Performance Verification of a Geogrid Mechanically Stabilized Layer Flexible Pavement Design as Part of the La Media Road Widening Project

L. Nelson[1], G.B. Fountain[2], GE and M.H. Wayne[3], Ph.D., P.E., M. ASCE

[1] Tensar International Corporation, 17160 Botero Drive, San Diego, CA 92127 PH (949) 300-3750; FAX (949) 661-2029 email: lnelson@tensarcorp.com
[2] Southern California Soil & Testing, Inc., 6280 Riverdale Street, San Diego, CA 92120 PH (877) 215-4321; FAX (619) 280-4717; email: gfountain@scst.com
[3]Tensar International Corporation, 2500 Northwinds Parkway, Suite 500, Alpharetta, GA 30009; PH (770) 344-2133; FAX (770) 344-2084; email: mwayne@tensarcorp.com

A field study was performed to document the benefit of a punched and drawn polypropylene triaxial geogrid. The triaxial geogrids have triangular apertures and increased rib thickness as compared to many geogrids with square apertures. These fundamental changes to the geogrid structure, coupled with high junction efficiency, gives greatly improved aggregate confinement and interaction, leading to improved structural performance of the mechanically stabilized layer (MSL). The project consisted of the widening of La Media Road as part of the Highway 905 improvements. La Media Road and Highway 905 typically experience heavy truck traffic loads from the Mexico/U.S. border crossing. The subgrade material beneath La Media Road is comprised of clayey sand and clayey sand with gravel. Additionally, cobbles ranging up to about 8 inches in diameter were observed on the surface of the subgrade. R-Values of 21 and 24 were determined for the subgrade material. Laboratory testing included grain size analysis, Atterberg limits, maximum density, optimum moisture content and R-Value tests. The field-testing consisted of 5-inch diameter plate load tests on the subgrade and at various levels of the pavement cross-section. Results of plate load testing indicate that the triaxial geogrid increased the modulus of the mechanically stabilized section relative to the conventional unbound aggregate pavement section. The measured improvement of the MSL sections ranged between 27% and 52% greater than the 30% thicker unbound aggregate conventional design section.

INTRODUCTION

This paper presents the findings of testing performed on a triaxial geogrid mechanically stabilized pavement section field study performed for the La Media Road Widening project located in the City of San Diego, California. The project consisted of the widening of La Media road as part of the Highway 905 improvements. La Media Road and Highway 905 typically experience heavy truck traffic loads from the nearby Mexico/US border crossing.

The purpose of the research was to document the benefit of a Tensar TX5 punched and drawn integrally formed polypropylene triaxial geogrid. The triaxial geogrids have triangular apertures and increased rib thickness as compared to many geogrids with square apertures. These fundamental changes to the geogrid structure, coupled with high junction efficiency, gives greatly improved aggregate lateral confinement and interaction, leading to improved structural performance of the mechanically stabilized layer (MSL) as reported by White, et. al. (2010).

The subgrade material beneath La Media Road is comprised of clayey sand and clayey sand with gravel. Additionally, cobbles ranging up to about 8 inches (200mm) in diameter were observed on the surface of the subgrade. R-Values of 21 and 24 were determined for the subgrade material.

The stabilized pavement section consisted of 6 inches of asphalt concrete (AC)/ 6 inches (150mm) Class 2 Aggregate Base (AB) / TX5 geogrid / 11 inches (275mm) of Class 4 Aggregate Subbase (AS) / TX5 geogrid/Subgrade. The unbound aggregate (control) pavement section consists of 7.2 inches (180mm) AC/ 29.4 inches(735mm) Class 2 AB.

