Applications of natural geotextiles in asphalt overlays to retard reflection cracking

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ABSTRACT: Flexible pavements are multi-layered structures. The bond strength between these multi-layers is as much important as the strength and stiffness of the individual layers in controlling the life of these pavements. The repeated loading and the varying climatic conditions cause the cracks and joints in the existing pavement to reflect the overlay over a period of time. This phenomenon is called reflective cracking. Insufficient bonding between the layers of the hot mix asphalt (HMA) is one of the reasons for the early appearance of the reflective cracks. Many interlayer systems are introduced to retard the crack propagation, out of which geosynthetic interlayer system has gained attention due to the ease of installation and cost effectiveness. The index properties of natural geotextiles like coir and jute are found to meet the specifications for paving fabric by different standard organizations. This paper focuses on the study of the interface bond strength of natural geotextiles in asphaltic concrete layers by conducting shear tests. The results are compared with those of unreinforced samples to quantify the influence of the reinforcement layers. It has been observed that in most cases the jute and coir geotextile-reinforced samples reduces the bond strength by 37% and 14% respectively while the synthetic counterpart improves the shear strength by 26% compared with unreinforced samples.

Keywords: Interface bond strength, Luetner Shear test, Natural geotextiles, Reflective cracking, Paving fabric

1 INTRODUCTION

One of the common rehabilitation techniques against the deterioration of old asphaltic concrete layer is by placement of new HMA overlay. However, the cracks in the old pavement eventually propagate from the underneath layer to the new overlay. This phenomenon is known as reflective cracking, caused due to the inability of the asphaltic concrete overlay to withstand tensile and shear stresses developed at the interface of the crack and the new HMA layer due to repeated traffic and thermal movements. (Mackiewicz 2013; Zhou et al. 2006). The propagation of crack can be arrested by reducing the magnitude of tensile stresses at the crack-overlay interface by the installation of tensile reinforcing members (Loria-Salazar 2008). Geosynthetic reinforcement has gained importance due to its ease of installation and its widespread availability. Among them, natural geotextiles are getting more attention due to their promising performance compared to the synthetic counterpart. The strength parameters of the natural geotextile are comparable with the synthetic one (Nithin et al. 2014; Sudarsanan et al. 2016).

Apart from the strength and stiffness of the HMA layers, the bond between different layers affects the life of the asphalt pavements. The interlayer bond ensures that the adjacent layers act monolithically to withstand the traffic and environmental loadings (Hakim 2002). A weak bond between the layers causes easy debonding resulting in the reduction of the stiffness of layers thereby reducing the residual life of the pavement structures. Proper estimation of bond strength and its influence on the performance of asphalt layers is needed to estimate the life span of the pavement (Nithin et al. 2015; West et al. 2005).

Different modes of debonding failures are observed in asphaltic concrete layers. Most commonly found debonding failure mode in the field is due to shear failure. This paper focuses on evaluating the bond strength of samples reinforced with natural geotextiles like coir and jute. Leutner shear test is adopted for the evaluation of bond strength due to its simple experimental test set-up, ease of sample preparation, fast and precise making it more suitable for a laboratory based routine testing (Muslich 2010).

2 MATERIALS USED FOR SPECIMEN PREPARATION

2.1 *Geotextile.*

Three types of geotextiles are used to find the bond strength behavior: jute (JGT), coir (CGT) and synthetic (SGT). The mechanical properties of these geotextiles are compared with the basic mechanical properties specified for paving fabrics by many of the standards organization like ASTM D 7239-06, AASTHO M288-06 and IRC SP59 in table 1. Figure 1 shows the varieties of geotextile used.

