E'GRID®

Soft Soil Reinforcement

What is E'GRID® ?

E'GRID® is a range of geosynthetic products in a mesh or grid made from polymer. The purpose of E'GRID® is to reinforce or add strength to soil for applications including the strengthening of reinforced walls, pavements and highways, construction of earth walls, reinforcing embankments of earth dams, ponds, landfills, landslide repair, railway track reinforcement. The ribbed construction of E'GRID® is designed to significantly increase the structural integrity of soils.

E'GRID® Bi-axial

E'GRID® Bi-axial Geogrids are square meshes of polypropylene (PP) and widely used as subsoil reinforcement. Their prominent characteristic is excellent mechanical properties under intermittent high loading. As a bi-axial mesh strength is equal in both machine and cross directions. As granular materials are compacted into the apertures of the E'GRID® an interlocking effect is achieved. The stiffness of E'GRID® allows for load at low strain. Ultimately highway design relies more on economic solutions which E'GRID® provides, allowing for an estimated 40% reduction in granular materials with no loss of performance.

E'GRID® Bi-axial Geogrids

E'GRID® Uni-axial

E'GRID® Uni-axial Geogrids are meshes with elongated apertures made of high density polyethylene (HDPE) and are generally used as reinforcement of modular block walls, earth walls, slopes and bridge abutments. Their primary characteristic is good creep performance with low strain and high tensile strength under constant load.

E'GRID® Uni-axial Geogrids

Applications

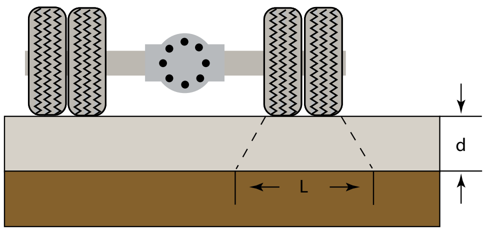
Stabilisation

Bi-axial E'GRID® geogrid, with its square aperture, provides high tensile strength in both directions. The optimised geometry of nodes and ribs increases the shear resistance by a process of interlocking between the square ribs and soil. E'GRID® geogrid can be used with any soil type.

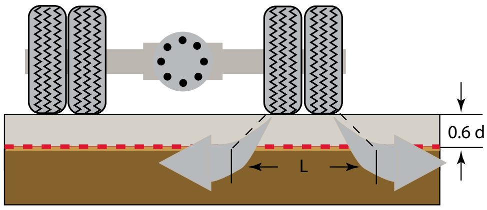
By establishing a composite platform from the fill materials and the interaction of E'GRID® geogrid, the load-spread angle can be increased to approximately 45˚. This makes load dispersal more effective and reduces the foundation height and construction cost.

Soft Soil Foundation Reinforcement

On poor foundations, vertical loading generates lateral stress in the fill, particularly at the base. The resulting horizontal shear applied to the foundation causes lateral displacement failure at the structure. A soft soil foundation has high compaction, often with low permeability and long settlement time. Embankment cracking and structural failure on soft soil foundations often occur due to differential settlement. Conventional measures such as wick drains, chemical consolidation, increasing the width and height of the foundation, piled embankments, surcharging, etc., are complex technically with complicated or lengthy construction or high cost. The shearing resistance of soft soil foundations reinforced by E'GRID® geogrid either alone or together with conventional measures is greatly improved. With compaction improved and reduction of differential settlement, the bearing capacity of foundations is enhanced. The cost of construction is reduced with less fill needed and time scale shortened.



thickness "d" without E'GRID



thickness "d" reduced to 0.6 using E'GRID geogrids

- **Roads, railways, ports and other paved areas**

One layer or multi layer E'GRID® geogrid construction distributes loading and disperses stress more effectively, leading to the reduction of differential settlement and improved foundation capacity.

- **Airport runways**

A tough platform can be established with E'GRID® geogrid reinforcement. Resistance to the impact of aircraft taking off and landing is improved with more effective and immediate load dispersal.

- **Temporary roads and other unpaved areas**

E'GRID® geogrid reinforcement gives ease of construction of temporary pavements with reduced construction costs.

Slopes Reinforcement

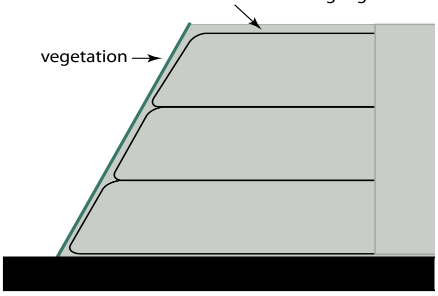
In construction of roads and railways, reduced land take, convenient construction and good safety margins at reduced cost can be achieved by the use of E'GRID® geogrids reinforcement. In environmentally sensitive areas, steep vegetated slopes can often be built in place of the hard-faced structures that would be needed with conventional techniques.

- **Failed slope reinstatement**

The material of the failed slope can be excavated and reused with E'GRID® geogrid reinforcement to reinstate the failed area. This process has low cost and minimal impact on the local environment.

- **Environmental protection of slopes**

E'GRID® geogrids reinforcement can retain the face soil and encourage growth of vegetation. Natural vegetation will cover the whole facing, and special seeding coverage can be sowed to conform to surroundings if needed.



slope vegetation

- **Reinstatement of spent quarries**

With E'GRID® geogrid reinforcement, safe structures and permanent vegetation can be established to reintegrate spent quarries into the local environment.

Walls/ Abutments Reinforcement

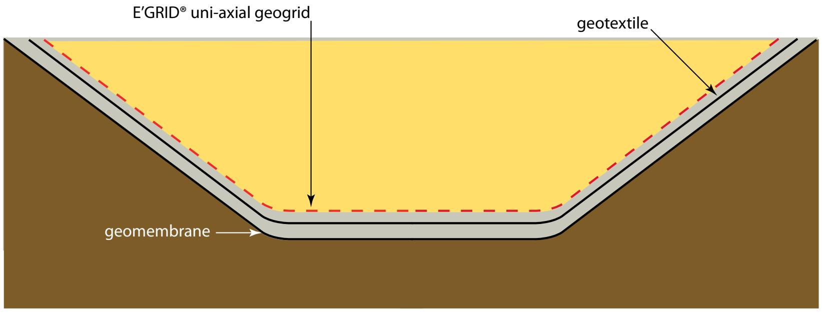
An E'GRID® geogrid reinforced wall is composed of geogrid, wall facing and fill. Because of the resistance of E'GRID® geogrids to chemical and biological attack and its interlock with the fill, a wide range of fill materials may be used, including general backfill soil, construction waste, pulverised fuel ash (FPA), etc. Reinforced walls can be constructed quickly with simple technology at low cost.