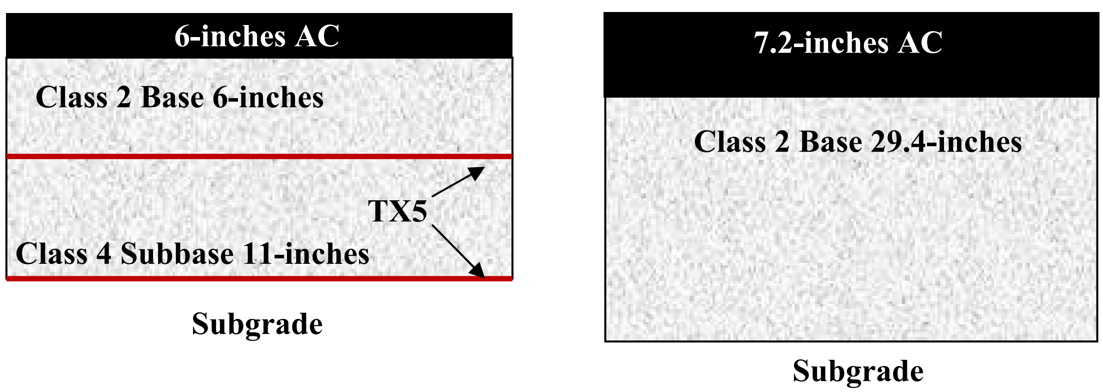

Figure 1 – Cross sections of pavements included in this research

LABORATORY TESTING

Laboratory tests were performed to evaluate selected engineering properties of the subgrade materials. The following tests were performed:

- Grain Size Analysis
- Atterberg Limits
- Maximum Density and Optimum Moisture Content
- R-Value Test

Test results for the subgrade are shown in Figure 2 below.

