A Case Study Featuring the Design and Validation of 26 km of Geogrid Stabilized Pavement for a Utah Highway

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Abstract

The West Davis Corridor is a 4-lane divided, state highway project North of Salk Lake City, Utah. It connects Interstate highway 15 to Legacy Parkway in Farmington addressing the growing population and transportation needs of the area. The project was a $500 million dollar design build project where the engineering team and the contractor collaborated on design decisions. The project's significant scope included the construction of 26 kilometers of embanked highway. One of the project highlights was the innovative use of geogrid to enhance the pavement structure and optimize construction. This resulted in the reduction of ~24,000 tons of Hot Mix Asphalt and replaced 218,000 cubic metres of engineered aggregate with embankment fill. The engineering team used Automated Plate Load Testing to validate the geogrid design. The presentation will outline the design process, and highlight the significant benefits realized including lowered construction cost, reduced construction schedule and a significant improvement in project sustainability and reductions in carbon emissions. The contractor completed the West Davis Corridor project in fall of 2023, one year ahead of schedule.

Introduction

West Davis Corridor consists of 26 kilometers of 4-lane divided highway constructed in western Davis County, Utah along the shores of the Great Salt Lake. The first phase of construction connects to Interstate 15 and Legacy Parkway at approximately Glovers Lane in Farmington, extending west and north, terminating at 4500 West. The contractor began road construction in the Spring of 2022 and completed road construction in the Fall of 2023. One of the biggest challenges on the project was building an embankment across soft soils. This consisted of the import of 5 million cubic yards of embankment material to reach the final planned subgrade elevation. Sourcing material and haul times created difficulty in maintaining construction schedule.

Planned Pavement Sections

To reach the planned embankment surface elevation of asphalt concrete the existing grade needed to be raised between 2 meters and 3 meters. Below the asphalt concrete layers, the initial design included lifts of untreated base course (UTBC), Granular Borrow (GB), embankment material consisting of imported AASHTO Classified material A-4, and onsite clayey embankment material, AASHTO Classified A-6. The initial design specified a geotextile at the interface of the granular borrow and A-4 material. Table 1 shows the approximate thicknesses of the asphalt concrete, UTBC, GB and embankment materials.

Table 1 – Planned Pavement Sections

Segment	I-15 to 950 N	950 N to 2700 W	2700 W to 2000 W	2000 W to SR-931
SMA (mm)	38	38	38	38
HMA (mm)	150	175	165	125
UTBC (mm)	150	150	150	150
Granular Borrow (mm)	305	305	305	305
Geotextile				
A4(mm)	610	610	610	610
A-6 Embankment	Varied thickness depending on grade			

SMA-Stone Matrix Asphalt, HMA – Hot Mix Asphalt, UTBC – Untreated Base Course

Innovation

Building the planned pavement sections required the contractor to import approximately 218,000 cubic meters of granular borrow (GB) for the project. This required extensive haul distances adding significant cost and time to the project. Additionally, at the time of construction haul trucks were not readily available and the imported geotextile was difficult to obtain because of undetermined lead times and overseas shipping delays. The pavement design team reached out to Tensar to evaluate the sections and determine if a geogrid alternative could reduce the GB and eliminate the geotextile. Using AASHOTWareME, the preferred pavement design method for Utah State projects and the design method for this project, Tensar evaluated the planned sections.

The Tensar section alternatives eliminated the GB, by increasing the UTBC thickness and stabilizing it with Tensar Geogrid, Figure 1. The InterAx geogrid interlocks with and confines the UTBC increasing the performance of the UTBC. The improved performance includes better drainage and less deformation. The Tensar section alternatives also allowed the reduction of HMA. Table 2 presents the geogrid properties.

Figure 1 – InterAx Geogrid

Table 2 – Tensar InterAx Geogrid Identification Properties[1]

Identification Properties	**General**
Aperture Shapes	Hexagonal, Trapezoidal and Triangular
Structure	Coextruded and Integrally Formed
Rib Shape	Rectangular
Continuous parallel rib pitch[2], mm	80
Rib Aspect Ratio[3]	>1.0
Node thickness[2], mm	3.25
Color identification	White/Black/White

1. Unless indicated otherwise, values shown are minimum average roll values determined in accordance with ASTM D4759-02
2. Nominal Dimensions
3. Ratio of the mid-rib depth to the mid-rib width

Table 3 presents the Tensar enhanced sections.

