Research Summary Enhanced Pavement Design Using Tensar Stabilization Technology

Topic: Evaluation of using TriAx geogrids for Flexible Pavements
Caltrans Contract No.: 11-2T1714
Location: I-5, North Coast Corridor, San Diego, California

Application:

Flexible Pavements

Type:

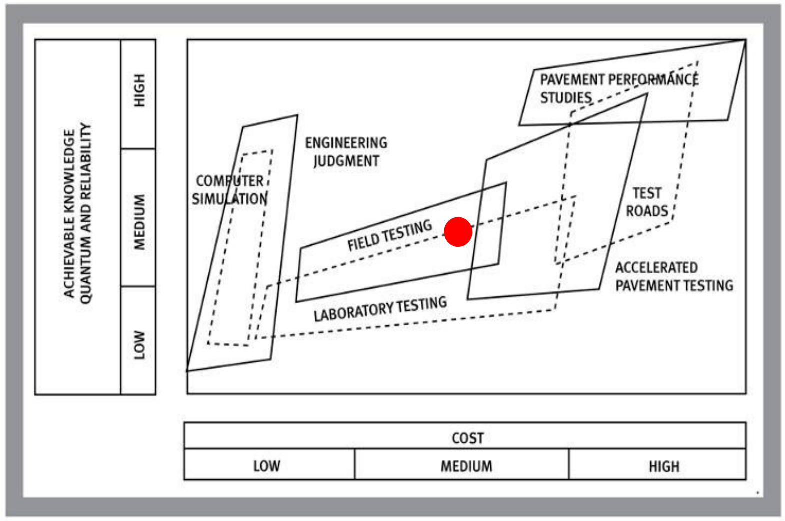
Field Structural Performance Study

Geogrid Products Tested:

- Tensar TriAx

Section Profiles:

- Enhanced Section: 10.2 inches (0.85 feet) thick aggregate base stabilized with TriAx Geogrid
- Control Section: 27 inches (2.25 feet) aggregate base
- Both sections constructed over a subgrade with Type II Soils (Subgrade R-Value between 10 and 40)



Importance of the Aggregate Base Layer

The aggregate base layer's initial resilient modulus and maintaining that modulus for the pavement's design life are essential for an enhanced pavements long term performance. The goal of a pavement agency is to construct pavements that provide service over an extended period with minimal repair beyond regular preservation activities. This goal includes supplying a comfortable ride for the public that minimizes traffic interruption because of construction lane closures. This will also maximize taxpayer's dollars and preserve the environment by selecting lifecycle cost effective and sustainable pavement solutions.

The aggregate base layers are critical components of a flexible pavement system. A poorly performing aggregate base layer below a flexible pavement can be detrimental to the pavement's performance. The purpose of unbound material layers (aggregate base and aggregate subbase) is to structurally improve the load supporting ability of the pavement section and help the surface structural layer (asphalt concrete) in carrying the traffic load. The increased ability to carry traffic loads reduces the potential for structural related distresses. Other benefits provided by the aggregate base include frost control and drainage.

Many structural distresses seen at the pavement's surface are the result of aggregate base failure. Typically, aggregate base failure consists of the loss of the in-situ material stiffness (Resilient Modulus Degradation). Many factors contribute to the in-situ aggregate base resilient modulus degradation including:

- Fines from the subgrade contaminating the aggregate base
- Subgrade shear failure, and
- Moisture saturation

The resilient modulus, Mr is the measure of the applied cyclic stress to the recoverable elastic strain after many cycles of repeated loading. The resilient modulus is the most important unbound material property input in most pavement design procedures (Christopher et al. 2006). Mechanistic empirical procedures rely on the Mr of the layered materials to evaluate the stresses, strains, and deformations induced in the pavement layers by the applied traffic loads.

The resilient modulus of geomaterials is stress-dependent:

- Increasing with increasing confining stress for coarse grained materials (such as the aggregate base and subbase), and
- Decreasing with increasing shear stress for fine-grained soils.

The aggregate base layer stiffness (strength) can control the development of structural distresses in flexible pavements. The influence of an insufficient base stiffness on the pavement overall performance accelerates the initiation and progression of several distresses including fatigue cracking, rutting, corrugations, bumps, depressions, potholes, and roughness (Christopher et al. 2006).

