



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.

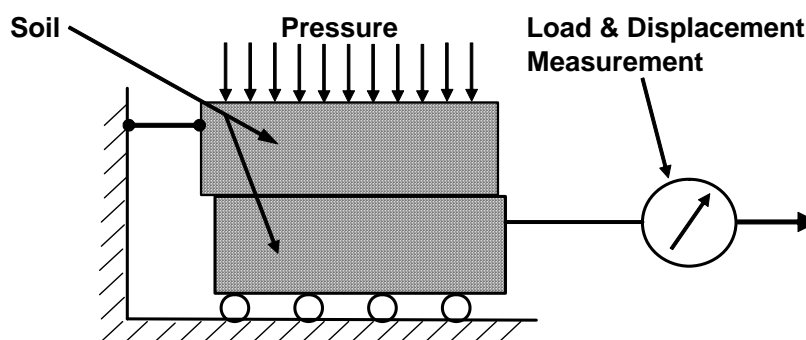


Figure 1: Shearbox with soil alone

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

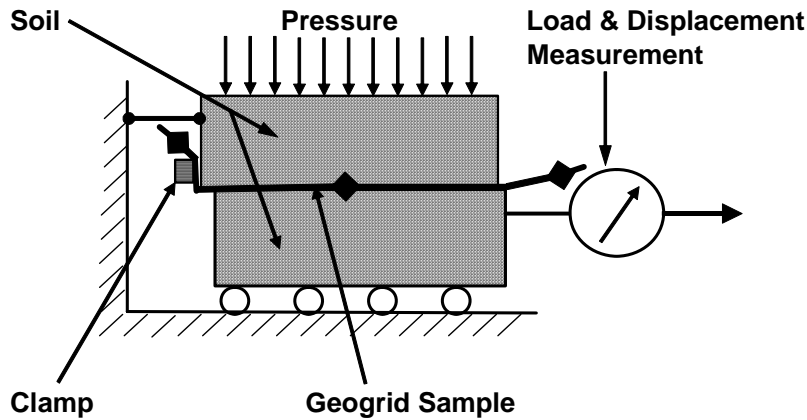


Figure 2: Shearbox with soil and geogrid

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:

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

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		E'GRID 50R	E'GRID 90R	E'GRID 170R
Soil				
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 through 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. This 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 but 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.

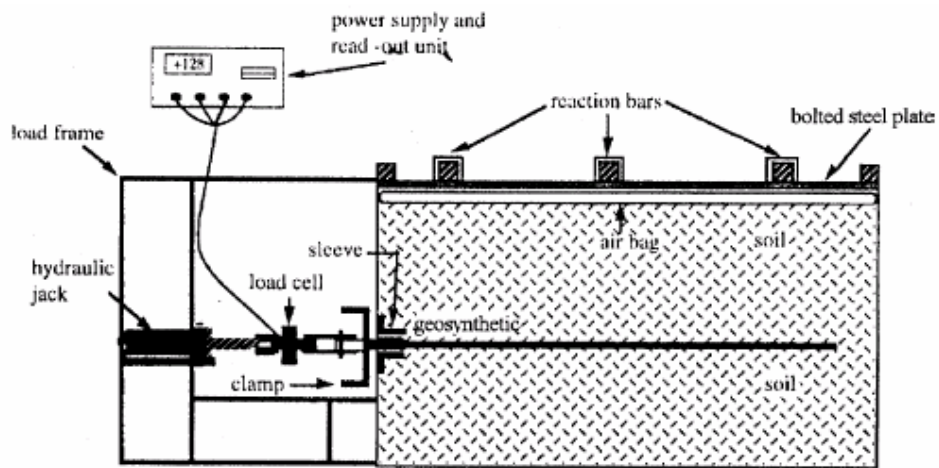


Figure 3: Pull-Out Test Equipment (from ASTM D 6706-01)

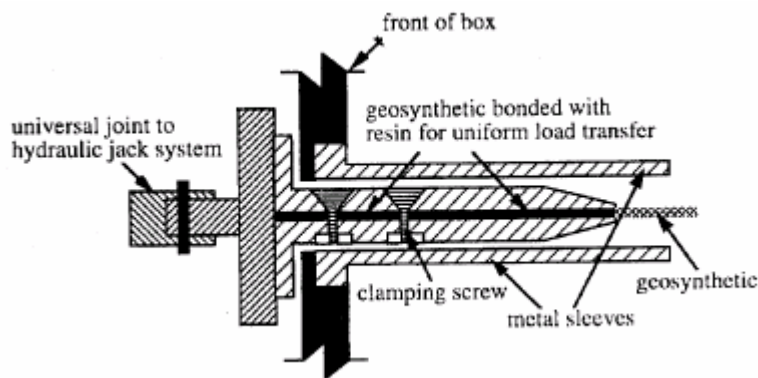


Figure 4: Recommended Load Transfer Sleeve and Sample Clamp (from ASTM D 6706-01)

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 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 C_i .

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

$$C_i = 0.85$$

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 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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