# Design Factors for E'GRID Products:

# Site Damage

## 1: Background:

When Geogrids are buried in earth structures some damage occurs. It is necessary to allow for this damage during design.

To assess the allowances to be made full-scale installation tests with Geogrids and real fill materials are carried out to make it possible to measure the damage caused by different fill materials.

A suitable test protocol for this is described in Annex D of BS8006 : 1995

This note describes testing carried out according to the principles of this protocol to determine the Site Damage factors to be applied to the range of E'GRID uniaxial geogrids from BOSTD Geosynthetics Qingdao Ltd, Qingdao, PR China.

## 2: Products to be Tested:

As each product in the E'GRID range is made from a different thickness material it was decided that all products should be tested to ensure that accurate factors for each were obtained. Therefore the following E'GRID products were tested:

**E'GRID 50R, 65R, 90R, 130R, 170R**

## 3: Fill Materials to be used for the Tests:

BS8006 recommends that 3 different fill materials be used: Fine, Medium and Coarse. However, it is known that in the international market reinforced soil structures are built with a wide range of different materials. It was therefore decided that five fill materials would be used for the tests that could be described as fine, medium-fine, medium, coarse and very coarse.

The materials selected for use were crushed granite obtained from quarries local to Qingdao, where the tests were carried out. The standard output from these quarries did not include well-graded fill mixtures that matched the range required for test. Therefore various standard and selected fill grades from the quarry were blended in a large cement mixer to achieve the gradings shown in table1 below. These gradings were selected to meet the requirements of Class 6I of Table 6/1 of the UK

Highways Agency Manual of Contract Documents for Highway Works: Specification for Highway Works (well-graded granular fill for reinforced soil structures)

| Material | Percentage by Mass Passing the Size Shown (mm) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 125 | 100 | 75 | 53 | 40 | 31.5 | 25 | 20 | 16 | 10 | 5 | 2.5 | 1.25 | 0.63 | 0.08 |
| **Fine** | | | | | | | | | 100 | 96.6 | 61.5 | 53.3 | 51.3 | 18.1 | 1.5 |
| **Medium -Fine** | | | | | | | 100 | 99.2 | 92.1 | 71.7 | 43.1 | 37.3 | 35.9 | 12.7 | 1.0 |
| **Medium** | | | | 100 | 87.5 | 78.8 | 75.7 | 74.7 | 72.4 | 63.9 | 38.0 | 32.3 | 30.9 | 11.0 | 0.9 |
| **Coarse** | | | 100 | 85 | 75 | 68 | 65.5 | 64.7 | 62.4 | 54.6 | 35.7 | 31.6 | 30.6 | 10.7 | 0.9 |
| **Very Coarse** | 100 | 85 | 85 | 75 | 67.5 | 62.3 | 60.4 | 59.7 | 57.4 | 50 | 34.6 | 31.3 | 30.5 | 10.6 | 0.9 |

**Table 1: Gradings of Fill Materials Used**

To illustrate the form of the particles of these fills Figure 1 is a photograph of a layer of the Coarse Fill before compaction.

**Figure 1: Coarse Fill before Compaction**

# 4: Test Layout:

In order to accommodate the number of grids needed and 4 fill materials, the layout of the test site was as shown in Figure 2 below. At both ends of the plan there were run-out areas at the same level as the finished fill.

BS8006 calls for fill layers above and below the geogrid samples to be either 150mm or 1.5 x Maximum Particle Diameter whichever is the greater. For these tests this would have given a layer thickness of 187.5mm. It was decided that a practical compromise for ease of construction would be 175mm. When laying the strips of geogrid across the site a small gap (>20mm) was left between adjacent strips to ensure that there was no overlap of adjacent samples.