Wall and slope faces can be designed economically to suit the clients requirements and to blend into the environment. Wall faces may be of brick, stone, or fully vegetated.

E'GRID® geogrid reinforced walls and abutments are tough and elastic composite structures of multiple layers of geogrid and fill. They can accommodate base deformation and have particularly good resistance to vibration and earthquakes. E'GRID® geogrid reinforcement can improve the bearing capacity and factor of safety of a structure and reduce construction cost.

Landfill

E'GRID® geogrids can be utilised with other geosynthetic materials in the base, cover, temporary pavements and banks of landfill sites. The use of E'GRID® geogrids can reduce landfill costs, increase capacity and improve safety margins.



Bodkin

E'GRID® uni-axial geogrids can be quickly joined together by using the bodkin bar. This provides full connection strength in the direction of the load. Typically these are used to connect joins from the reinforcement to short starts and to connect wrapped geogrids in slope reinforcement.

Bodkin Bar EGB 1225: for use with all grades	
Cross section dimension (width x thickness mm)	25 x 12 (typical)
Length (mm)	1050 (or as specified)
Polymer	HDPE (special grade)
Yield strength 1 (MN/ m^2)	22
Elongation at break 2 (%)	250 (min)
Carbon black (%)	2

Note1: Measured in accordance with BS 3412:1976 (ISO/R527-1966: Type 2 Speed D)

E'GRID® bodkins are manufactured from a specially selected grade of HDPE to ensure the long-term performance of bodkin joints with E'GRID® uni-axial geogrids. No assurances can be given for the performance of joints made with any other bodkins.

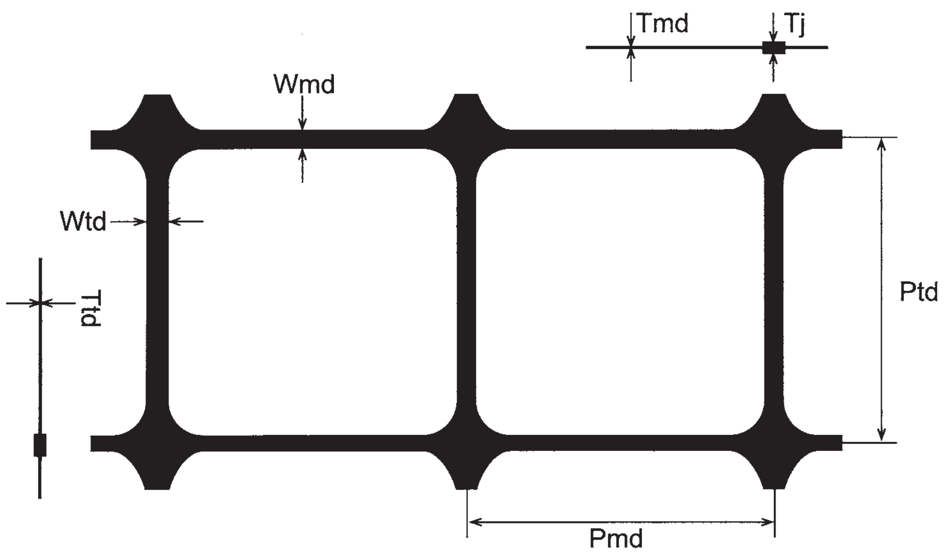
E'GRID® Design

We can provide professional solutions by way of design and product support.

A complete specialised software package is available to assist design and product selection. E'GRID Slopes and Walls and E'GRID Plus was developed for the design of walls, slopes and combinations of walls and steep slopes using the properties of E'GRID. This is based on the industry leading ReSlope and RESSA programmes.

E'GRID® Bi-Axial

	Mass	Tensile Strength		Tensile Load kN/m				Typical Dimensions						
		kN/m (2)		2% strain		5% strain		mm						
Product	kg/m^2	MD	TD	MD	TD	MD	TD	Pmd	Ptd	Wmd	Wtd	Tj	Tmd	Ttd
E'GRID 2020	0.2	20.0	20.0	7.4	7.4	14.8	14.8	40	40	2.0	2.4	4.1	1.0	0.8
E'GRID 3030	0.3	30.0	30.0	10.8	10.8	21.6	21.6	40	40	2.2	2.7	4.3	2.0	1.4
E'GRID 4040	0.5	40.0	40.0	14.0	14.0	28.0	28.0	33	33	2.3	2.6	5.5	2.3	2.0



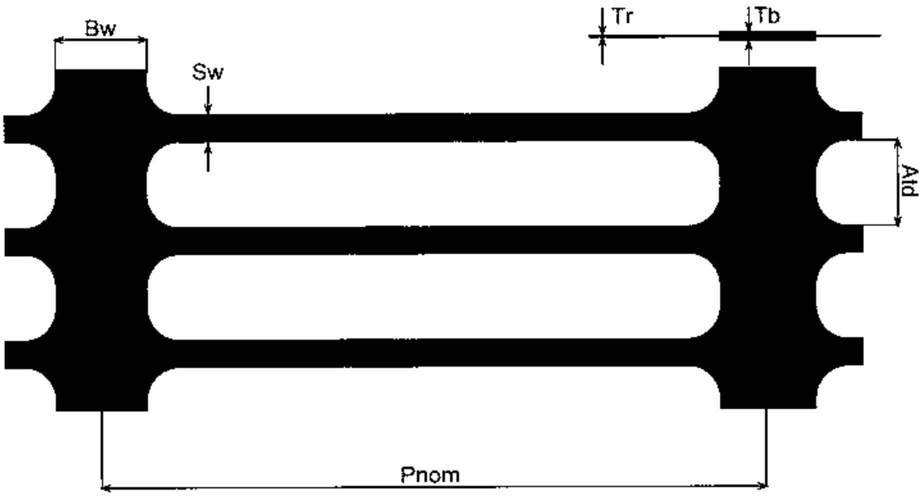
Note 1: In accordance with BS2782 Part 4, Method 452B, 1993.
Note 2: Measured in accordance with ISO 10319 at 20 ± 2° C; calculated as the 95% lower confidence limit in accordance with ISO 2602 1980 (BS 2846 Part 2 1981). Quality Control test certificates will be issued according to customer's requirements.