Table 3 – Tensar Enhanced Pavement Section Thickness

Segment	I-15 to 950 N		950 N to 2700 W		2700 W to 2000 W		2000 W to SR-931	
	Planned	Tensar	Planned	Tensar	Planned	Tensar	Planned	Tensar
SMA (mm)	40	40	40	40	40	40	40	40
HMA (mm)	150	115	175	140	165	125	125	115
UTBC (mm)	150	250	150	305	150	280	150	150
Tensar Geogrid		Geogrid		Geogrid		Geogrid		Geogrid
Granular Borrow(mm)	305		305		305		305	
Geotextile	GT		GT		GT		GT	
A-4(mm)	610	610	610	610	610	610	610	610
A-6 Embankment(mm)		240		185		215		315

SMA-Stone Matrix Asphalt, HMA – Hot Mix Asphalt, UTBC – Untreated Base Course, GB-Granular Borrow

Design Validation

As part of the project documentation Utah Department of Transportation (UDOT) required Tensar to verify the Mr design value for the stabilized UTBC. The resilient modulus, Mr, is the measure of the applied cyclic stress to the recoverable elastic strain after 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.

Tensar contracted with Ingios Geotechnics to perform Automated Plate Load Testing (APLT) for this. APLT is a system developed to perform fully automated static and repetitive/cyclic plate load tests, per AASHTO and ASTM test methods.

Field Test

The testing was located along a short section of the planned West Davis Corridor Alignment in the Farmington area outside of Salt Lake City, Utah. The planned testing consisted of the Tensar geogrid with UTBC placed on the geogrid along with a control section.

Ingios® performed a series of Automated Plate Load Tests (APLTs). The tests consisted of stress dependent testing with deviatoric stresses ranging between about 30 KPa and 280 KPa cycled 100 times at each stress. The stress dependent testing determines the K_1, K_2 and K_3 regression parameters for the resilient modulus of the materials using the AASHTO (2015) equation, Figure 2.

Figure 2 – AASHTO 2015[2]

Model: AASHTO (2015) σ_{cyclic} [psi]

$$M_r = k_1^* P_a \left(\frac{\theta}{P_a}\right)^{k_2^*} \left(1 + \frac{\tau_{oct}}{P_a}\right)^{k_3^*}$$

Parameter	Value	P-Value
$k^*_{1\,(Base)}$	2667.4	1.03E-05
$k^*_{2\,(Base)}$	-0.164	2.67E-01
$k^*_{3\,(Base)}$	1.612	1.21E-01
Adj. R^2	0.944	
Std. Error [psi]	813	
$k^*_{1\,(Subgrade)}$	1354.7	2.42E-05
$k^*_{2\,(Subgrade)}$	-0.220	1.60E-02
$k^*_{3\,(Subgrade)}$	2.328	2.04E-02
Adj. R^2	0.972	
Std. Error [psi]	82	

Results / Key Findings:

Tensar evaluated a total of 24 tests. The final as-built test sections in this analyzed area ranged between 230 mm and 450 mm thick. Ingios Geotechnics performed 3 tests on each section and then Tensar representatives average the results for each section to determine the stabilized UTBC Mr for design. Figure 3 shows the sections used for a performance comparison.

