3904 Virginia Ave • Cincinnati, Ohio 45227 • Phone (513) 271-6000 • Fax (513) 271-4420

WHY GEOGRID TORSIONAL RIDIGITY (Aperture Stability) IS NOT RELEVANT TO THE PERFORMANCE OF GEOGRIDS IN REINFORCED ROADS

Fueled by effective promotion, rigid, "punched & drawn" polypropylene geogrids have become the civil engineer's geosynthetic of choice for base stabilization. Well meaning specifiers have placed their faith in a successful, yet proprietary product, misunderstanding punched and drawn polypropylene geogrids unique physical properties to be an actual technology. One of these proprietary physical properties is aperture stability modulus, known more widely as torsional rigidity.

NO SOLID TECHNICAL EVIDENCE

It is important to realize that currently, there is **no solid technical evidence in published literature that can demonstrate the relationship between geogrid torsional rigidity and the performance of geogrid reinforced road sections**.

BIRTH OF TORTIONAL RIGIDITY

The US Army Corps of Engineers, performed large-scale geogrid reinforced paved road tests at the Waterways Experiment Station. Several different geogrid types were tested, but one particular type was used most often. In an effort to explain the relative improvement afforded by the geogrids, a researcher was retained by one of the geogrid manufacturers to establish which geogrid property most related to the functioning of the geogrid in base reinforcement applications. Thus was born the property and associated test method known as tortional rigidity. It was also discovered that "stiff" geogrids demonstrate substantially higher torsional rigidity than do "flexible" geogrids.

PROPRIETARY PROPERTY / TEST METHOD

It is important to note that the initial testing procedures for torsional rigidity developed by Kinney & Yuan (1995) were **developed for single-layer geogrids** with a single junction being clamped for testing. While BaseGrid* geogrids are a "stiff" type of geogrid, they are a multi-layer product with junctions in more than one plane and therefore cannot be tested by this method. Therefore, torsional rigidity is a **proprietary property since the manufacturer of the single-layer punched and drawn geogrid used in the testing has manufacturing patents preventing like-manufactured "stiff" products from entering the marketplace.**

EMPIRICAL CORELLATIONS: WHERE'S THE THEORY?

Torsional rigidity was **empirically** correlated to the stress distribution angle of the reinforced base course over subgrade from a laboratory cyclic load testing program on unpaved sections conducted at North Carolina State University (Gabr, 2001). The unpaved test results were also presented later by Leng & Gabr (2002). It is interesting to note that through back-analysis, Leng & Gabr (2006) used the same test results to demonstrate an **empirical correlation between geogrid tensile strength at 2% strain and section performance**. So which, if any, of these empirical correlations are relevant to base reinforcement methods? Where is the theory?

STANDARDIZED TEST METHOD?

There is currently no standardized test method for torsional rigidity (ASTM or GRI). Tensar's latest data sheets (August 2005) have this note on the test method for torsional rigidity: " . . . in accordance with US Army Corps of Engineers methodology for measurement of torsional rigidity." There is no mention of ASTM or GRI. The Geosynthetics Research Institute (GRI) attempted to standardize the tortional rigidity test method but was met with much resistance. GRI proposed a similar procedure to Kinney with one very important difference: The Kinney method defines "aperture stability modulus" as the test result and this modulus is calculated at a high torque (2 N-m) resulting in a rather substantial amount of angular rotation (up to 20 degrees). The GRI method prefers to report "initial" and "offset" tangent moduli. In this case, the initial modulus relates to small torques and associated angular rotation and the offset modulus is derived at larger torques and associated larger rotations. Which of these, if any, are relevant to base reinforcement methods?

INDEX TESTS

The TRI in-plane rotation modulus test of geogrids was intended to be a quality control test of the index type and used to compare the index response of one geogrid product to another. The Kinney method is also an index test.