Polymer: Polypropylene
Resistance to Ultra-Violet Light: A high level of resistance to UV light is given to E'GRID® by the incorporation of ≥ 2% of weathering grade carbon black, well dispersed in the polymer matrix (1). These products may be used for many years in exposed conditions.

Chemical and Biological Resistance:
E'GRID® bi-axial geogrids are manufactured from polypropylene which is unaffected by all chemicals, including acids, alkalis and salts, normally found in soils. Also, it is not a nutrient, therefore these products are not affected by micro-organisms in the soil.

E'GRID® Uni-Axial

Product	Tensile Strength kN/m (1)	Tensile Load kN/m		Typical Strain at Peak Load	Ultimate Creep Limited Strength for 120 Years kN/m (2,3)			Weight	Typical Dimensions mm					
		2% Strain	5% Strain	%	10° C	20° C	30° C	kg/m²	Atd	Bw	Sw	Tb	Tr	Pnom
E'GRID 170R	170.0	52.5	103.0	11	75.8	68.3	61.5	1.1	16	18	6	7.4	2.0	255
E'GRID 130R	141.9	38.0	75.5	11	63.3	57.0	51.3	0.8	16	18	6	5.6	1.6	255
E'GRID 110R	112.0	29.9	56.5	11	49.9	45.0	40.5	0.7	16	18	6	5.0	1.3	255
E'GRID 90R	90.0	23.7	45.2	11	40.2	36.2	32.6	0.55	16	18	6	4.1	1.1	255
E'GRID 65R	68.7	16.1	30.9	11	30.6	27.6	24.8	0.4	16	18	6	2.9	0.8	245
E'GRID 50R	54.0	12.7	24.7	11	24.1	21.7	19.5	0.3	16	18	6	2.1	0.6	235



Note 1: Measured in accordance with ISO 10319 at 20 ± 2° C; calculated as the 95% lower confidence limit in accordance with ISO 2602 1980 (BS 2846 Part 2 1981).
Note 2: Calculated from data obtained in accordance with ISO 13431; creep strength predicted for 120 years design life, taking account of prediction and production.
Note 3: For in-soil design temperatures as shown.
Note 4: In accordance with BS2782 Part 4, Method 452B, 1993.
Quality Control test certificates will be issued according to customer's requirements.

Polymer: High Density Polyethylene
Resistance to Ultra-Violet Light: A high level of resistance to UV light is given to E'GRID® by the incorporation of ≥ 2% of weathering grade carbon black, well dispersed in the polymer matrix (4). These products may be used for many years in exposed conditions.

Creep Performance
A good creep performance under sustained loading is essential for the use of geogrids in critical structures such as walls, abutments and steep embankments. Qingdao Etsong Geogrids Co., Ltd. maintains constant Creep testing programmes in its laboratories and works closely with National and International experts in the performance of geogrids to ensure that its products meet the strictest demands in all markets.

Chemical and Biological Resistance:
E'GRID® uni-axial geogrids are manufactured from high density polyethylene which is unaffected by all chemicals, including acids, alkalis and salts, normally found in soils. Also, it is not a nutrient, therefore these products are not affected by micro-organisms in the soil.

E'GRID® is a registered Trade Mark.

Etsong Bi-Ax Geogrids

E’GRID xxxx

Declaration of Conformity & Accompanying Document

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E’GRID 2020, E’GRID 3030, E’GRID 4040 Geogrids

Qingdao Etsong Geogrids Co., Ltd., Qingda Industrial Zone
Qingdao, Shandong, 2666111, China

03

0338 CPD 107, 108, 109

EN 13249:2000 and EN13250:2000 and EN 13251:2000 and EN13252:2000 and EN 13253:2000 and EN13254:2000 and EN 13255:2000 and EN 13257:2000 and EN13265:2000

Geogrids for application in roads, other trafficked areas, railways, earthworks, foundations, retaining structures, reservoirs, dams, canals, solid and liquid waste disposals, tunnels and underground structures
Intended uses: R + S

MD Tensile Strength (EN ISO 10319)	E’GRID 2020 E’GRID 3030 E’GRID 4040	21.2kN/m (-0.9kN/m) 31.8kN/m (-1.6kN/m) 42.1kN/m (-1.6kN/m)
CMD Tensile Strength (EN ISO 10319)	E’GRID 2020 E’GRID 3030 E’GRID 4040	21.4kN/m (-1.1kN/m) 32.8kN/m (-2.6kN/m) 43.5kN/m (-2.9kN/m)
MD Elongation at Maximum Load (EN ISO 10319)	All Products	11.6% (± 2.5%)
CMD Elongation at Maximum Load (EN ISO 10319)	All Products	10.7% (± 2.1%)
Durability	• To be covered within one month after installation. • Predicted to be durable for more than 100 years in soils with 1.6 ≤ ph ≤12.6 and soil temperatures ≤ 25^{0}C on the basis of durability assessments to ENV ISO 13438 and EN 14030	

Signed by: *liuwei*

Liu Wei, Director of Technology
Qingdao Etsong Geogrids Co., Ltd.

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Etsong Uni-Ax Geogrids

E'GRID xxxR

Declaration of Conformity & Accompanying Document

CE

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E'GRID 50R, E'GRID 65R, E'GRID 90R, E'GRID 110R, E'GRID 130R, E'GRID 170R Geogrids

Qingdao Etsong Geogrids Co., Ltd., Qingda Industrial Zone
Qingdao, Shandong, 266111, China

04

0338 CPD 251, 252, 253, 256, 254, 255

EN 13249:2000 and EN13250:2000 and EN 13251:2000 and EN 13253:2000 and EN13254:2000 and EN 13255:2000 and EN 13257:2000 and EN13265:2000

Geogrids for application in roads, other trafficked areas, railways, earthworks, foundations, retaining structures, reservoirs, dams, canals, solid and liquid waste disposals, tunnels and underground structures

