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Evaluation of geosynthetic-asphalt interface characteristics using Leutner shear tester

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ABSTRACT: Geosynthetics are widely adopted within the asphalt layers to enhance the pavement performance through various functions such as reinforcement, stiffening, and moisture barrier. Specifically, these functions help retard the reflective cracking, formation of rut and permanent deformation, and fatigue cracking in the asphalt layers. However, a major concern of adopting geosynthetic reinforcements is the reduction in interlayer shear resistance between the asphalt layers. In this study, the impact of various geosynthetic-asphalt interface characteristics on the interface shear resistance was evaluated by testing cores obtained from an in-service highway. Specifically, the Leutner shear device was used to test seven interfaces including an unreinforced (control) interface and six asphalt-geosynthetic interfaces that were formed by different types of geosynthetic reinforcements including both polymeric and fiber-glass products. Although the Leutner shear test results indicated reduced interface shear resistance in all geosynthetic-reinforced specimens, the percentage reduction was found to be particularly affected by the composition of the reinforcements. Specifically, the reinforcement materials (glass or polymer) and form (grid or textile or composite) were found to significantly affect the asphalt-reinforcement bond strength. Additional factors affecting the geosynthetic-asphalt interface characteristics included tack coat application rates, characteristics of the apertures, and the thickness of the geosynthetic reinforcements.

1 INTRODUCTION

Geosynthetics have been widely used within or as the interface between pavement layers to enhance roadway performance. Reinforcement inclusions in asphalt layers have been reported to mitigate reflective cracking and enhance pavement structural performance (e.g., Brown *et al*. 2001; Ferrotti *et al*. 2012; Kumar & Saride 2018). However, geosynthetic inclusion can compromise the bonding between the asphalt layers through interlayer de-bonding effect. This effect is described as a condition where the adhesion between two adjacent asphalt layers weakens and the two layers may eventually separate under excessive

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horizontal stresses (e.g., Brown *et al.* 2001; Kumar & Saride 2018). Debonding may undermine the design benefits from geosynthetic interlayers and dissuade owners on using them. With the development of a wide range of geosynthetic interlayers with various designs and textures, understanding the asphalt-geosynthetic bonding strength and extents of potential debonding has become crucial.

A wide variety of experiments have been developed to characterize various aspects of bonding strength between two asphaltic layers. The most common experimental method for evaluating interlayer bonding strength involves direct shearing of the interface and various experimental setups have been adopted to generate such shear loading on the interface. A few examples include the Leutner shear test (Leutner 1979), the Layer-Parallel Direct Shear (LPDS) test, the Florida Department of Transportation (FDOT) shearing device (Sholar *et al.* 2002), Ancona Shear Testing Research and Analysis (ASTRA) (Canestrari *et al.* 2005), and large-scale interface shear strength test device (Kumar *et al.* 2017). The variations among the shear mechanisms involved in the tests has made comparison of test results particularly difficult. However, several experimental studies could identify the most important parameters that impact the bond strength as temperature, aggregate gradation, and surface roughness, normal pressure, tack coat type, and tack coat application rate among others (e.g., Canestrari *et al.* 2005; Correia *et al.* 2022; Kumar *et al.* 2017; Kumar & Saride 2018; Roodi *et al.* 2017; Sholar *et al.* 2002; West *et al.* 2005).

While most experimental studies on asphalt-geosynthetic bonding strength involved remolded samples, comparatively limited research has been conducted on asphalt cores obtained from roadways that have been constructed with geosynthetic reinforcements. Testing of such field samples that had subjected to construction impact provides more realistic insights into asphalt-geosynthetic bonding strength. This paper presents results of asphalt-geosynthetic bond testing program that aimed at understanding the various parameters affecting the bond strength, including impacts from construction damages. Asphalt cores were collected from an unreinforced and six geosynthetic-reinforced roadway sections and their interface bond strength was tested using the Leutner shear tester. Geosynthetic reinforcement included different polymeric and fiberglass products with different forms of grids, textiles, and composites. Factors affecting the geosynthetic-asphalt interface bonds were evaluated.

2 PROJECT BACKGROUND

As part of Texas Department of Transportation (TxDOT) rehabilitation program, a 32-km-long stretch of State Highway (SH) 21 was restored by treatment of distresses in the pre-existing asphalt surface followed by construction of a 75-mm-thick structural overlay. The original overlay design included geosynthetic interlayer to be placed between the existing asphalt and the new overlay. To establish basis for future expansion in the use of geosynthetic interlayers, TxDOT retained the research team to investigate the effectiveness of various geosynthetic interlayers in enhancing roadway performance. A 1.34-km-long section of the four-lane highway was split into 34 test sections that were constructed with different designs in plan and profiles. Geosynthetic-reinforced sections were constructed side-by-side and along with unreinforced sections to compare their performances under similar conditions.