Table 1. Comparative table of geosynthetics used with requirements of standards

Mechanical Properties	Test Methods	Units	Requirements				JGT	CGT	SGT
			AASTHO	IRC	ASTM Type I	ASTM Type IV			
Grab Strength	ASTM D 4632	N	450	450	—	—	1511	—	519
Ultimate Elongation	ASTM D 4632	%	≤ 50	≤ 50	—	—	11	—	5
Breaking Elongation	ASTM D 5035	N/50mm	—	—	200	3250	1250	635	3500
Ultimate Elongation	ASTM D 5035	%	—	—	≤ 5	≤ 10	5	25	5
Mass per unit area	ASTM D 5261	gm/m2	140	140	125	450	500	950	500
Asphalt retention	ASTM D 6140	ℓ/m2	b&c	b&c	b&c	b&c	1.75	2.8	1.86
Melting Point	ASTM D 276	°C	150	150	205	205	245	240	400

Type I: A single layer of nonwoven paving mat of 136 g/m2
Type IV: A multidirectional high strength hybrid geosynthetic paving mat consisting of a Type I mat plus reinforcement strands in both the machine and cross direction.
(a) Asphalt required to saturate paving mat only. Asphalt retention must be provided in manufacturer certification. Value does not indicate the asphalt application rate required for construction
(b) Asphalt retention property must meet the MARV value provided by the manufacturer certification

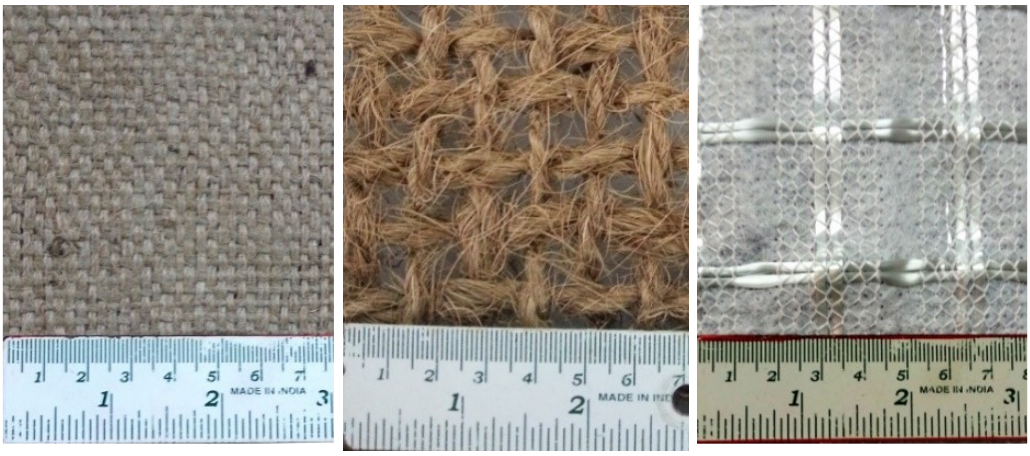

Figure 1. (a) Jute woven geotextile (JGT) (b) Coir geotextile (CGT) (c) Synthetic Geotextile (SGT)

2.2 *Bituminous Concrete.*

As per Section 500 of MORTH, the composition for the bituminous concrete as the surface course was designed for grading 2. The VG-30 binder content of 5.5% is added as per the Marshall stability value.

3 SAMPLE PREPARATION

The core specimens for Leutner shear test were extracted from a test pavement section constructed in the field. The bottom layer of 100 mm thickness, compacted at 25 mm lift of asphaltic concrete layer is laid over the reinforced subgrade. Over the asphaltic concrete layer, all the three types of geotextiles which are used for the bonding tests are placed as shown in figure 2(a). The required amounts of asphaltic tack coat (based on the retention capacity for each geotextile) was applied before placing them on the pavement layer (figure 2(b)). After the application of asphalt, the next layer of 50 mm thick asphaltic concrete is laid. The pavement section is cut into beams of movable size (figure 2(c)). Then the core samples of 150 mm diameter were cored and trimmed to the required specimen dimensions as shown in figure 2(d).