Intended use: R

MD Tensile Strength (EN ISO 10319 at 20^{O}C)	E'GRID 50R E'GRID 65R E'GRID 90R E'GRID 110R E'GRID 130R E'GRID 170R	56.8kN/m (-2.8kN/m) 72.4kN/m (-3.7kN/m) 94.7kN/m (-4.7kN/m) 117.4kN/m (-5.4kN/m) 148.0kN/m (-6.1kN/m) 178.8kN/m (-8.8kN/m)
MD Elongation at Maximum Load (EN ISO 10319)	All Products	11.8% (±3.2%)
Tensile Creep (EN ISO 13431) The 120 year ultimate design strength at 20^{0}C	E'GRID 50R E'GRID 65R E'GRID 90R E'GRID 110R E'GRID 130R E'GRID 170R	22.7kN/m (-1.0kN/m) 28.9kN/m (-1.3kN/m) 37.9kN/m (-1.7kN/m) 47.2kN/m (-2.2kN/m) 59.6kN/m (-2.6kN/m) 71.4kN/m (-3.1kN/m)
Durability	• To be covered within one month after installation. • Predicted to be durable for more than 100years in soils with 1.6 ≤ ph ≤12.6 and soil temperatures ≤25^{0}C on the basis of durability assessments to ENV ISO 13438 and EN 14030	

Signed by: Liuwei

Liu Wei, Director of Technology
Qingdao Etsong Geogrids Co., Ltd.

Qingdao Etsong Geogrids Co., Ltd.
Qingda Industrial Zone, Chenyang District
Qingdao, Shandong, P.C. 26111
P.R. China

Designing with

E'GRID Products

Technical Factors

Design Factors
for E'GRID Products:

DURABILITY

1: Introduction:

In use, soil reinforcement materials may be subjected to many environmental factors that could have an influence on their durability. For example: chemical attack (acids and alkalis), micro-biological attack, oxidation and hydrolysis. The key features that enables a product to resist these factors is material selection.

2: Materials used to Manufacture E'GRID Products:

The materials selected for the manufacture of E'GRID products are internationally-sourced engineering grades of Polypropylene (PP) and High Density Polyethylene (HDPE). These two types of polymer are among the most inert of all bulk materials available to the engineer. They are widely used in critical applications such as gas pipes, hot and cold water pipes and fittings, chemical storage, automobile fuel tanks and various under-bonnet applications including battery cases. In a study carried out when the use of Geogrids was in its infancy it was concluded that PP and HDPE are the ideal materials for their manufacture (ref). They are resistant to chemical and biological attack and well-protected from oxidation by anti-oxidants included by their makers. They are not subject to hydrolysis. There is no known solvent that will dissolve PP or HDPE at ambient temperatures

The only addition to the base polymer during E'GRID product manufacture is Carbon-Black masterbatch. This is included to provide protection against weathering. No externally-sourced re-cycle materials, including post-consumer re-cycle, are used in the manufacture of E'GRID products.

3: Specific Tests on E'GRID Products:

As part of their assessment for CE Marking it was necessary to subject samples of E'GRID products to various environmental durability screening tests. These were:

- ENV ISO 13438: Resistance to Oxidation
- EN 12225: Resistance to Micro-Biological Degradation
- EN 14030: Resistance to Acid and Alkali Liquids

The samples tested were of the lightest grades of products in the ranges: E'GRID 50R and E'GRID 2020.

At the end of the tests the retained strength of exposed samples compared to control samples tested at the same time is shown in the table below (ref):

Test Method	Notes	Retained Strength (%)		
		E'GRID 50R	E'GRID 2020	
		MD	MD	CMD
Oxidation: ENV ISO 13438	100^0C for 56 Days	102.36		
	110^0C for 28 Days		101.1	104.34
Micro-Biological: EN 12225	16 Weeks	101.14	101.4	101.4
Chemical: EN 14030 Method A	Inorganic Acid	100.45	100.75	102.23
EN 14030 Method B	Inorganic Base	102.21	102.18	103.73

4: Conclusion:

E'GRID products manufactured from PP and HDPE are do not suffer from environmental attack in soil reinforcement applications.

Therefore: $\mathbf{RF_D = 1.0}$

References:

- Wrigley N E: Durability and Long-Term Performance of Tensar Polymer Grids for Soil Reinforcement: Materials Science and Technology, Vol 3, March 1987, The Institute of Metals, London, England.

- CE Marking – Durability Tests: Confidential Test Reports 12949/HPM005 and 12949A/HPM005, 1st August 2003, BTTG, Manchester, England.

QEG/NewGrids/Jan04

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Design Factors for E'GRID Products:

Soil-Geogrid Friction Coefficients

1: Introduction:

In design and use the interaction coefficients between soil reinforcement materials and the fill around them are critical. It is necessary to ensure that adequate safety margins exist against failure by direct sliding and pull-out.

"Direct Sliding" failure occurs if a two- or three-part wedge failure surface passes along the surface of a layer of reinforcement material and there is not sufficient friction to prevent sliding. To ensure that this does not occur it is necessary to know for design the "Direct Sliding Coefficient" **(C_{ds})** between the reinforcement material and the proposed soil fill.

Pull-Out failure occurs if the anchorage length of the reinforcement material behind potential failure planes is too short. To ensure that this does not occur it is necessary to know for design the "Interaction Coefficient" **(C_i)** between the reinforcement material and the proposed soil fill.

2: Direct Sliding:

2.1: Test Method:

C_{ds} for E'GRID products has been measured in accordance with ASTM Standard D 5321-02. This test uses a large soil shearbox.

First the friction angle of the soil alone (Φ_{soil}) was measured with the shearbox operating as shown in Figure 1.