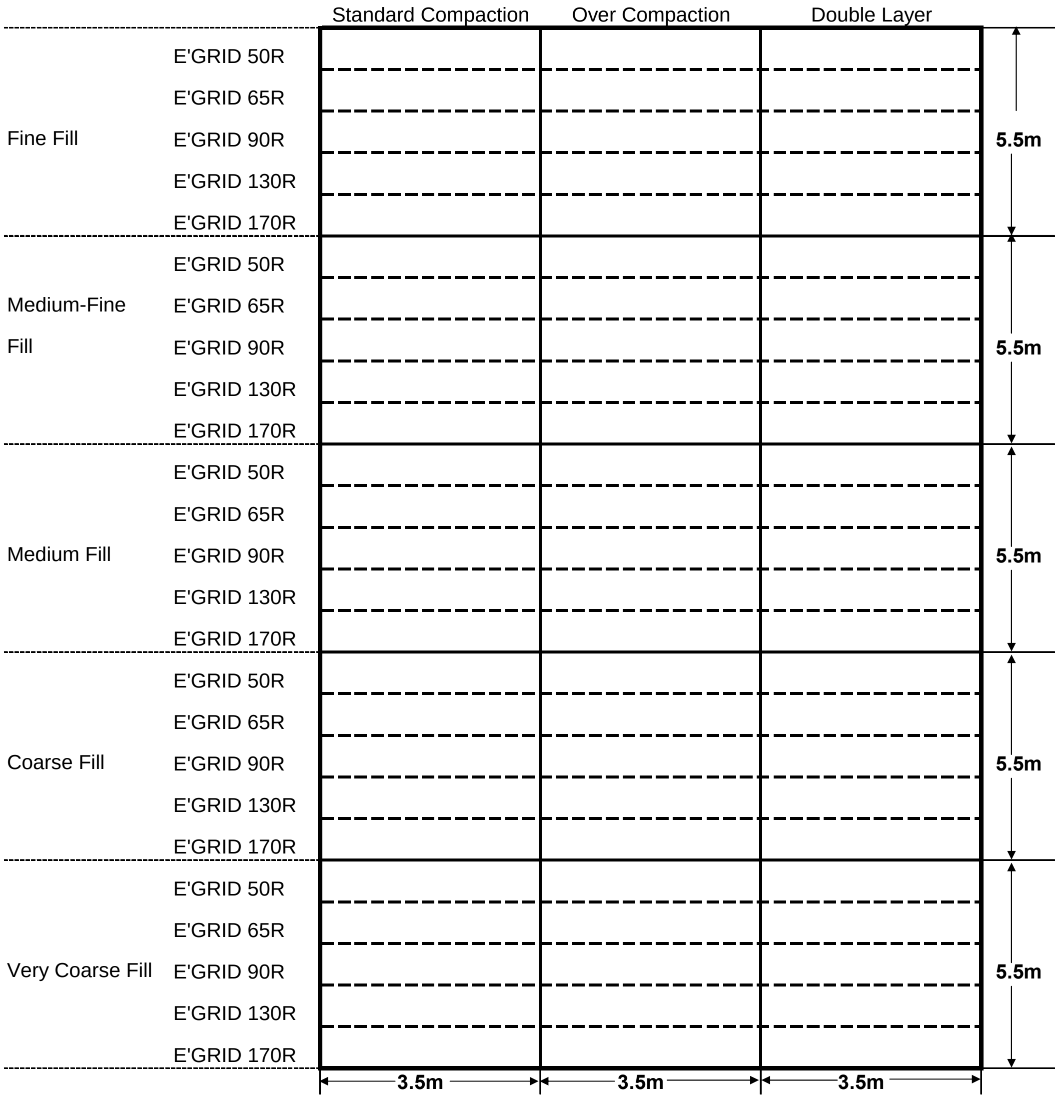


**Figure 2: Test Site Layout**

## 5: Compaction of the Fill Materials:

BS 8006 calls for the fill in the tests to be compacted in accordance with Table 6/4 of the UK Specification for Highway Works. This details the different types of compaction equipment that can be used with each class of fill and the number of passes required to achieve Standard Compaction. For these tests a suitable piece of equipment was determined to be a ride-on Vibratory Roller. From the restricted number of such machines available for hire in the Qingdao area the following machine was selected:

- Front Vibratory Roll: Steel, weight 5.4Te, width 2.1m (2.57Te/m)

- Rear Wheels: 2off, Rubber-Tired, weight 2.8Te each

From Table 6/4 it was determined that Standard Compaction with this machine would require 4 passes at a speed of 2km/hr. Thus, Over Compaction would be 8 passes of the machine and Double Compaction would be 4 passes each on two layers of 175mm. This machines is shown in action in Figure 3.