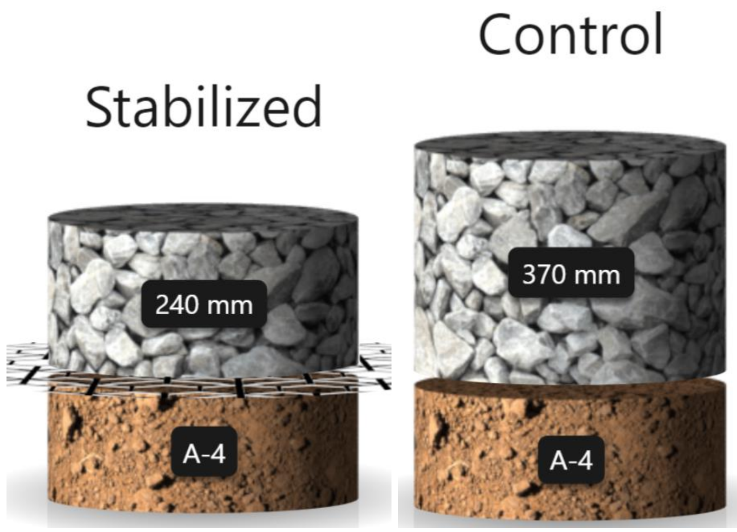
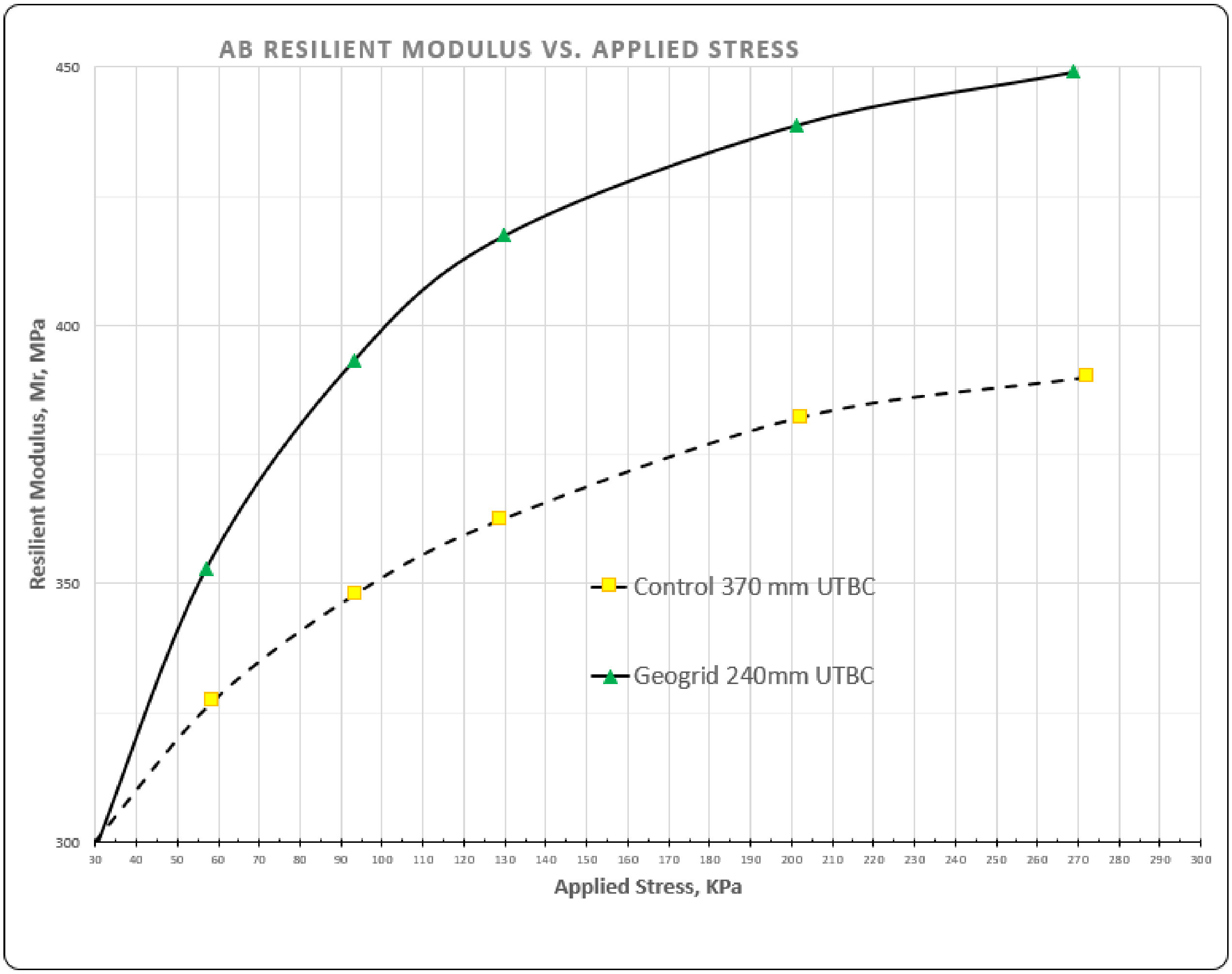


Figure 3

Figure 4 shows the average resilient modulus of the UTBC versus the applied stress using the 305 mm diameter plate. The results show how the resilient modulus of the stabilized sections underlain by Tensar Multi-Shaped geogrid is stiffer as compared to the thicker control section. Additionally, the testing confirms that the use of UTBC Mr design value of 350 MPa for pavement areas underlain with Tensar Multi-Shaped Geogrid is acceptable.