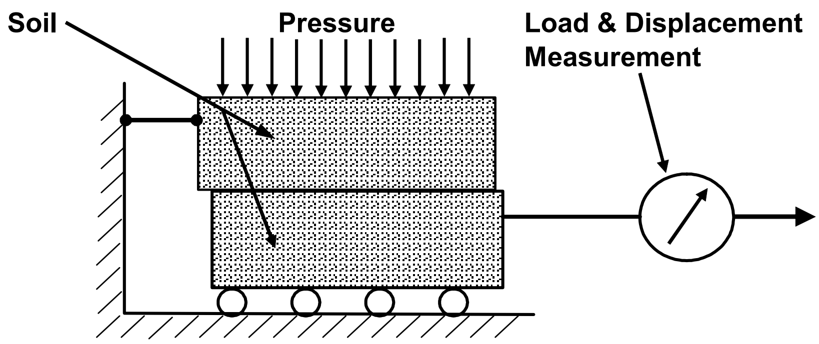

Figure 1: Shearbox with soil alone

Then the friction angle of a soil-geogrid interface (Φ_{ds}) was measured with the shearbox operating as shown in Figure 2:

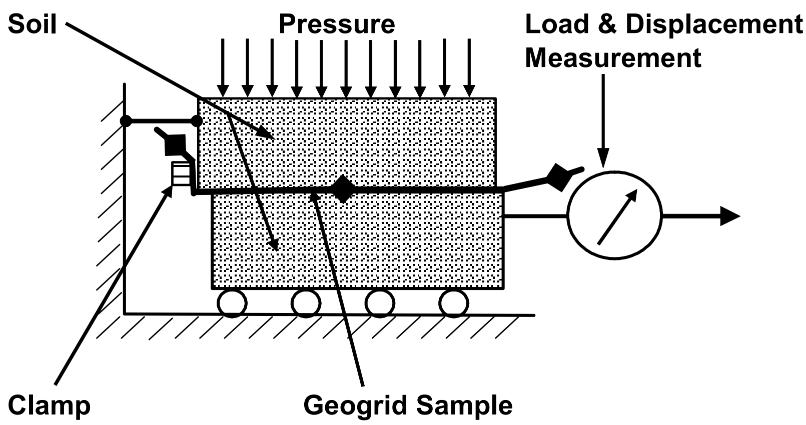

Figure 2: Shearbox with soil and geogrid

Note: The shearbox used was 300mm square in plan. This is only slightly larger than one grid pitch of the E'Grid products. It was therefore decided that all tests would be run as shown in Figure 2, with just one transverse bar of the geogrid sample in the centre of the box.

From the results of these tests the Direct Sliding Coefficient of the geogrid with the soil is calculated by the formula below:

$$C_{ds} = \{\mathrm{Tan}(\Phi_{ds})\}/\{\mathrm{Tan}(\Phi_{soil})\}$$

2.2: Test Results

Tests were carried out at the laboratories of TRI/Environmental Inc. in Austin, Texas, USA using E'GRID 50R, E'GRID 90R and E'GRID 170R and three different soils available in the laboratory. The soils used were types 1,2 and 4 shown in Table 1 below:

Sieve Size (mm)	**Percent Passing**			
	Type 1 (Coarse Gravel)	**Type 2 (Sandy Gravel)**	**Type 3 (Silty Sand)**	**Type 4 (Sandy Silty Clay)**
38	100			
25	51.6			
19	32.8			
12.5	6.0			
9.5	1.8	100	100	
4.75	0.5	60.2	99.9	100
1.7	0.5	9.8	88.5	99.9
0.85	0.5	4.8	66.4	99.8
0.425	0.5	3.9	52.3	98.6
0.25	0.4	3.5	43.9	96.3
0.15	0.2	3.2	37.4	89.6
0.075	0.1	2.6	31.1	67

Table 1: Soil Gradings

E’GRID 90R was tested with all three soils. E’GRID 50R and E’GRID 170R were tested with just Type 2 soil. The results of the tests are summarised in Table 2 below:

	Direct Sliding Coefficient : C_{ds}		
Product / Soil	**E’GRID 50R**	**E’GRID 90R**	**E’GRID 170R**
Coarse Gravel		0.88	
Sandy Gravel	1.03	0.84	0.88
Sandy Silty Clay		0.62	

Table 2: Test Results for Direct Sliding

2.3: Design Values:

From the data in table 2 it is recommended that the following figures may be safely used in design:

- For Granular, Frictional Fills: **C_{ds} = 0.84**
- For Cohesive Clay Fills: **C_{ds} = 0.62**

3: Pull-Out:

3.1: Test Method

The difference between Direct Sliding and Pull-Out is that in the latter both surfaces of the geogrid are sliding though the soil. Therefore more complex interactions between the soil and grid are generated. Without specific testing it is not possible to say whether for a particular product range these interactions will increase or reduce the friction coefficient measured by direct sliding. Therefore a specific test method is required and ASTM Standard D 6706-01 has been developed for this purpose. Tgis test method has been applied to the E’GRID products.

The operation of the test is illustrated in Figure 3 which is taken from ASTM D 6706-01. A key feature of this test method is the load transfer sleeve where the sample exits the box. This sleeve, illustrated in Figure 4, ensures that loads in the soil caused by the shearing action from the geogrid are dissipated within the soil rather than against the end wall of the box.

The length of the box should be 5 times the geogrid aperture length. However, with products of the E’Grid type it is impossible to generate pull-out with such long samples except at extremely low over-burden pressures. All bar one of the tests on E’Grid products were done with 610mm of product in the soil. The one sample that was tested with 915mm embedment ruptured within the soil without pulling out.

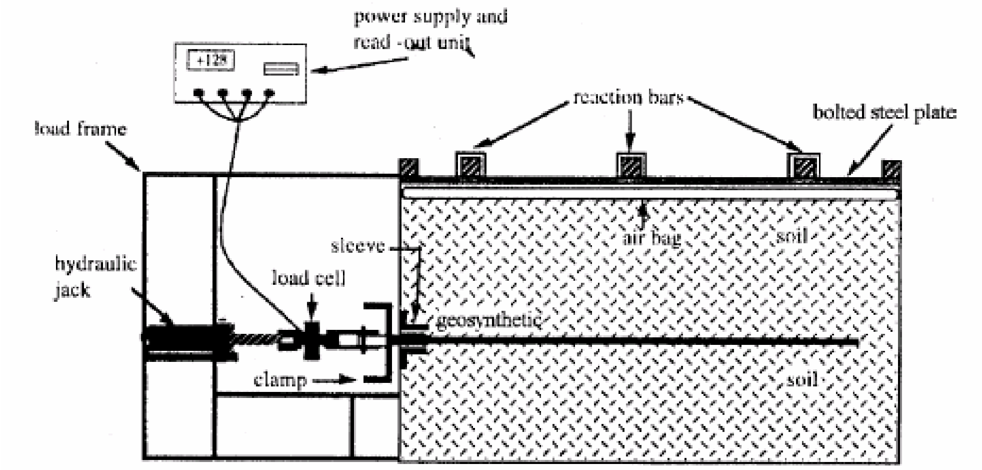

Figure 3: Pull-Out Test Equipment (from ASTM D 6706-01)