**Figure 3: Compaction**

## 6: Construction of Test:

A level site was prepared in the grounds of the BOSTD Geosynthetics Qingdao Ltd manufacturing site. On this five test bays were constructed by laying and compacting level the required areas of the five different fills.

The geogrid samples were then carefully laid out and the required fill placed on them as shown in Fig. 4. Great care was taken to not disturb the position of the samples or damage them by walking or driving machinery on them before they were covered with fill. Sufficient fill was placed to give a finished layer thickness of 175mm ±10mm.

**Figure 4: Placement of Fill on Geogrid Samples**

After compaction of the fill layers measurement of the finished thickness of the fill in the centre of each test area gave results of 172 – 175mm

## 7: Sample Recovery

The fill was removed from over the samples by hand as shown in Fig 5.

**Figure 5: Recovery of Geogrid Samples**

Any areas of samples that were accidentally damaged by spades during recovery were marked and not used in tensile testing.

## 8: Sample Examination and Test:

Three samples that were typical of the overall section were prepared from each section of damaged geogrid for visual assessment and tensile testing.

Under visual assessment the damage on each sample was classified in accordance with Annex D of BS 8006 into General Abrasion, Splits, Cuts and bruises. As an example, the results of the visual assessment for the E'GRID 90R samples are shown in Table 2 below. These results are typical of those found on all samples. I.e. all samples had general abrasion, many were bruised and some had split ribs. None had any cut ribs

| Product | Fill Materials | Standard Compaction | | | Double Layer Compaction | | | Over (Twice Standard) Compaction | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Visual Assessment | | | Visual Assessment | | | Visual Assessment | | |
| | | Sample1 | Sample2 | Sample3 | Sample1 | Sample2 | Sample3 | Sample1 | Sample2 | Sample3 |
| E'GRID90R | Fine | G | G | G | G | G | G | G | G | G |
| | Medium-Fine | G | G | G | G | G | G | G | G | G |
| | Medium | G 3/B | G 3/B | G 1/B | G 4/B | G 2/B | G 4/B | G 3/B | G 2/B | G 1/B |
| | Coarse | G 2/B | G 5/B | G 1/S 3/B | G 5/B | G 1/B | G 3/B | G 3/B | G 3/B | G 6/B |
| | Very Coarse | G 4/B | G 4/B | G 4/B | G 5/B | G 1/S 9/B | G 5/B | G 6/B | G 1/S 11/B | G 7/B |

**Table 2: Visual Assessment results for E'GRID 90R**

The samples were then tested in accordance with ISO 10319. Also, two sets of control samples of undamaged geogrid that had been retained in the laboratory were tested to ISO 10319. A summary of the results obtained for E'GRID 90R is shown in Table 2 below