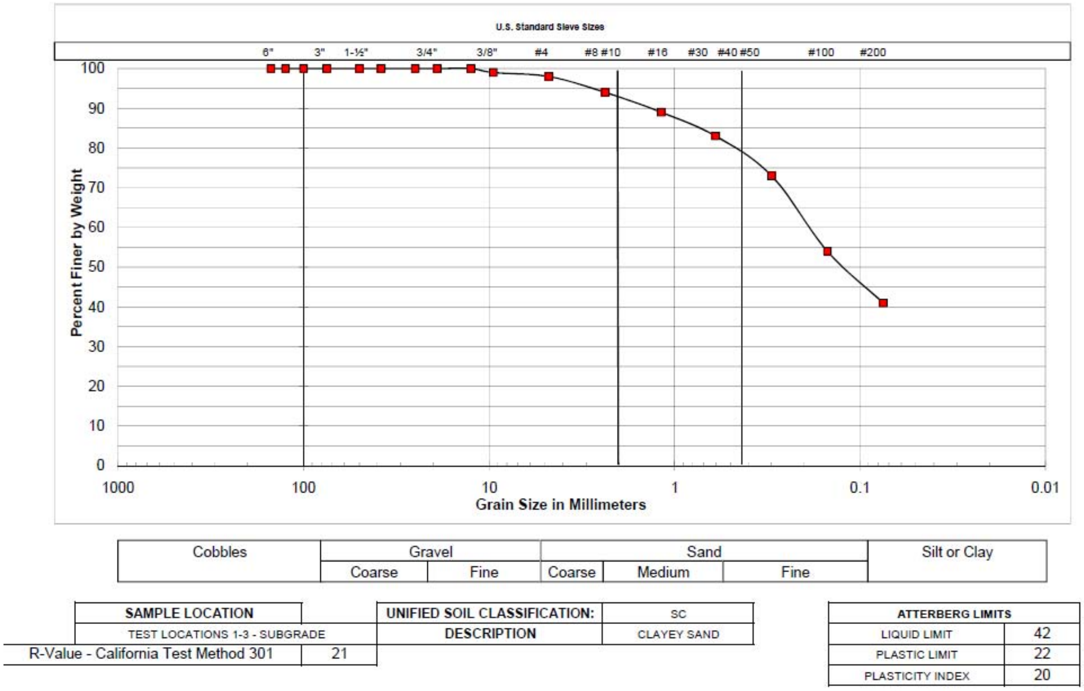

Figure 2 – Subgrade Soil Testing Results

IN-PLACE STRENGTH EVALUATION

Plate Load Test

Plate load testing was performed to determine pavement material stiffness values for the control and stabilized sections. This was done to insure that the reduced section exhibited stiffness values that were at least equal or greater than those of the control. Plate load tests were performed at the locations shown in Figure 3. The diameter of the plate was selected based on its depth of influence. In accordance with Boussinesq theory for a uniformly loaded circular area more than 90% of the vertical stress is supported by soil at a depth of 2 times the diameter of the loaded area (Das, 1984). To determine the improvement of a MSL a smaller diameter plate is required to evaluate stress behavior within a thin lift thickness. The exposed surface at each test location was leveled. A 5-inch diameter steel bearing plate was then placed on the leveled ground surface. A total of 2 dial gauges accurate to the nearest 0.001 inch were located near each extremity of the bearing plate to measure the ground deformation. A seating load of 200 pounds was then applied, released and reloaded, and the dial gauges were then set at their zero mark. Loads were then applied at a moderately rapid rate to the plate with a 10-ton hydraulic ram. After each increment of load was applied its action was allowed to continue until a rate of deflection of not more than 0.001 inches/minute was maintained for 3 consecutive minutes.

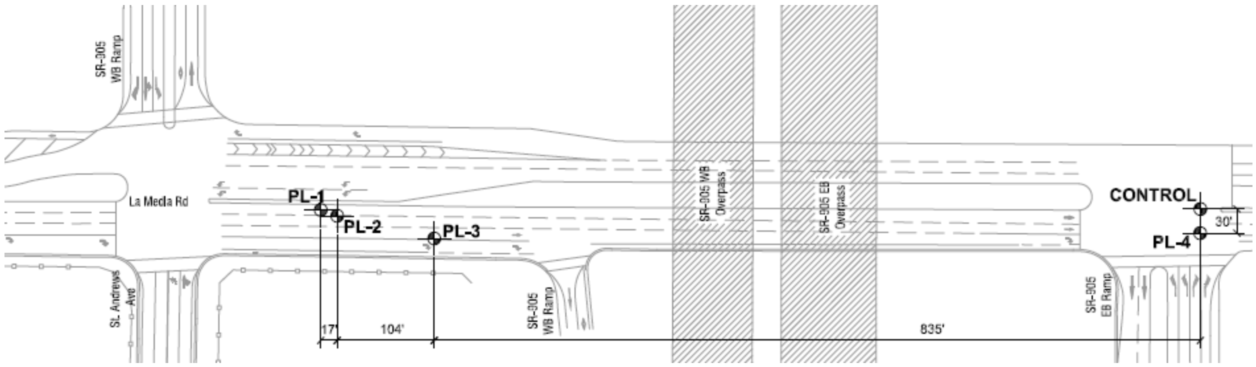

Figure 3 – Plate Load Test Locations

The plate load test was performed at the following pavement section elevations:

- Mechanically Stabilized Class 4 Aggregate Sub-Base Elevation (11 inches above subgrade) Locations 1, 2 and 3.
- Final aggregate base elevation, locations 1, 2 and 4.
- Control section, 29 inches of Class 2 aggregate base placed on the subgrade.

The loads measured at 0.1 and 0.2 inches of deformation were used to calculate the modulus of subgrade reaction. The measured loads are presented in Table 1.

Table 1. Summary of Testing Results

	Measured Loads, Pounds			
Deformation	**0.1 inches**		**0.2 inches**	
		Average		**Average**
	Finished Aggregate Base Elevation			
Location 4	4600		7000	
Location 2	6100	5417	8300	7900
Location 1	5550		8400	
	Mechanically Stabilized Class 4 Aggregate Subbase Elevation			
Location 1	4000		5700	
Location 2	5800	5333	8100	7333
Location 3	6200		8200	
	Control - Finished Aggregate Base Elevation			
Control	4200		5200	

The modulus of subgrade reaction (k) was calculated in accordance with the "Interim Advice Note 73/06 Revision 1, Design Guidance for Road Pavement Foundations (UK Highway Agency, 2009)." The IAN correlation curve was used to generate results from the smaller plate size to those that could be expected for a 30-inch (762-mm) diameter plate. These values are presented in Table 2.