NO RELATIONSHIP BETWEEN TEST & PERFORMANCE

The procedure involves the complete geogrid structure including its machine direction ribs, cross-machine direction ribs and their junctions. Though the resulting in-plane rotational modulus may be indicative to the performance of geogrids in stone base courses, the **relationship of the in-plane rotational modulus obtained from this test method has not been directly related to laboratory or field performance of pavements**. To date no standard exists and no new evidence has been introduced to help resolve the debate.

NO CORRELATION BETWEEN CONFINEMENT & TORSIONAL RIGIDITY

TRI/Environmental participated with TXDOT in a study on the correlation between geosynthetic properties and the confinement factor in base reinforcement applications. As shown in Table 1, TRI's results indicate that **no correlation exists between the confinement factor and torsional rigidity.** ***In fact, the geotextile tested was reported to have the lowest confinement factor while having a higher torsional rigidity value than most of the geogrids tested!***

WHERE IS THE RELATION?

The results of numerical modeling show that road section **performance is mainly related to geogrid-aggregate interface shear stiffness and geogrid tensile stiffness** for both flexible pavement sections (Perkins, 2001) and unpaved road sections (Leng & Gabr, 2005).

Table 1. Test Results from a Range of Geosynthetics (TRI/Environmental, 2001)

PRODUCT	IN-PLANE ROTATIONAL STIFFNESS												Confinement Factor (Coarse Aggregate)	Confinement Factor (Well Graded Aggregate)
	In-Plane Deformation (degrees) Torque (in-lb) (N-m)						Secant Modulas (N-m/deg) Torque (in-lb) (N-m)					Initial Tangent Modulus (N-m/deg)		
	0.00	4.42	8.84	13.26	17.68	22.1	4.42	8.84	13.26	17.68	22.1			
	0.00	0.50	1.00	1.50	2.00	2.50	0.50	1.00	1.50	2.00	2.50			
Grid #1	0	.70	2.20	3.65	5.15	6.95	0.72	0.46	0.42	0.39	0.36	0.84	1.58	1.15
Grid #2	0	3.35	12.00	14.90	17.25	18.00	0.16	0.09	0.11	0.12	0.14	0.18	1.37	1.10
Grid #3	0	6.65	10.40	13.90	17.35	19.93	0.08	0.10	0.11	0.12	0.13	0.07	1.21	-
Grid #4	0	6.80	10.35	13.55	16.25	18.70	0.07	0.10	0.11	0.12	0.13	0.07	1.21	-
Grid #5	0	6.15	10.70	14.50	17.40	20.10	0.08	0.09	0.10	0.11	0.12	0.08	1.36	1.09
Grid #6	0	0.60	2.25	4.50	9.00	14.70	0.83	0.44	0.33	0.22	0.17	0.90	-	1.24
Grid #7	0	0.60	1.50	2.55	6.45	14.85	0.83	0.67	0.56	0.31	0.17	0.90	-	1.22
Textile	0	1.85	4.90	6.30	7.80	9.30	0.27	0.22	0.25	0.27	0.27	0.30	0.97	-

Torsional Rigidity

GRI Proposed Initial Tangent Modulus

PULLOUT TESTING

A better way to determine if the maximum interlocking of soil has taken place is to conduct a pullout test. This is a direct measurement of the capacity of a geogrid to effectively interlock the soils. BaseGrid* geogrids exhibit an excellent coefficient of interaction against pullout, which is supported by test results obtained during large scale pullout testing. As shown in Table 2, BaseGrid* geogrids have coefficient of interaction from 0.9 to 1.1, which indicates an excellent geogrid-soil interlocking.