Seven of the test sections, including an unreinforced section and six geosynthetic-reinforced sections, were selected for more robust investigation that involved installing various types of sensors and conducting controlled traffic loading on sensors (Kumar *et al.* 2022). To complement the investigation and provide insight into the bonding strength between asphalt and various geosynthetic types, several cores were collected from each test section two months after construction. Figure 1 shows design profile of the rehabilitated test section along with an example picture of cores depicting various asphalt layers. As shown in the figure, the asphalt layers included approximately 150 mm of preexisting asphalt and level-up layers, with geosynthetic interlayer installed on applied tack coat at the interface, and overlain by 75 mm asphalt overlays placed in two layers including a 50-mm-thick dense-graded asphalt mixture (Type D) and a 25-mm-thick wearing-course asphalt mixture (TOM). The asphalt mixtures (Type D and TOM) were adopted from TxDOT standard specifications for construction and maintenance of highways, streets, and bridges (TxDOT 2014).

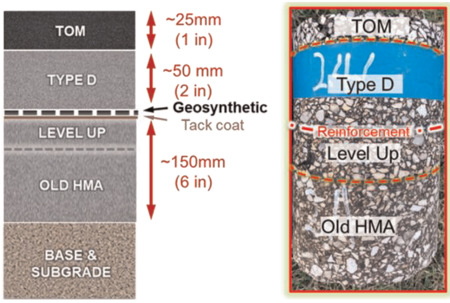


Figure 1. Roadway profile of test sections: (a) Schematic design profile; (b) Example picture of asphalt core.

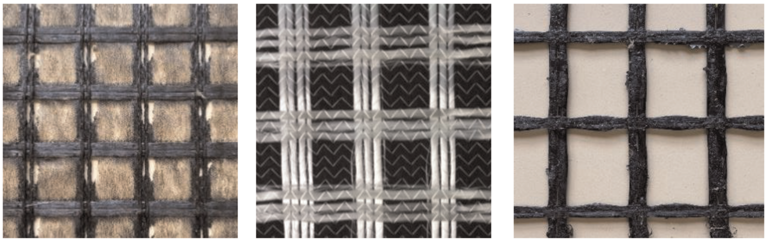
3 MATERIALS AND METHODS

3.1 *Geosynthetic reinforcements*

Six different types of geosynthetic reinforcements including three each of polymeric and fiberglass products were adopted as asphalt reinforcements in this study. Specifically, the geosynthetic reinforcements were adopted based on their material composition, tensile, and physical characteristics. Figure 2 presents the three polymeric products evaluated in this study, which includes two polyester geogrid composites and a polyvinyl alcohol geogrid composite. The product GR-1 (Figure 2a) is a geocomposite made up of high modulus polyester geogrid and a woven fabric, while GR-2 (Figure 2b) is a geocomposite made up of high modulus polyester geogrid and an ultra-lightweight non-woven fabric. The third product, GR-3 (Figure 2c) is a geocomposite made up of a high modulus polyvinyl alcohol geogrid and an ultra-lightweight non-woven fabric. All the three products are completely coated with a binder to enhance the bonding characteristics. The three fiberglass products evaluated in this study are as shown in Figure 3, which includes two fiberglass geogrid composites and a fiberglass geogrid. The product GR-4 (Figure 3a) is a geocomposite made up of high strength fiberglass filaments and an ultra-lightweight non-woven fabric that is completely coated with binder, while GR-5 (Figure 3b) is a geocomposite comprising fiberglass filament yarns incorporated into a thick nonwoven polypropylene paving fabric. The final product, GR-6 (Figure 3c) is a self-adhesive geogrid made up of high strength fiberglass filaments that are completely coated with elastomers. The physical and tensile properties of the geosynthetic reinforcements evaluated in this study is summarized in Table 1.

GR-1 GR-2 GR-3

Figure 2. Polymeric Geosynthetic Reinforcements evaluated in the study: a) GR-1; b) GR-2; and (c) GR-3.



GR-4 GR-5 GR-6

Figure 3. Fiberglass Geosynthetic Reinforcements evaluated in the study: a) GR-4; b) GR-5; and (c) GR-6.

Table 1. Properties of geosynthetic reinforcements and tack application rates.