The test samples were composed of two layers as shown in figure 3(a). The top layer is of thickness 30 mm and the bottom layer is of thickness 70 mm. The interface is installed with or without geotextile. The asphalt required for bonding is usually 0.23 liters/m2 for a rough surface. When geotextile is placed an additional asphalt equivalent to its retention capacity was applied. The details of the retention capacity are listed in Table 1.

Figure 2. (a) The three interlayer systems were laid in the field pavement. (b) The required asphalt tackcoat was applied for proper bonding between the layers (c) Prismatic beams were made for easy mobilisation (d) Leutner shear samples were cored from the beams.

4 LEUTNER TESTING

The shear bonding resistance of the asphalt layers can be evaluated as per DIN EN 12697-48:2013-12. Leutner shear test is a simple test that can be carried out to measure the same. The Leutner test was done under standard condition, strain rate of 50 mm/min and at a temperature of 25°C. The load was applied with the help of a Servo controlled Universal testing machine. The test setup is shown in figure 3(b).

From the shear test, the response of shear deformation, w, against the shear force F is established. The maximum shear force, F_{max}, measured during the test is used to calculate the nominal average shear stress, τ, using the cross section area of the cylindrical sample, A, of diameter d, with the relation below.

$$\tau = \frac{\mathrm{F}}{\mathrm{A}} = \frac{4F_{max}}{d^2\pi} \tag{1}$$

Moreover, the shear modulus G of the sample is defined as the maximum slope of the nominal shear stress versus shear displacement diagram.

$$\mathrm{G} = \frac{\Delta\tau}{\Delta\mathrm{w}} \tag{2}$$

(a) (b)

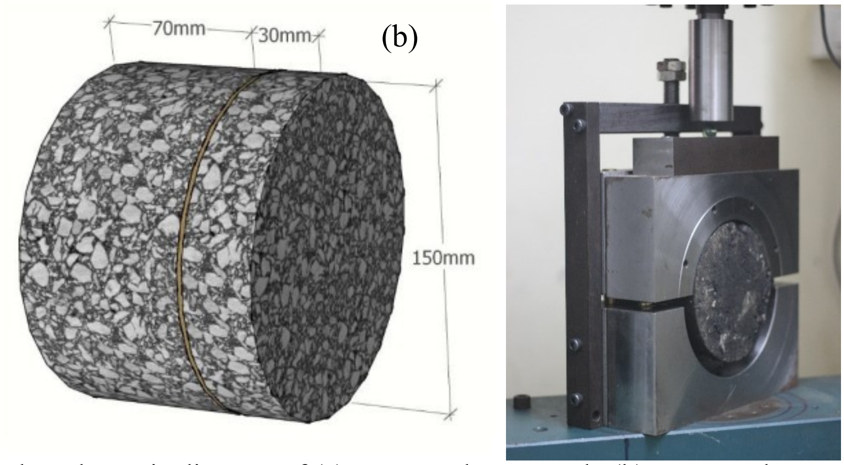

Figure 3. (a) The schematic diagram of (a) Leutner shear sample (b) Leutner shear test apparatus

5 TEST RESULTS AND DISCUSSIONS

Figure 4(a) shows the shear stress versus strain diagram for the three types of geosynthetics and unreinforced control specimen. The bond strength of the sample varies depending upon the type of geosynthetics used. It could be observed that the introduction of JGT and CGT causes a reduction in the shear strength by 37% and 14% respectively while the SGT increases the shear strength by 26%. This observation is in agreement with the experimental results reported by (Raab and Partl 2004) that the addition of stress absorbing interlayer may lead to negative effects on the interlayer bond strength. The factors which affect the bond strength of geosynthetic reinforced asphaltic concrete depends not only on the tensile strength of the geosynthetic material but also on the compatibility of the same with the asphaltic concrete. There are two types of mechanism that powers the bond strength; (1) Through hole bonding (THB) and (2) adhesion. The mechanism of THB is to mobilise the bond strength due to the interlock between aggregate and the grid (see Figure 5(a)). The nominal maximum aggregate size and the grid size are the influential factors which determine the compatibility to mobilize the tensile strength of grid as an aid for better bonding causing CGT to outperform JGT.