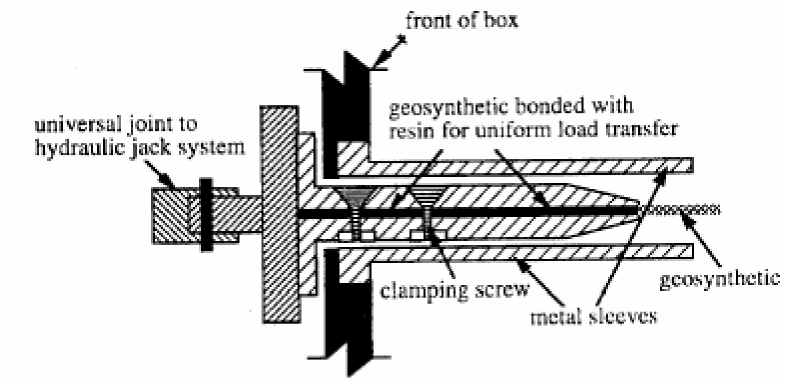

Figure 4: Recommended Load Transfer Sleeve and Sample Clamp (from ASTM D 6706-01)

3.2: Test Results

All pullout tests were done using E'GRID 90R in soils of types 1,3 and 4 from Table 1.

The results achieved are shown in Table 3:

Test #	Width of Geogrid (mm)	Geogrid Embedment Length (mm)	Normal Load (kPa)	Approx. Soil Depth (m)	Peak Tensile Capacity (kN/m)	Mode of Failure	Pullout Interaction Coefficient*, C_i
Coarse Gravel							
1	305	610	10	0.6	14.1	Pullout	1.52
2	305	610	30	1.8	33.4	Pullout	1.20
3	305	915	60	3.6	59.3	Tear	
Medium Sand							
1	305	610	10	0.6	22.9	Pullout	3.47
2	305	610	24	1.4	30.8	Pullout	1.95
3	305	610	52	3.1	39.1	Pullout	1.14
Sandy Silty Clay							
1	305	610	10	0.6	17.2	Pullout	2.97
2	305	610	24	1.4	23.9	Pullout	1.72
3	305	610	52	3.1	26.4	Pullout	0.88

Table 3: Pull-Out Test Results

3.3: Design Values

The results in Table 3 show that $\mathbf{C_i}$ reduces as overburden pressure increases. This is, however, not a constraint on design as at high overburdens only very short anchorage lengths are required even with low values of $\mathbf{C_i}$.

From Table 3 it is clear that a safe value to use for all sol types is given by:

$$\mathbf{Ci = 0.85}$$

If this value leads to unnecessarily long anchorage lengths in design near the top of structures then a designer may wish to take advantage of the higher values demonstrated for $\mathbf{C_i}$ for the upper layers.

References:

Test Reports from TRI/Environmental Inc., Austin, Texas, USA

TRI Log# E2161-59-01: Coarse Gravel: Internal Shear
TRI Log# E2161-59-01: Sandy Gravel: Internal Shear
TRI Log# E2161-59-01: Silty Sand: Internal Shear
TRI Log# E2161-59-01: Sandy Silty Clay: Internal Shear
TRI Log# E2161-59-01: EG50R Geogrid vs Sandy Gravel
TRI Log# E2161-59-01: EG90R Geogrid vs Coarse Gravel
TRI Log# E2161-59-01: EG90R vs Sandy Gravel
TRI Log# E2161-59-01: EG90R vs Silty Sandy Clay
TRI Log# E2161-59-01: EG 170R vs Sandy Gravel
TRI Log# E2161-59-01: Pullout Resistance Report: E'Grid 90R in Coarse Gravel, Sand and Sandy Silty Clay

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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 The Etsong Geogrids Co., 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.