Geosynthetic Reinforcements	Mass/ unit area (g/m^2)	Aperture size (mm)	Ultimate tensile strength (kN/m)	Strain at elongation (%)	Asphalt retention capacity (l/m^2)	Melting point (°)	Tack application rate (l/m^2)
GR-1	275	34 × 34	50	12	0.47	250	0.54
GR-2	270	40 × 40	50	10	0.47	250	0.54
GR-3	210	40 × 40	50	5	0.47	235	0.54
GR-4	596	30 × 30	100	3	0.47	300	0.54
GR-5	678	38 × 38	115	3	1.2	800	1.35
GR-6	432	25 × 25	100	3	–	232	–

3.2 *Asphalt and tack*

Two different types of asphalt mixtures were used as asphalt overlays that included a dense-graded asphalt mixture (Type D) overlain by a thin asphalt overlay mixture (TOM). However, it is important to note that the geosynthetic reinforcements were installed below the Type D layer in the reinforced sections using a polymer modified asphalt cement (AC-15P) applied at different rates, per geosynthetic manufacturer recommendations and prior trials. While, a cationic, slow-setting, low-viscosity, and comparatively hard residue emulsion (CSS-1H) was applied at a residual rate of 0.27 l/m^2 on the level-up course prior to the placement and compaction of Type D layer in the unreinforced (UR) section. Table 1 provides the tack application rates for different geosynthetic-reinforced sections evaluated in this study and as shown, the tack application rates of all the geosynthetic reinforcements except GR-5 and GR-6 was 0.54 l/m^2, since GR-5 had the maximum rate of 1.35 l/m^2, while GR-6 did not require tack during the installation.

3.3 *Core extraction and specimen preparation*

Several cores were collected from the 7 test (6 geosynthetic-reinforced and 1 unreinforced) sections considered for evaluation in this study. Specifically, about 2 months after the completion of the overlay construction, cores were extracted from the test sections using a trailer-mounted core drill with inside diameter of 150 mm. The core heights were extended from the pavement surface to the bottom of the old asphalt as shown in Figure 1b. The top and the bottom of the specimens were trimmed to obtain a height that was consistent with the dimensions of the Leutner shear tester device and the interface plane will be aligned with the applied shear plane imposed by the device. Careful attention was paid to ensure that the interface where the reinforcement layer is located has remained intact during drilling, transportation, and trimming of the specimens.

3.4 *Leutner shear test*

Leutner shear test is one of the most common interlayer shear tests that applies a constant rate of shearing displacement between the two asphalt interfaces to determine the bond strength between them. The cores extracted from the unreinforced and geosynthetic-reinforced test sections were tested using the Leutner shear tester to determine their interface shear strength characteristics. Specifically, the Leutner shear tester was used in an Instron 8872 loading machine and a monotonic load was applied at a displacement of 50 mm/min until failure or displacement of 12.5 mm, at a temperature of 22°. Additionally, a width of 2.5 mm was maintained between the two shearing rings of the Leutner shear tester matching the interface zone of the core specimens being tested. Similar conditions were maintained and recommended by Correia *et al.* (2022).

4 RESULTS AND DISCUSSION

The results from Leutner shear tests are obtained in the form of shear load vs relative shear displacements. The interface shear strength is then determined by the ratio of shear load and the cross-sectional area of the specimen tested and the variation of interface shear strength with displacements are plotted. Figures 4a and b show the variations of interface shear strengths with displacements respectively, for unreinforced and geosynthetic-reinforced (GR-3) specimens tested in this study. As shown in the figures, the interface shear strengths increased with increasing displacements and reached a peak value and reduced thereafter with further increase in the displacement values for both the specimens (UR and GR-3). However, the geosynthetic-reinforced specimen witnessed a lower peak interface shear strength value compared to that of the unreinforced specimen, suggesting a reduction in the interface shear strength with the inclusion of geosynthetic reinforcements. In addition, the displacement corresponding to the peak interface shear strength increased in the geosynthetic-reinforced specimen compared to that of the unreinforced specimen tested in this study. The peak interface shear strength values for different interface (6 reinforced and unreinforced) conditions were determined from multiple cores tested in this study and reported in Figure 5. As shown in the figure, the peak interface shear strengths for all the specimens tested in this study ranged between 0.44 MPa and 0.87 MPa, which is similar to that recommended in the literature for mostly unreinforced asphalt layers.

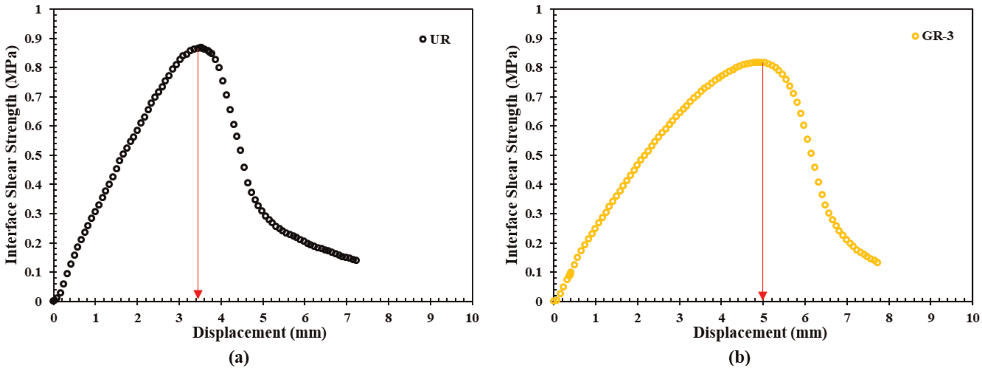


Figure 4. Typical interface shear strength trends: (a) Unreinforced specimen and (b) Geosynthetic-reinforced (GR-3) specimen.