Table 2. Calculated Modulus of Subgrade Reaction*

Pavement Section Elevations	0.1 inches of deformation		0.2 inches of deformation	
	K_{762} pci	Percent Improvement	K_{762} pci	Percent Improvement
Finished Base Elevation 17 inches above subgrade	644	29%	470	52%
Mechanically Stabilized Class 4 Aggregate Sub-Base Elevation (11 inches above subgrade)	634	27%	436	41%
Control-29 inches of Base	499	-	309	-

*Note – Percentage improvement is relative to the Control Section. The mechanically stabilized layered section is 12 inches thinner than the control section and has 23 inches less aggregate base.

CALIFORNIA DEPARTMENT OF TRANSPORTATION PAVEMENT DESIGN METHOD USING GEOGRIDS

Typically flexible pavement sections in California are designed using the California Department of Transportation pavement design method or CDM (CalTrans, 2006). This pavement section design method is based on the R-Value of the subgrade material determined in accordance with California Test Method 301 and the Traffic Index determined for the planned street. The R-Value is an indication of the pavement support characteristics. R-Values commonly range from less than 5, indicating poor pavement support characteristics, to greater than 50, indicating good pavement support characteristics. As reported by CalTrans (2006), the Traffic Index (TI) is a measure of the number of ESALs expected in the traffic lane over the design life of the pavement. The TI, determined to the nearest 0.5, does not vary linearly with the ESAL's but rather according to the exponential formula found as Eq. 1 below.

$$TI = 9.0 \times \left(\frac{(ESAL \times LDF)}{10^6} \right)^{0.119} \quad (1)$$

Where:

TI = Traffic Index

ESAL = Total number of cumulative 18-kip Equivalent Single Axle Loads

LDF = Lane Distribution Factor

These two values are then used to determine the required Gravel Equivalent (GE) needed for an adequate pavement section.

$$GE\ (feet) = 0.0032 * (100 - R_{Value}) * TI$$

The total GE of the designed pavement section is then determined by multiplying the thickness of each pavement section layer times a pre-determined “gravel factor” for each of the materials in the pavement section. Gravel Factors (GF) for asphalt concrete and aggregate base are provided in the CDM. The GE of each layer is then added together to determine the total GE of the design pavement section.

The original unreinforced pavement section designed in accordance with the CDM consisted of 7.2 inches (183 mm) of AC over 29.4 inches (747 mm) of Class 2 AB. The reinforced pavement section consisted of improving the subgrade by placing a Class 4 AS (R-Value 35) underlain by TX5 geogrid on the subgrade and then placing 6 inches of Class 2 aggregate base on the Class 4 AS that was underlain by the TX5 geogrid. The reinforced pavement section decreased the AC thickness to 6.0 inches (152 mm), 1.2 inches (31 mm) less than the originally designed pavement section. The benefit of geogrids within the pavement section system can be modeled by considering one or a combination of the following methods:

- Method 1: Increasing the R-Value of the subgrade material.
- Method 2: Decreasing the TI determined for the street. (AASHTO, 2009, 2001)
- Method 3: Increase the gravel factor for the aggregate base and/or aggregate subbase. (GMA, 2000)

Table 3. Pavement Design Examples

Pavement Section	TI	R-value	Gravel Factors (ft.)		Thickness (inches)			Gravel Equivalency	
			AB	AS	AC	AB	AS	GE Req'd	GE Actual
Un-Reinforced (Original Design Section)	12.0	5	1.1	1.0	7.2	29.4	-	3.65	3.72
Method 1: Increasing R-value	12.0	42	1.1	1.0	6.0	6.0 / TX 5	11.0/ TX 5	2.23	2.29
Method 2: Decreasing TI	8.0	5	1.1	1.0	6.0	6.0 / TX 5	11.0/ TX 5	2.23	2.29
Method 3: AB/AS Gravel Factor Increase	12.0	5	2.2	2.0	6.0	6.0 / TX 5	11.0/ TX 5	3.65	3.75

The final geogrid design used 2 layers of Geogrid. Therefore, 2 design methods can be used to model the benefits of the Geogrid. For this projects Method 1(Increase in R-Value) and Method 2 (Decreasing the TI) were used in the analysis. The final design section is presented in Table 4.