Table: Summary table of the pullout test results and test conditions

PRODUCT NAME	PROPERTY	BASE GRID* 22	BASE GRID* 22	BASE GRID* 22	BASE GRID* 22	BASE GRID* 22	TENSAR BX 1100	TENSAR BX 1100	TENSAR BX 1100	TENSAR BX 1100
Test Direction		TD	TD	TD	TD	TD	TD	TD	TD	TD
Normal Stress	kPa	40	30	20	20	10	40	30	20	10
Test	n	6	14	5	8	7	11	27	10	12
Max. Pullout Strength	KN/m	25.72	23.72	18.27	18.91	9.58	19.50	17.10	13.76	6.70
Max. Pullout Stress	kPa	43.96	40.55	31.24	32.33	16.38	33.30	29.20	23.52	11.40
Failure Type		Tension	Tension	Pullout	Pullout	Pullout	Tension	Tension	Pullout	Pullout
Ø soil	deg	38.00	38.00	38.00	38.00	38.00	38.00	38.00	38.00	38.00
Specimen Length, L	m	0.585	0.585	0.585	0.585	0.585	0.585	0.585	0.585	0.585
Pullout Interaction Factor	fpo	0.70	0.87	1.00	1.03	1.05	0.53	0.62	0.75	0.73

PRODUCT NAME	PROPERTY	BASE GRID* 22	BASE GRID* 22	BASE GRID* 22	BASE GRID* 22	BASE GRID* 22	TENSAR BX 1100	TENSAR BX 1100	TENSAR BX 1100	TENSAR BX 1100
Test Direction		TD	TD	TD	TD	TD	TD	TD	TD	TD
Normal Stress	kPa	30	20	10	30	20	10	30	20	10
Test	n	17	15	16	23	21	22	20	18	19
Max. Pullout Strength	KN/m	24.93	18.71	10.53	26.14	17.70	10.18	22.00	14.90	7.60
Max. Pullout Stress	kPa	42.62	31.99	17.99	44.69	30.26	17.40	28.30	25.50	13.00
Failure Type		Pullout	Pullout	Pullout	Pullout	Pullout	Pullout	Pullout	Pullout	Pullout
Ø soil	deg	38.00	38.00	38.00	38.00	38.00	38.00	38.00	38.00	38.00
Specimen Length, L	m	0.585	0.585	0.585	0.585	0.585	0.585	0.585	0.585	0.585
Pullout Interaction Factor	fpo	0.91	1.02	1.15	0.95	0.97	1.11	0.80	0.82	0.83

LTRC REPORT: PRODUCTS "PERFORM EQUALLY"

The Louisiana Transportation Research Center (LTRC) Technical Assistance Report No. 18 is a case history of BaseGrid* and Tensar geogrids for base course stabilization. It concludes that BaseGrid 22* and Tensar BX 1100 **" . . . performed equally in the field when exposed to similar conditions."**

SUMMARY

There is no published solid technical evidence demonstrating a relationship between tortional rigidity and geogrid in-situ performance. The test method is simply an index test and offers little relevance to in-situ performance. There is currently no standardized test method (ASTM or GRI) for this property or a way to test multi-layered geogrids for tortional rigidity. Tortional rigidity was only *empirically* shown to relate to performance through back-analysis of existing research data. In fact, no correlation exists between the important confinement factor and tortional rigidity. When tested side-by-side BaseGrid* geogrids have proven an equal in performance to Tensar geogrids.

*BaseGrid geogrids are a private label of Tenax Geogrids.

References:

TRI/Environmental (2001), "In-Plane Rotational Stiffness (A.K.A. Torsional Rigidity): Is this a relevant property for base reinforcement geosynthetics?"

Perkins, S.W. (2001), "Numerical Modeling of Geosynthetic Reinforced Flexible Pavements: Final Report", Montana Department of Transportation, Helena, Montana, Report No. FHWA/MT-01/002/99160-2, p. 97

Leng, J., Gabr, M.A., (2002), "Characteristics of Geogrid-Reinforced Aggregate Under Cyclic Load", Journal of Transportation Research Board, No. 1786, National Research Council, Washington, D.C., pp. 29-35

Leng, J., Gabr, M.A., (2005), "Numerical Analysis of Stress-deformation Response in Reinforced Unpaved Road Sections", Geosynthetics International, Vol

Louisiana Transportation Research Center (LTRC), "Louisiana Transportation Research Technical Assistance Report, Report No. 18"