaded area.

Normalisation of test data and determination of isochronous curves from constant rate of strain and sustained loading showed that this family of geogrids can be represented in designs or back-analysis with reasonable accuracy, by a narrow-band of uniaxial load-strain curves.

When suitably factored for working conditions within biaxially loaded structures, the geogrids can be represented by normalised uniaxial isochronous load-strain curves.

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