Table 4. Final Pavement Design Section

Pavement Section	TI	R-value	Gravel Factors (ft.)		Thickness (inches)			Gravel Equivalency	
			AB	AS	AC	AB	AS	GE Req'd	GE Actual
Unreinforced (Original Design Section)	12.0	5	1.1	1.0	7.2	29.4	-	3.65	3.72
Final Design Section	10.5[2]	35[1]	1.1	1.0	6.0	6.0/ TX5	11.0/ TX5	2.18	2.34

1. R-Value increase based on Design Method 1.
2. TI-decrease based on Design Method 2.

DISCUSSION OF RESULTS

The field plate load testing results located in Table 2 *Modulus of Subgrade Reaction* provides verification testing for the initial design assumptions located in Table 3 *Pavement Design Examples*. The field plate load tests demonstrated the mechanically stabilized pavement section performed better than the conventional section. A 29% percent increase of the pavement section modulus was observed at the final aggregate base elevation at 0.1 inches of deformation and a 52% increase of the pavement section modulus was observed at the final aggregate base elevation at 0.2 inches of deformation.

This is most likely the result of a transfer of loads from unbound aggregate to the geogrid and development of a mechanically stabilized layer (MSL). The MSL is the creation of a semi-bound layer within which the soil matrix and penetrated openings in the geogrid have become locked in-place. This process adds enhanced shear strength to the pavement section and increases the modulus of the soil and aggregate base.

The benefits of using triaxial geogrids in pavement section designs consist of better support characteristics that could result in potentially longer pavement life and thinner pavement sections where cost savings can be realized. The constructed MSL layers consisted of the following:

- Approximately 40% less aggregate (Class 2 aggregate base and aggregate subbase combined)

- Approximately 80% less Class 2 aggregate base as compared to the control section.
- A total of 6 inches of asphalt instead of 7 inches as originally designed.

The field test results indicate that the pavement test section designs with the inclusion of geogrid are conservative. However, it is our opinion that additional studies should be performed to determine a better relationship between the gravel factor of un-reinforced and reinforced aggregate base for flexible pavement section design using the California Department Transportation Method. Also, the focus of this study was on short-term improvements. Additional studies should be performed that represent the long-term performance of the pavement sections reinforced with geogrid.

REFERENCES

AASHTO. (2009). "Standard Practice for Geosynthetic Reinforcement of the Aggregate Base Course of Flexible Pavement Structures." AASHTO Publication R 50-09. American Association of State Highway and Transportation Officials, Washington, D.C.

AASHTO. (2001). "Recommended Practice for Geosynthetic Reinforcement of the Aggregate Base Course of Flexible Pavement Structures." AASHTO Publication PP46-01. American Association of State Highway and Transportation Officials, Washington, D.C.

CalTrans. (2006). "Highway Design Manual." Chapter 610 Pavement Engineering Considerations, California Department of Transportation.

Das, B.M. (1984). Principles of Foundation Engineering, PWS Publishers, Boston, MA.

GMA. (2000). "GMA White Paper II: Geosynthetic Reinforcement of the Aggregate Base/Subbase Courses of Pavement Structures." Geosynthetic Materials Association, Industrial Fabrics Association International.

UK Highways Agency. (2009). *Interim Advice Note 73/06 (Revision 1)* Design Guidance for Roads and Pavement Foundations, (Draft HD25)

White, D.J., Vennapusa, P.KR., Gieselman, H., Zhang, J and Eidem, M. (2010). "Accelerated Implementation of Intelligent Compaction Technology for Embankment Subgrade Soils, Aggregate Base, and Asphalt Pavement Materials: US 12 Marmarth, North Dakota." Final Report ER10-08 US12, ND Field Project August 9 to 12, 2011.