Permanent deformation (rutting), depressions and roughness are examples of distress that create poor ride quality. Base stiffness affects fatigue cracking and rutting of flexible pavements. The lateral tensile strain at the bottom of the asphalt concrete layer affects the fatigue cracking along the surface. The vertical compressive strain at the top of the subgrade can affect the development of rutting that occurs along the pavement surface. The importance of the aggregate base layer in flexible pavement is assessed by the aggregate base layer stiffness (resilient modulus) that affects the strains within the asphalt concrete.

Figure 1 shows the effect of the granular base stiffness (EBS) on the AC tensile strain and subgrade vertical compressive strain (that control cracking and rutting, respectively). The strain ratio in Figure 1 shows the strain that would result for a given aggregate base resilient modulus divided by the strain that develops for a base layer with a 30,000-psi resilient modulus. The simulations are based on (Multi-Layer Elastic Theory) MLET with a three-layer system consisting of

- 6 inches of AC (500,000 psi modulus), over
- 18 inches of AB (30,000 modulus), over
- Subgrade (3000 psi modulus)

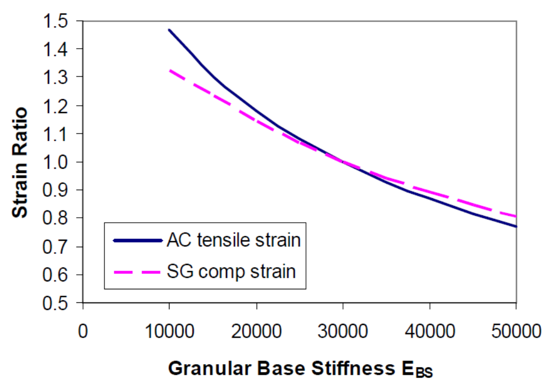
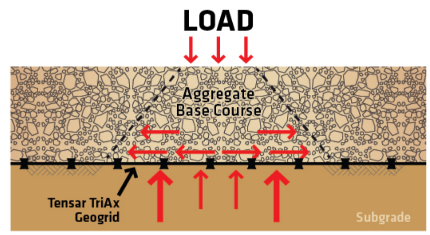


Figure 1. Effect of granular base stiffness on strains (Christopher et al. 2006).

The system was trafficked with a 10-kip load and 100 psi tire pressure. The results show that aggregate base stiffness over a wide range of values affects both the tensile strain that controls fatigue cracking in asphalt concrete and compressive strain that controls rutting. The tensile strains can increase by 50% and the compressive strain by 30% when resilient modulus of the base drops from 30,000 psi to 10,000 psi. Similarly, the strains decrease by ~20% when the base modulus increases from 30,000 psi to 50,000 psi. This has a significant effect on fatigue cracking and rutting.

Benefits of the Geogrid Mechanically Stabilized Layer (MSL)



Incorporating geogrids into the roadway section is an effective method of creating a stiffer and more uniform foundation that will maintain integrity over time improving the Load Transfer. The geogrid enhancement results in less deformation during construction, and during the pavement's life. The geogrid achieves this by interlocking with and confining the aggregate base. The confinement reduces the potential for contamination of the aggregate base with the subgrade soil. The geogrid and aggregate base together create a mechanically stabilized layer (MSL). The MSL is a resilient layer that minimizes the potential for differential movements of the concrete surface that initiate faulting and corner breaks.

Purpose/Objective of Field Testing:

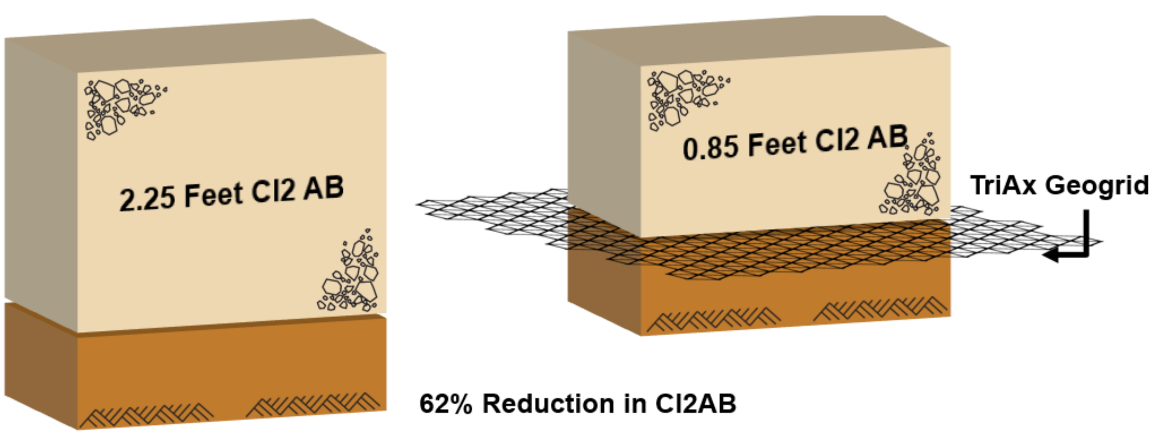
The purpose of the testing was to show that an MSL below a flexible pavement will reduce deformation better than a thicker aggregate base section creating more uniform support and reduce the stress on the underlying subgrade. Additionally, the MSL will create a more resilient foundation section and not lose strength over time.