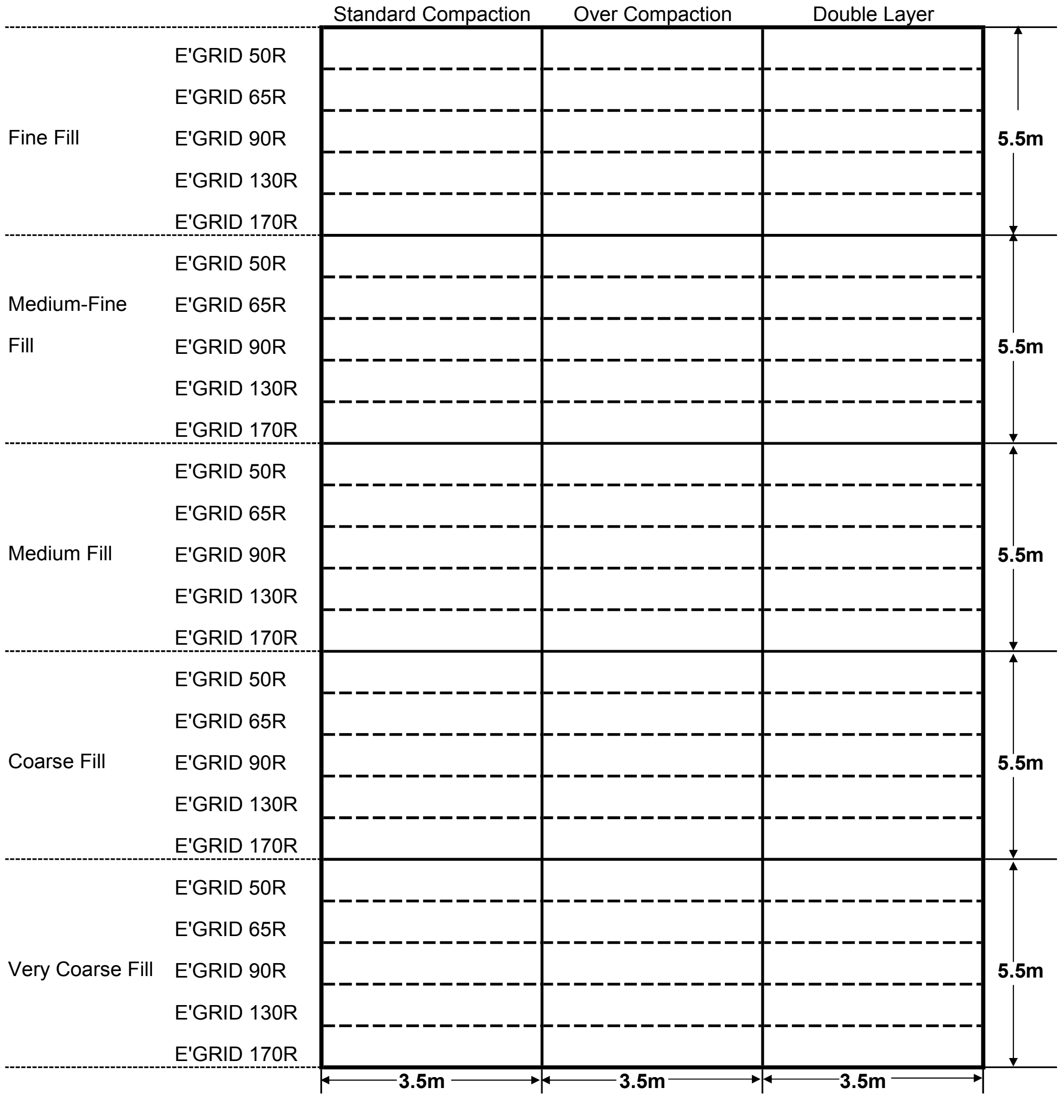

Figure 2: Test Site Layout

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 Qingdao Etsong Geogrids Co. 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	E'GRID 65R	E'GRID 90R	E'GRID 130R	E'GRID 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:

PRODUCT / FILL		E'GRID				
		50R	65R	90R	130R	170R
Fine	≤ 10mm	1.05	1.05	1.05	1.05	1.05
Medium	≤ 50mm	1.09	1.09	1.09	1.09	1.09
Coarse	≤ 75mm	1.13	1.13	1.13	1.13	1.13
V Coarse	≤ 125mm	1.15	1.13	1.13	1.13	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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Design Factors for E’GRID Products:

Weathering

1: Introduction:

In use, soil reinforcement materials may be subjected to either short-term or long-term weathering. The main detrimental component of this is attack by Ultra-Violet light (UV). This will, in time, cause breakdown of the structure of most polymers.

2: Short-Term Exposure:

Prior to a soil reinforcement product being buried, it may be exposed on the ground for a period from hours up to a few weeks. To screen whether products will suffer during this period a test in accordance with EN 12224 is a compulsory part of the approval process for CE Marking. A retention of strength of ≥80% in this test is deemed to be acceptable for products performing critical reinforcement roles.

When tested in accordance with EN 12224, samples of the lightest products in the ranges: E’GRID 2020 and E’GRID 50R suffered no significant changes in strength (ref).

3: Long-Term Exposure:

In some applications, e.g. embankments with wrap-around faces, a soil reinforcement product may be exposed to UV for long periods. In these circumstances a significant retention of strength is required for many years. To provide the necessary protection for such uses, all E’GRID products contain >2% weathering-grade Carbon Black well-dispersed in their polymer matrix.

In Information published in 1987 (ref) it was estimated that a PP or HDPE product protected by the inclusion of >2% finely divided Carbon Black would degrade at a rate of 2.5 microns per year if fully exposed to sunlight in the UK or similar northern European climates. The annual exposure to Ultra-Violet light in such climates at that time was 70-80 KiloLangleys per year. Based on recent data on international levels of exposure to U-V light (ref) and the above estimate it has been calculated that E’GRID Geogrids will retain 75% of their initial strength for the numbers of years shown in the table below.

The approximate regions covered by each column in this table are:

Region A: Canada, Europe and central China
Region B: USA, most of South America, Mediterranean Coastal areas, most of Asia
Region C: Central America, parts of South America, Africa, Middle East, Arabia, India, Australasia.

U-V Exposure Level	Kilo Langleys per year	≤120	120 - 160	≥160
Product \ Region		A	B	C
E'GRID 50R		40	30	24
E'GRID 65R		53	40	32
E'GRID 90R		73	55	44
E'GRID 130R		>100	80	64
E'GRID 170R		>100	100	80
E'GRID 2020		67	50	40
E'GRID 3030		>100	100	80
E'GRID 4040		>100	>100	92

Time to 75% of Initial Strength (Years)

Notes: 1: More detailed information on regional variations is available on Ref. 2.
2: The times given are for full, direct exposure. Any shading, e.g by vegetation or nearby structures, or alignment out of direct sunlight will increase these times.

References:

- CE Marking – Durability Tests: Confidential Test Reports 12949/HPM005 and 12949A/HPM005: BTTG, Manchester, England, ist August 2003
- Wrigley, N E: Durability and Long-Term Performance of Tensar Polymer Grids for Soil Reinforcement; Materials Science and Technology, Vol 3 pp 161-170, The Institute of Metals, London England, March 1987.
- Kilo Langley Map; Ciba Speciality Chemicals Inc., 1998. www.cibasc.com/view.asp?id=6218

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Design Factors for E'GRID Products:

Connection to Keystone® Blocks

1: Introduction:

In many countries, a popular use of integral geogrids such as E'GRID products is on the construction of dry block-faced reinforced soil walls. Often the block system used for these walls is from the Keystone company or one of its licensees. There are also smilar block systems in some countries from other manufacturers.

With these block systems the connection of the geogrid to the block facing is largely by friction. Therefore it is necessary for design to now how much connection strength is mobilised and how it varies with wall height above the connection and between products in the range.