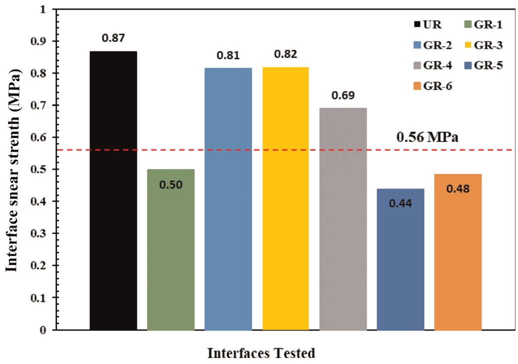


Figure 5. Peak Interface shear strength for different interfaces tested.

On the other hand, FGSV 770 (2013) suggested that the minimum bond strength required between two asphalt layers is about 10 kN (0.56 MPa for a specimen with 150 mm diameter). While, it is important to note that the unreinforced specimen had a highest interface shear strength value of 0.87 MPa compared to that of the geosynthetic-reinforced specimens tested in this study. In other words, the interface shear strength of all the geosynthetic-reinforced specimens were lower than the unreinforced specimen confirming the reduction in bond strength with the inclusion of geosynthetic reinforcements between the asphalt layers. Among the geosynthetic-reinforced specimens, GS-3 had the maximum interface shear strength of 0.82 MPa, followed by GR-2 (0.81 MPa), GR-4 (0.69 MPa), GR-1 (0.50 MPa), GR-6 (0.48 MPa), and finally GR-5 (0.44 MPa). However, it is important to note that the tack application rates for GR-5 and GR-6 were different from the rest of the geosynthetic products evaluated in this study.

The reductions in interface shear strengths were on the order of 42.61% (GR-1), 6.13% (GR-2), and 5.63% (GR-3) for the polymeric products, and 20.57% (GR-4), 49.42% (GR-5), and 44.12% (GR-6) for the fiberglass products respectively. It is evident that polymeric products performed better than the fiberglass products, in terms of bond strength, especially GR-2 and GR-3 specimens. The high bond strengths witnessed in GR-2 and GR-3 specimens may be due to their aperture sizes and the ultrathin nonwoven backing that can promote through hole bonding to enhance the interface bond strength. In addition, the products GR-2 and GR-3 were completely coated with a binder to enhance their interface bonding characteristics. While the other polymeric product, GR-1 had a fabric woven into the polymeric grids that did not promote through hole bonding and hence, reduced bond strength. On the other hand, among the fiberglass products, GR-4 performed better than GR-6 that performed better than GR-5. The variations in the performances may be due to the thickness of geotextile backing (especially in GR-5) and the presence/absence of tack (especially in GR-6). In addition, the apertures of GR-6 were smaller in comparison to GR-4, while the apertures of GR-5 were not significant because of the thick geotextile backing. Overall, it can be summarized that the interface bond strength is crucial for the performance of geosynthetic-reinforced asphalt layers and depends on multiple factors including the tack type and application rates, nominal aggregate size of the asphalt mix, and geosynthetic properties including the aperture size, presence/absence of geotextile backing, and the thickness of geotextile backing among others.

5 CONCLUSIONS

In this study, the impact of various geosynthetic-asphalt interface characteristics on the interface shear resistance was evaluated by testing cores obtained from an in-service highway. Specifically, the Leutner shear device was used to test seven interfaces including an unreinforced interface and six asphalt-geosynthetic interfaces that were formed by different types of geosynthetic reinforcements including both polymeric and fiberglass products. The following conclusions can be drawn from the study.

The geosynthetic reinforcements reduced the interface shear strength between the asphalt layers and the reductions were on the order of 42.61% (GR-1), 6.13% (GR-2), and 5.63% (GR-3) for the polymeric products, and 20.57% (GR-4), 49.42% (GR-5), and 44.12% (GR-6) for the fiberglass products evaluated in this study, respectively.

The reduction was found to be particularly affected by the composition of the reinforcements. Specifically, the reinforcement materials (glass or polymer) and form (grid or textile or composite) were found to significantly affect the asphalt-reinforcement bond strength. Additional factors affecting the geosynthetic-asphalt interface characteristics included tack application rates, aperture size, and the thickness of geosynthetic reinforcements.

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