Test Procedure:

Ingios® performed a series of Automated Plate Load Test's (APLTs) at the subject site. APLT is a system developed to perform fully automated static and repetitive/cyclic plate load tests, per AASHTO and ASTM test methods. To evaluate the stress dependent resilient modulus a 12-inch diameter plate cycles 100 times at each stress level at increments between about 5 pounds per square inch and 40 pounds per square inch.

Test Location and Section Description

The test was located along Interstate 5 in Encinitas, California. A contractor constructed the test section within the limits of project area. Figure 2 presents the test sections:



Results / Key Findings:

Figure 3 shows the composite resilient modulus of the aggregate base versus the applied stress using the 12-inch diameter plate. The results show how the composite resilient moduli of the 0.85 feet of Cl2AB underlain by TriAx is essentially equivalent to the 2.25 feet of Class 2 AB section. However, the TriAx section performed better by decreasing the deformation by about 20%.

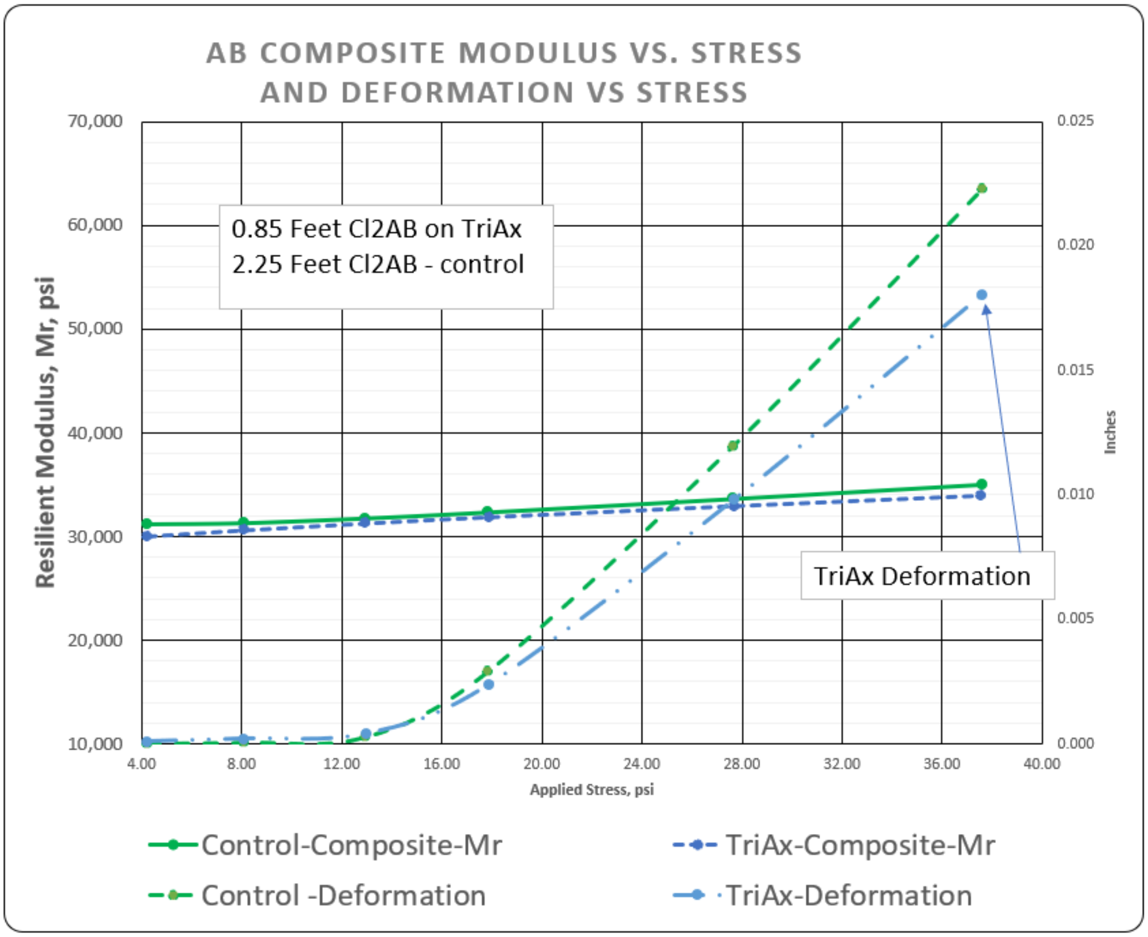


Figure 3

Why is this concept significant to flexible pavement design?

The aggregate base within a flexible pavement section is the foundation that supports the flexible wearing surface. As discussed above a poorly performing aggregate base layer below a flexible pavement can be detrimental to the pavement's performance. The purpose of unbound material layers (aggregate base and aggregate subbase) is to structurally improve the load supporting ability of the pavement section and help the surface structural layer (asphalt concrete) in carrying the traffic load. The increased ability to carry traffic loads reduces the potential for structural related distresses. Tensar representatives performed a

MLET to evaluate the structural mechanics of the TriAx Section compared to the Control Section using WinJulea®. The model used the APLT results with a three-layer system consisting of:

- 0.6 Feet of HMA (300,000 psi modulus), over
- 0.85 Feet of Cl2 AB/TriAx (56,000 psi modulus), and a 2.25 Feet of Cl2 AB (46,000 psi modulus) over
- Subgrade (3500 psi modulus)

The analysis assumed a 100 pound per square inch (PSI) tire pressure applied on the surface of the HMA layer to evaluate the structural mechanics of the TriAx Section compared to the Control Section. Figure 4 presents the findings. The stresses at the bottom of the HMA layer are nearly equivalent but drops significantly within the TriAx Enhanced 0.85-foot AB layer. Comparing the stress at the subgrade elevation of the TriAx section to the control section at the same depth still within the AB section, the stress in the TriAx section is 1/3 of that in the control section. This reduction in stress creates more uniform support characteristics and reduces the potential for non-uniformities in the subgrade soil to cause pavement distress.