The second mechanism of bonding is driven by adhesion between the geotextile and the surrounding asphaltic concrete layer (see Figure 5(b)). The adhesion need not be stronger than the bond strength of the unreinforced samples as the bonding is developed due to aggregate interlocking and tack coat adhesion. Meanwhile, in the case of JGT, the bond strength is due to the adhesion between the aggregate and the geotextile on its both side. The measured strength shows that a reduction in bond strength in comparison to the unreinforced samples. The JGT behaves as a shear plane reducing the contribution of aggregate interlock to bond strength into minimal.

The through hole bonding mechanism is more effective compared to adhesion making the grid to become more popular. In the case of SGT composite, the glasgrids in the surface helps to give THB on one side while the non-woven geotextile helps to provide adhesion on the other side (see Figure 5(c)). This helps in mobilizing the tensile strength of the glasgrid leading to improvement in the bond strength. It is also observed that the shear modulus of the composite and grid is 123% and 34% higher than that of the fabric respectively. Figure 4(b-d) shows the comparative results of stiffness, ultimate breaking stress and strain for CS, SGT, JGT, and CGT respectively.

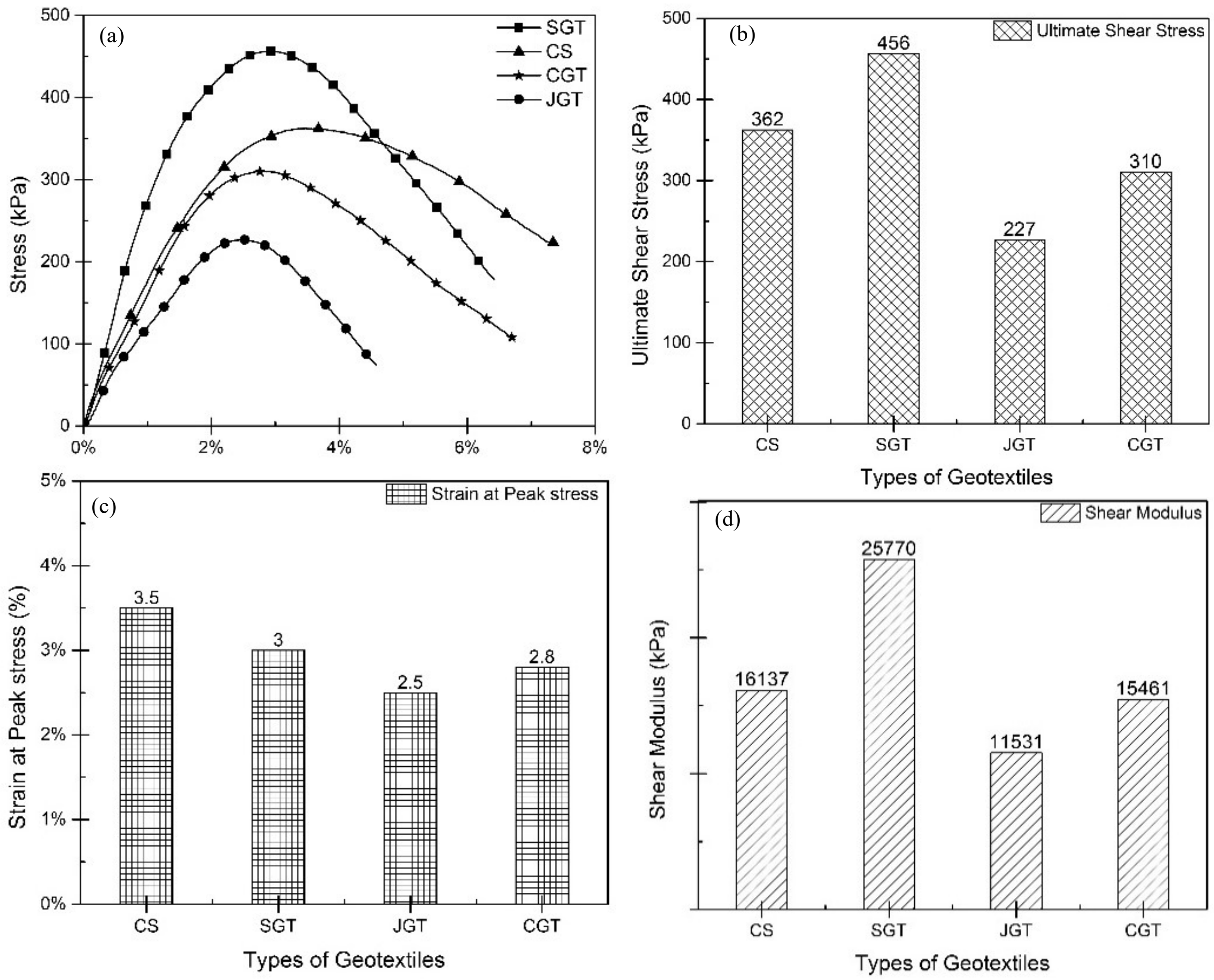

Figure 4. (a) Shear stress vs. shear strain (b) Variation of stiffness modulus for different types of geotextile (c) Comparison of ultimate shear stress of different type of geotextiles (d) Comparison of shear strain at peak stress with different geotextiles

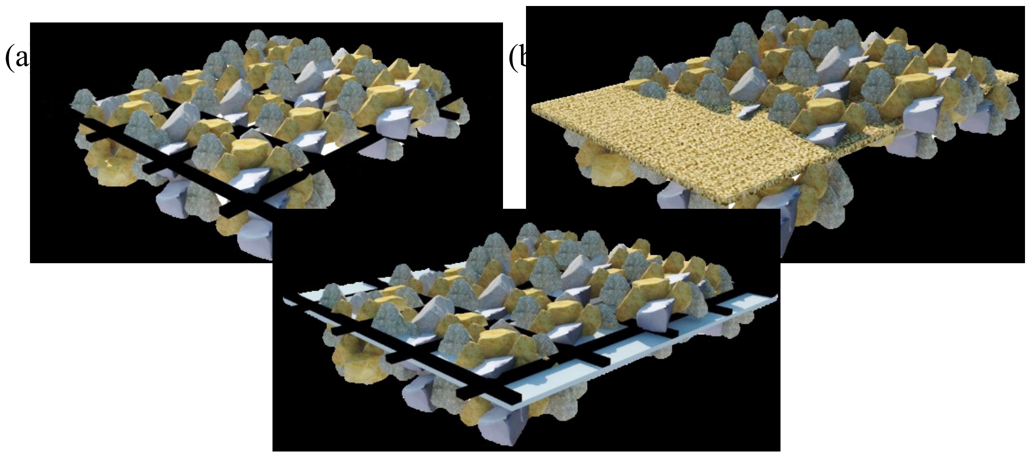

Figure 5. The mechanism of bonding (a) THB/THB (b) Adhesion/Adhesion (c) THB/Adhesion

6 CONCLUSIONS

The life span of the asphaltic concrete pavement can be increased by reducing the distresses with the introduction of the geosynthetic interlayers. Bond strength is one of the important factors that controls the improvement. The results of the tests conducted in different geosynthetic reinforced asphaltic concrete show that the introduction of the interlayer may lead to a reduction in the bond strength. The efficiency of bonding depends upon the compatibility of the geosynthetic and asphaltic concrete. The grid systems perform better than the fabrics and the former can mobilise the available tensile strength more effectively than the later.

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