To investigate this tests in accordance with ASTM D6638 Standard Test Method for Determining Connection Strength using E'GRID 50R and E'GRID 170R and Keystone® Compac Blocks at TRI/Envionmental Inc., Austin, Texas, USA. (ref)

2: Test Results:

The results of the tests are shown in the Chart below:

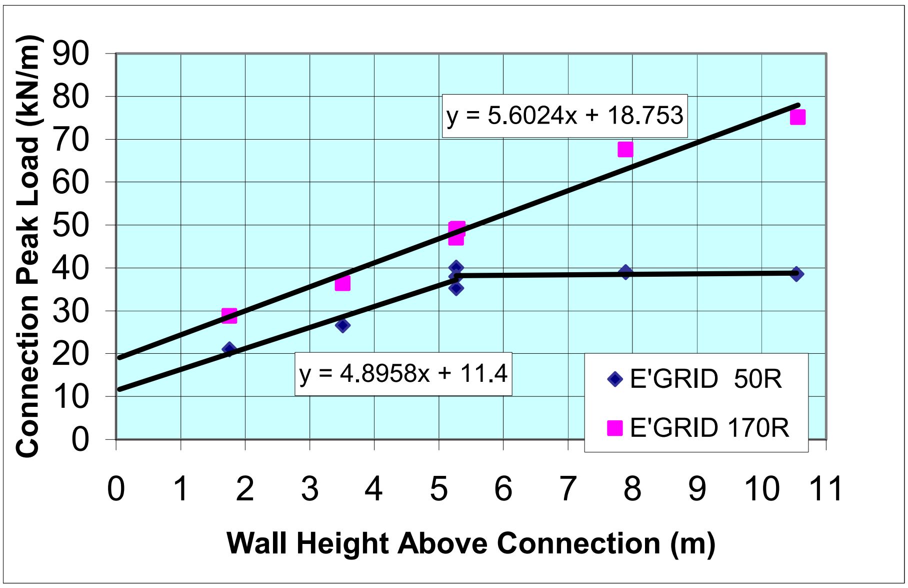

Figure 1: ASTM D6638 Tests with E'GRID Products and Keystone® Compac Blocks.

For the tests with E'GRID 170R all samples pulled out of the test wall, rupturing only in the transverse bars where they had passed behind the pins that locate one layer of blocks relative to the next.

For the tests with E'GRID 50R the geogrid ruptured at wall heights above the connection of 5.3m and greater at a load of about 39kN/m. In view of the slow speed of these tests this is approximately the rupture load that would be expected of this product. At lower wall heights all samples pulled out of the test wall, rupturing only in the transverse bars where they had passed behind the pins that locate one layer of blocks relative to the next.

3: Connection Strengths for use in Design

In figure 1 it can be seen that the equations for the two plots are of the form:

$$C = A + BxH \qquad \textbf{(1)}$$

Where: C = Connection peak load
H = Height of wall above connection

In equation 1, the fixed element A, is largely due to the trapping and rupture of transverse bars of the geogrid behind pins between block layers. As this element of the load is rupture-dependant then it will also be creep dependant. Therefore, for long-term design connection strengths this factor must be reduced to allow for creep. As the overall creep strength of E'GRID products is about 40% of their short-term strength, then it is reasonable to reduce A to 40% of its short-term value to allow for creep.

The element BxH in equation 1 is the friction element of the connection. This is not creep dependant. Therefore, it does not need to be factored when determining long-term strengths.

Thus, from equation 1 the long-term connection strength for design of a product can be calculated as:

$$C_D = 0.4xA + BxH \qquad \textbf{(2)}$$

The only question then left is how to interpolate between the two plots for E'GRID 50R and E'GRID 170R for the intermediate products in the range.

There is, in fact very little difference between the two plots. Therefore a simple form of interpolation is appropriate. This can be done on the basis of the thickness of the products as the variations in factors A and B of equation 1 are certainly related to this. From such an interpolation the set of equations shown in the table below were generated:

Product	Design Connection Strength (kN/m)
E'GRID 50R	$C_D = 4.6 + 4.9xH$
E'GRID 65R	$C_D = 5.0 + 5.0xH$
E'GRID 90R	$C_D = 5.6 + 5.1xH$
E'GRID 130R	$C_D = 6.7 + 5.4xH$
E'GRID 170R	$C_D = 7.5 + 5.6xH$

Note: H = Height of wall above connection (m)

Table: Design Connection Strength of E'GRID Products with Keystone® Compac Blocks

From the equations of the above table the plot below was produced:

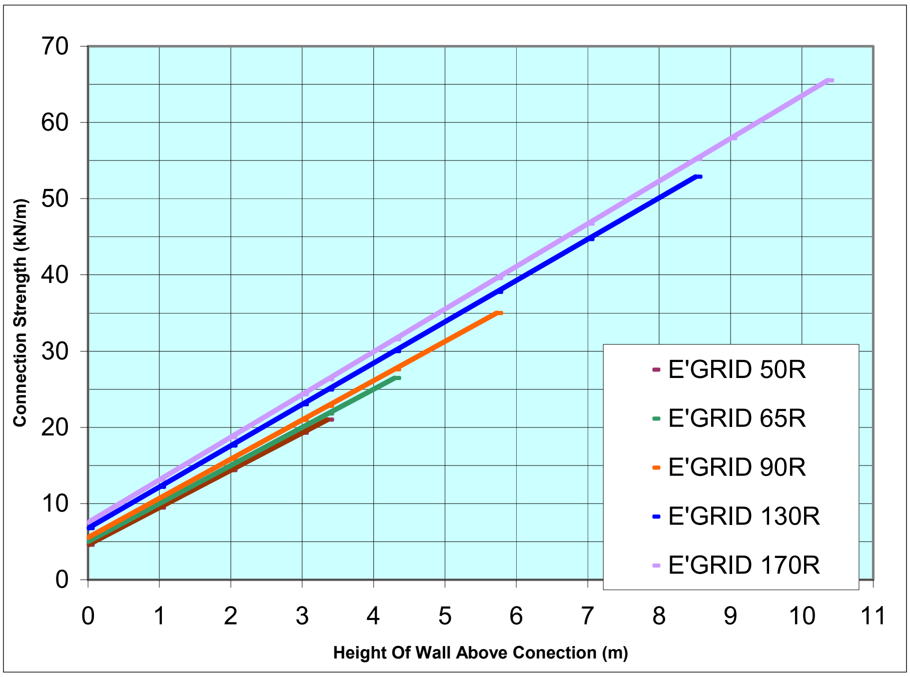

Figure 2: Design Connection Strength of E'GRID Products with Keystone® Compac Blocks

In Figure 2 the plot for each product has been terminated at a connection strength equal to the Creep Strength of the product. This indicates the minimum height of wall above a connection for each product that will guarantee a full-strength connnection between the grid and blocks.

Reference:

• TRI/Environmental Inc: Connection Strength Reports (Log#2161-59-07) Keystone Compac/E'GRID 50R and Keystone Compac/E'GRID 170R, Austin, Texas, USA, September 7th 2003.

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