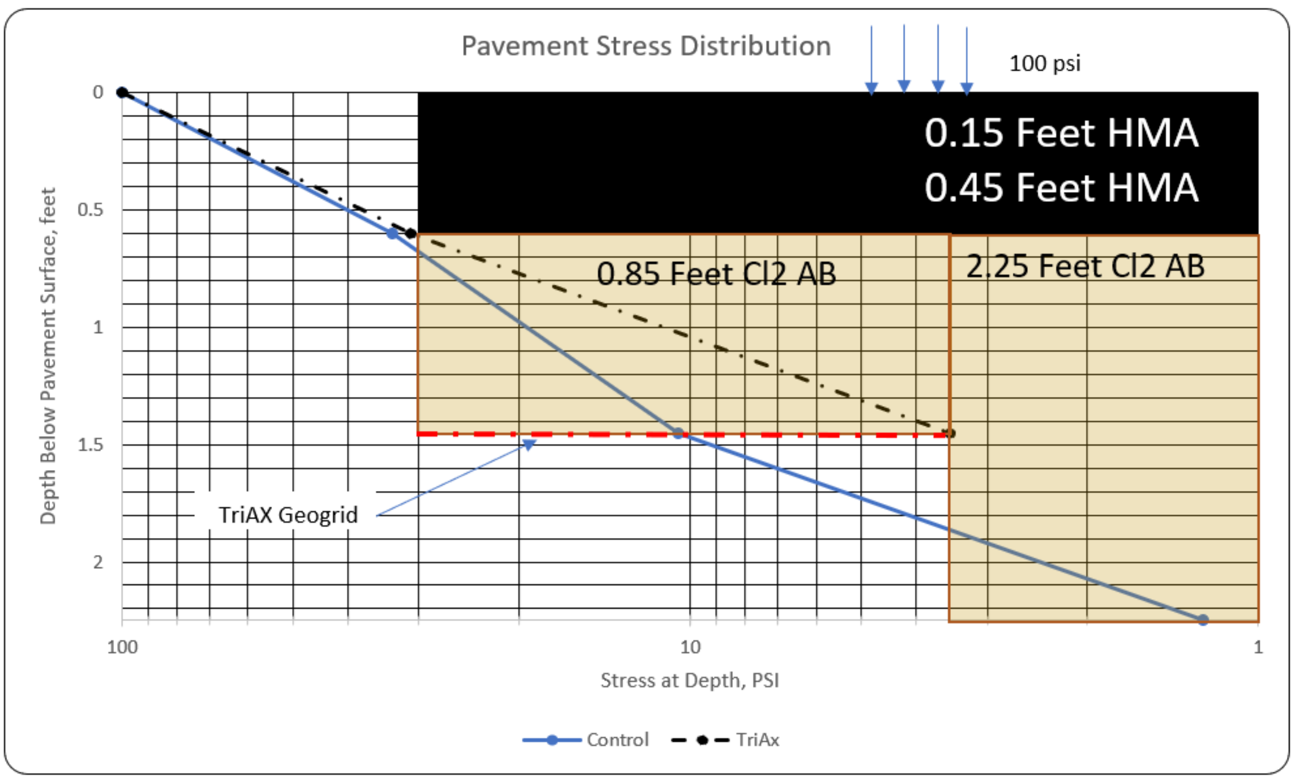


Figure 4 – Mechanistic Analysis Results

<u>How does this apply to the Caltrans Design Method?</u>

Based on the mechanistic analyses above approximately 1.3 feet of Cl2 AB without TriAx would achieve the same subgrade pressure of about 3½ psi as 0.85 feet of CL2 AB with TriAx. Using the Gravel Equivalency method, the composite TriAx/Cl2AB gravel factor would be about 2.85 to achieve the required Gravel Equivalent for the design Traffic Index of 12 and R-Value of 10. This is significantly higher than the 1.1 gravel factor prescribed. This equates to about a 62% reduction in aggregate base using the typical Caltrans Gravel Equivalency Methods. Figure 5 below shows an example of the calculations to evaluate and compare the sections with the Gravel Equivalency Method.

			R-Value		**10**	
Design Calculations -Control Section			Traffic Index		12	
Pavement Layer	Gravel Factor	Required Gravel Equivalent (feet)	Layer GE	Actual GE (ft)	Thickness (feet)	**Profile**
HMA	1.70	3.46	1.02	3.50	0.60	**HMA**
Cl2 AB	1.10		2.48		2.25	**Cl2AB**
			Total Thickness:		2.85	**Subgrade**

			R-Value		**10**	