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 distresses including fatigue cracking, rutting, corrugations, bumps, depressions, potholes, and roughness (Christopher et al. 2006). The Mr of the UTBC material increased about 20% by adding geogrid below the UTBC. This improvement raises the UTBC performance and reduces the potential for distress. Additionally, the tests demonstrate that designing with less UTBC stabilized with geogrid can maintain or increase performance. The stabilized section was about 35% thinner than the control section.

Figure 4 -APLT Results[1]



The contractor constructed the sections discussed above prior to the actual construction to prove the concept and validate that the design values. During construction Tensar performed additional testing of the untreated base course to further validate the sections. The subsequent testing showed improved untreated base course Mr values of about 425MPa. This is above the design target value of 350MPa. In general, the results are consistent with the measured performance Tensar representatives have observed with tests performed at multiple locations, aggregate types, and aggregate thicknesses.

The geogrid stabilized sections performed well during construction. The thinnest section of UTBC placed was 150mm. The contractor or State of Utah representatives did not report any rutting pumping or other distresses during construction.

Conclusions

This is an example of using geogrid to solve construction challenges and validating the geogrid innovation in the field. The design team reached out to Tensar for geogrid stabilized pavement section alternatives when faced with the challenge of not having enough trucks available to deliver the quantity of GB material needed and not having the ability to obtain the planned geotextile. These items influenced the contractor's ability to maintain schedule. Tensar developed alternative pavement sections using the AASHTOWareME™ software design protocol required for the project. By adding geogrid below UTBC, the increased UTBC performance eliminated the need for GB and the geotextile as well as allowing a reduction in the HMA.

This permitted the use of aggregates from nearby sources and optimization of on-site materials reducing the number of trucks needed to keep up with construction. Also, the contractor established shorter hauls in a combination of ways:

- Overall volume of engineered material was reduced, meaning that more of the embankment material could be sourced from wetland mitigation ponds that were being created all along the project alignment.
- Imported A-4 Sand material, though not reduced in thickness, still saw significant reduction in the 6:1 shoulder by significantly moving them up in the trapezoidal roadway cross-section.
- Granular Borrow (Subbase) was eliminated. This had a major impact because the source for this material was much farther from the project than any of the other imported aggregates.
- Untreated Base Course (UTBC) Quantity was increased. This is important because the source for the UTBC was closer to the project than the imported aggregate materials.
- Reduction in thickness of asphalt combined with all other reductions, has an impact in the volume of all imported materials beneath it. This is, once again, due to the layers moving up in the trapezoidal cross-section.
- The final improvement to truck flow comes from the geogrid providing the option for the trucks to continue forward along the project alignment as another egress point becomes closer than turning around and exiting the work zone where it entered. Before the geogrid, trucks had to turn around and drive back the way they came, even if another exit ahead was much closer.

Reducing a project's Carbon Footprint is an ancillary benefit to reducing construction materials. Table 4 provides a brief explanation of the assumptions made and environmental impact the Tensar solution provided.

Table 4 Reducing Carbon Footprint

Per Unit Values				
Material	**Unit**	**Amount**	**Cradle to Gate GWP/Unit**	**Cradle to Gate GWP kg co2 equivalent**
HMA	Metric Tons	1	68.6	68.6
Tensar InterAx	M2	1	0.93	0.93
Trucking	Km	1	0.29	0.29
Project Totals				
HMA	Metric Tons	1	24,000	1,646,400-Reduction
Tensar InterAx	M2	1	618,833	575,515-Additional
Trucking	Km	1	640,000	185,600 - Reduction
Tensar kg. CO2 eq. Reduction				1,256,485 - Reduction
Tensar kg. CO2 eq. Reduction (tons)				1,256 Reduction

From a sustainability perspective using geogrid saved approximately 1,256 tons of CO_2. This is equivalent to CO_2 emissions from 4,237 barrels of oil consumed.

Summary

This project used geogrid to create a more constructible solution while minimizing DOT risk of not getting a quality product. Tensar used Automated Plate Load Testing technology to allow the DOT to gain information and understand the potential risk associated with moving forward with a geogrid design. The geogrid created a solution that accelerated the construction schedule benefiting the DOT and contractor. Using the geogrid also created a more sustainable project reducing the volume of raw materials used. Tensar will be following up with performance testing measuring IRI values and PCI values to validate the design and calibration for future ME models.

References

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