| Product | Fill/Compaction | Peak Load kN | SD kN | Strain at maximum load % | Strength Retained % | Damage Factor |
|---|---|---|---|---|---|---|
| E'GRID 90R | Control | 19.28 | 0.02 | 10.14 | | |
| E'GRID 90R | Control | 18.70 | 0.05 | 10.09 | | |
| E'GRID 90R | Fine/Over | 18.60 | 1.02 | 9.25 | 96.50 | 1.036 |
| E'GRID 90R | Fine/Standard | 19.03 | 0.11 | 9.88 | 98.71 | 1.013 |
| E'GRID 90R | Fine/Double | 18.36 | 0.20 | 9.77 | 95.23 | 1.050 |
| E'GRID 90R | Medium-Fine/Double | 18.23 | 0.61 | 9.04 | 94.53 | 1.058 |
| E'GRID 90R | Medium-Fine/Standard | 18.52 | 0.36 | 9.14 | 96.04 | 1.041 |
| E'GRID 90R | Medium-Fine/Over | 18.55 | 0.45 | 8.85 | 96.23 | 1.039 |
| E'GRID 90R | Medium/Over | 18.29 | 0.36 | 8.71 | 94.86 | 1.054 |
| E'GRID 90R | Medium/Standard | 18.62 | 0.63 | 9.25 | 96.56 | 1.036 |
| E'GRID 90R | Medium/Double | 18.80 | 0.50 | 9.41 | 97.51 | 1.026 |
| E'GRID 90R | Coarse/Over | 18.56 | 0.59 | 9.44 | 96.24 | 1.039 |
| E'GRID 90R | Coarse/Standard | 18.67 | 0.22 | 9.64 | 96.85 | 1.033 |
| E'GRID 90R | Coarse/Double | 18.41 | 0.86 | 9.06 | 95.47 | 1.047 |
| E'GRID 90R | Very Coarse/Over | 17.11 | 1.00 | 8.63 | 88.76 | 1.127 |
| E'GRID 90R | Very Coarse/Standard | 18.12 | 1.22 | 9.21 | 94.00 | 1.064 |
| E'GRID 90R | Very Coarse/Double | 18.04 | 1.35 | 9.51 | 93.59 | 1.068 |

**Table 3: Tensile test Results for E'GRID 90R**

Notes:

1: In this table the figures given for "Peak Load" are the mean peak load for 3 samples. It can be seen that the Control samples have slightly different values. This is to be expected when only three samples are tested from each.

2: In calculating the "Strength Retained" for the damaged samples, the strength of the damaged sample is compared with the higher of the two Control sample results.

3: The "Damage Factor" is 1/(Strength Retained).

In Table 3 the highest Damage Factor found for each fill grading is highlighted in pink.

The highest factors for all products are shown in Table 4 below. Also, so that these figures can be accurately related to the design situation, the nominal maximum particle diameter for each fill grading is given.

| FILL \ PRODUCT | | E'GRID | | | | |
|---|---|---|---|---|---|---|
| | | 50R | 65R | 90R | 130R | 170R |
| **Fine** | **≤ 10mm** | 1.039 | 1.029 | 1.050 | 1.018 | 1.050 |
| **Medium-Fine** | **≤ 20mm** | 1.027 | 1.033 | 1.058 | 1.032 | 1.088 |
| **Medium** | **≤ 50mm** | 1.047 | 1.050 | 1.054 | 1.058 | 1.071 |
| **Coarse** | **≤ 75mm** | 1.066 | 1.072 | 1.047 | 1.106 | 1.122 |
| **V Coarse** | **≤ 125mm** | 1.145 | 1.065 | 1.127 | 1.100 | 1.097 |

**Table 4: Highest Damage Factor for each product**

## 9: Observations and Selection of Design Damage Factors:

The following observations can be drawn from the results shown in Tables 2,3 and 4:

A: There is a significant amount of visual damage on all samples, which is greater with coarser fill gradings.

B: The reductions in strength caused by the visual damage are quite low for all samples and all fills.

C: The magnitude of the strength reduction is more related to the fill grading then the product grade. Within a single grading many of the variations seen must be statistical.

Applying an engineering judgement to the results shown in Table 4 gives the figures shown in Table 5 as suitable Damage Reduction Factors for use with E'GRID products in design:

| FILL \ PRODUCT | | E'GRID 50R | E'GRID 65R - 170R |
|---|---|---|---|
| Fine | ≤ 10mm | 1.05 | 1.05 |
| Medium | ≤ 50mm | 1.09 | 1.09 |
| Coarse | ≤ 75mm | 1.13 | 1.13 |
| V Coarse | ≤ 125mm | 1.15 | 1.13 |

**Table 5: Damage Reduction Factors for use in Design ($RF_{ID}$)**

Note: The results for the 20mm and 50mm gradings in Table 4 are so similar that there is no need to differentiate between them in design.

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