Tensar Alternative Mechanical Analysis			Traffic Index		12	
Pavement Layer	Gravel Factor	Required Gravel Equivalent (feet)	Layer GE	Actual GE (feet)	Thickness (feet)	**Profile**
HMA	1.70	3.46	1.02	3.46	0.60	**HMA**
Cl2 AB	2.85		2.43		0.85	**Cl2AB**
			Total Thickness:		1.45	**Subgrade**

FIGURE 5

Why does a TriAx geogrid improve performance?

A geogrid's performance is based on the materials ability to interlock with the aggregate base and confine the aggregate from moving laterally. Triangle apertures with high ribs create a hexagonal structure of aggregate creating stiffer structures. Initial lateral and vertical confinement during construction is clear as aggregate locks into geogrid and "soil-arching" begins. Performance is dependent on a geogrids rib shape, rib height, confinement ring geometry, aperture size, geogrid stiffness, and junction efficiency. Performance is dependent on the efficiency and stability of the confinement ring geometry, less potential for movement equals less surface deformation and better performing pavements.

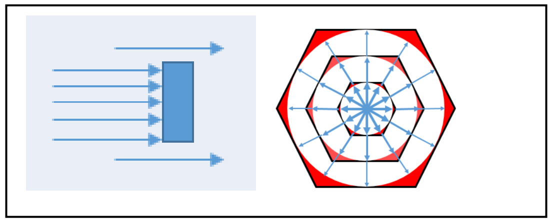


Figure 2 summarizes these benefits.

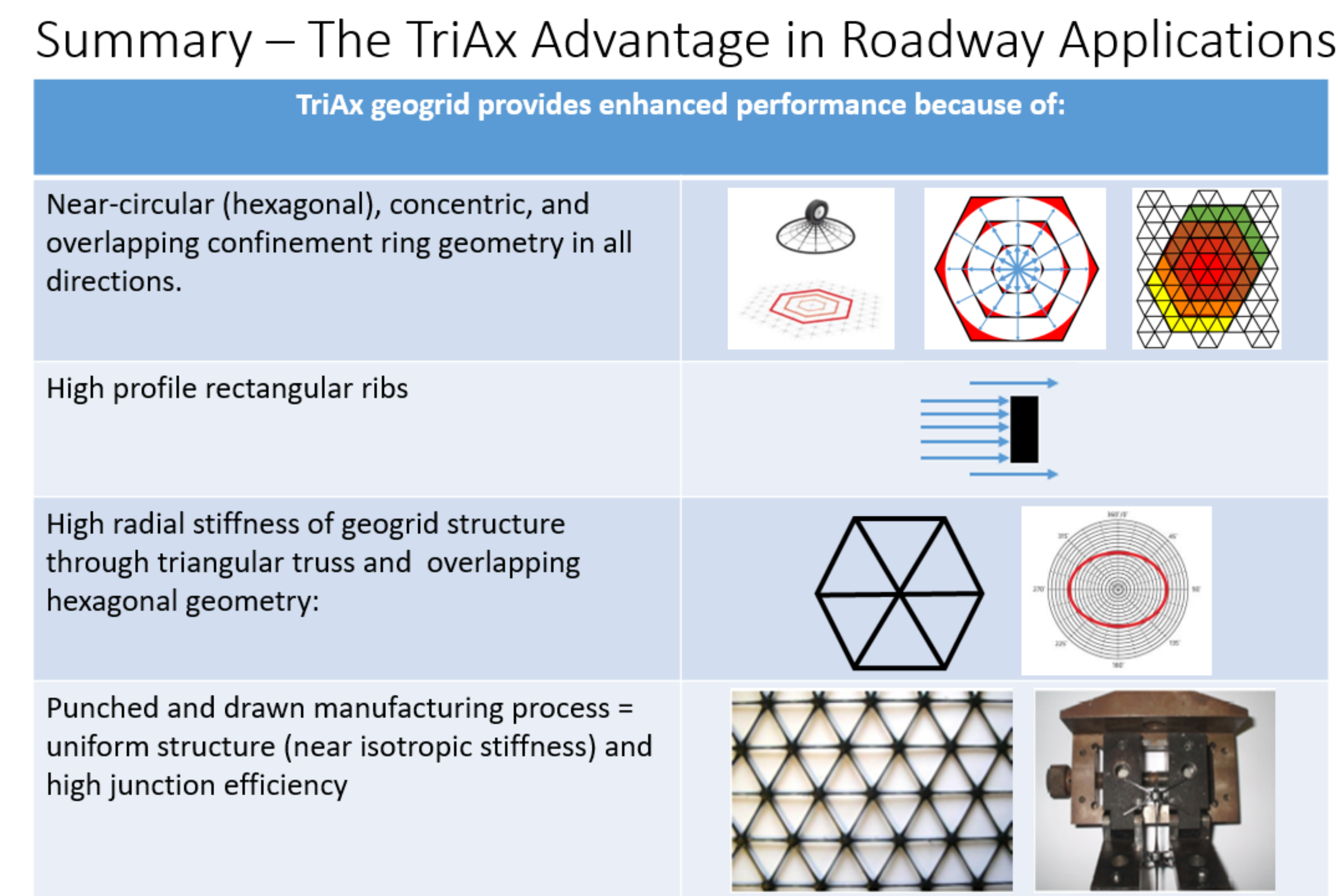


Figure 2

Conclusions

The testing here shows how TriAx geogrids improve the performance of the aggregate base and thereby creating better performing pavement sections. Additionally, it shows how the gravel equivalency method for pavement design may be overly conservative and 50% reductions of aggregate base using TriAx geogrid are reasonable. Additionally, it proves that HMA thickness reduction based on the reduced deformation of the aggregate base experienced with TriAx is reasonable. The results of the testing are consistent with the findings of the Accelerated Pavement Testing and over 200 APLT's performed on sections enhanced with TriAx geogrid. Results can vary depending on the quality of the aggregate, type of geogrid and subgrade strength.

References:

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