



# An investigation on the interface bond strength of geosynthetic-reinforced asphalt concrete using Leutner shear test

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## HIGHLIGHTS

- Bond strength between asphalt and different types of geosynthetics was investigated.
- An equation is proposed to predict the interlayer bond strength of geosynthetic reinforced AC layers.
- Interlayer factor is introduced to understand the reduction or improvement in the bond strength.

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## ABSTRACT

The application of geosynthetics between the cracked asphalt pavement layer and new asphalt layers to retard reflective cracking has gained interest in the past decades. The performance of the interlayer system depends on its capacity to bond between the old and newly laid overlay layers. This study is taken up to evaluate the interlayer bond strength between the asphalt pavement layers that is reinforced with a geosynthetic product impregnated with asphalt as a tack coat material. Three geosynthetic reinforcement materials made of coir, jute, and glasgrid are used for the bond strength evaluation. The strength of the unreinforced (UR) interface samples are also evaluated for comparison. A trial pavement section was constructed to obtain the reinforced and unreinforced samples for the current research work. The main objective is to study the effects of these geosynthetic products at different temperatures on the interface shear strength behaviour of the reinforced asphaltic concrete layer. Leutner shear tests are employed for the estimation of the shear strength of these samples. The tests are performed at five different temperatures,  $-10$ ,  $0$ ,  $10$ ,  $20$  and  $30$  °C to understand the thermal effects on the composite interface in the pavement. The shear tests conducted at a strain rate of  $50$  mm/min shows an increase in strength by  $10$ – $15\%$  with change in temperature from  $-10$  to  $10$  °C followed by  $80\%$  reduction in strength up to  $30$  °C. It is observed that the shear strength of the geosynthetic-reinforced interface samples reduces by  $20$ – $50\%$  compared to the unreinforced samples depending upon the type of geosynthetic material. This paper proposes an equation to predict the Leutner shear strength at any temperature varying from  $-10$  to  $30$  at the studied range of strain rates knowing the peak shear modulus of unreinforced samples at  $-10$  °C and the reduction factor for the geosynthetic interlayer.

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## 1. Introduction

The maintenance and service costs of highways are increasing day by day due to the scarcity of raw materials. The demand for more improved, safer, and sustainable roads increases with the increase in the vehicle commuters yearly. The outrageous climatic conditions alongside an ever expanding traffic volumes lead to faster degradation of pavements. This faster degradation imposes

severe economic burden on highway agencies. Treating the distress without the knowledge of its failure mechanism will not cure the issue. Many factors influencing the deterioration phenomenon make the problem more complex. Installation of thin asphalt concrete (AC) overlays on top of the weakened roadways is the prevalent rehabilitation technique. However, there is a probability of rapid generation of cracks in these fresh overlay. Repeated traffic loading and/or thermal loading (day/night or seasonal changes) induces stress concentrations/movements over the cracks in the existing pavement. Consequently, a similar pattern of cracks in the underlying pavement propagates to the overlay resulting in the phenomenon of reflective cracking [41]. The formation of

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## Notations

Basic SI units are given in parenthesis

|                           |                                                                         |
|---------------------------|-------------------------------------------------------------------------|
| $v_1$                     | test speed 1 (mm/min)                                                   |
| $\tau_{max}$              | peak shear stress (MPa)                                                 |
| $\delta_{max}$            | displacement at peak shear stress (mm)                                  |
| $\sigma_r (\tau_{max})$   | allowable standard deviation for peak shear stress (MPa)                |
| $\sigma_r (\delta_{max})$ | allowable standard deviation for displacement at peak shear stress (mm) |
| $v_x$                     | test speed $x$ (mm/min)                                                 |
| $\tau_{v_1}$              | shear stress at test speed 1 (MPa)                                      |
| $\tau_{v_x}$              | shear stress at test speed $x$ (MPa)                                    |
| $A$                       | cross section area of Leutner shear sample (m)                          |
| $A_g$                     | area of geotextile specimen before test (m <sup>2</sup> )               |
| $D$                       | diameter of Leutner shear sample (mm)                                   |
| $d$                       | diameter of Leutner shear sample to be predicted (mm)                   |
| $F_{max}$                 | maximum shear force (kN)                                                |

|            |                                                          |
|------------|----------------------------------------------------------|
| $G$        | specific gravity of asphalt cement at 21 °C              |
| $K_{peak}$ | peak shear stiffness modulus (MPa/mm)                    |
| $N_i$      | interlayer factor                                        |
| $R_A$      | asphalt retention (ℓ/m <sup>2</sup> )                    |
| $T$        | temperature (°C)                                         |
| $W_g$      | weight of geotextile test specimen before saturation (g) |
| $W_{sat}$  | weight of saturated test specimens (g)                   |

## Abbreviations

|     |                      |
|-----|----------------------|
| AC  | asphalt concrete     |
| CGT | coir geotextile      |
| DS  | direct shear         |
| HMA | hot mix asphalt      |
| JGT | jute geotextile      |
| RE  | reinforced           |
| SGT | synthetic geotextile |
| UR  | unreinforced         |

reflective cracks break the continuity of the pavement section and reduces the long term durability. It further worsens the strength by allowing the water to seep through the cracks [30]. Many reinforcement techniques are employed to prevent or delay reflective cracking. They include laying a thin interlayer at the interface between the fresh and old layers, breaking up and sealing the existing pavement, rubberizing the existing concrete pavement, increasing the thickness of the AC overlay and improving the AC strength by adding additives [11,36,39,46,52]. Interlayer systems are the most efficient among the aforementioned techniques in controlling reflective cracking. The factors that influence the performance of interlayer system in a pavement section depends on the type and method of installation [9,41]. Geosynthetic interlayer system gained attention over other interlayers due to its ease in installation, less cost and less demand of skilled labours.

The durability of AC pavements not only depends on the strength and stiffness of its individual layers but is also significantly controlled by the bond strength between them. The application of a bituminous/emulsion tack coat, ensures an effective interlayer bond among the adjacent layers to act monolithically [40]. However, the presence of geosynthetic interlayer reinforcement may lead to debonding. Conversely, it could affect the pavement performance [11,14,51,57].

Field studies since the 1970s show a significant premature bond failure on fresh overlays reinforced with geosynthetics. Slippage and tearing failures were reported in regions where excessive shear force had been induced. These high horizontal load zones are common at the curves, intersection of roads, descending & ascending of gradients, and areas of recurring breaking [37]. Lack of bonding creates compaction difficulties and excessive movement under the rollers. The lack of bonding of geosynthetic to the bottom layer may result in sticking and moving along with the wheels of construction vehicles. The deficient bond between the HMA layers and geosynthetic interlayer may be credited with premature fatigue, top-down cracking, and surface delamination. Legitimate measurement of bond strength and its impact on the behaviour of AC layers ought to be considered for the improvement in pavement's life expectancy [10,16,24,57].

## 2. Factors influencing the bond strength

Longevity in adherence and interface shear resistance ensure to utilise the complete structural strength of geosynthetic reinforced AC pavement section [55]. The influencing parameters that can

control the bonding are the type of tack coat and its dosage, aggregate characteristics, surface texture & condition, type of geosynthetics, ambient temperature and the loading rate (vehicular speed or test speed). Understanding the influence of these variables on the bonding of AC layers can aid to keep off many pavement deterioration phenomena. While measuring the bond strength, the test control (load or displacement), the magnitude of the normal loads & the shearing rate governs the outcomes [25,42].

Delamination due to tack coat failures are related to the adhesion issues. Different additives have significant impact on the adhesion properties of tack coat and also have effect on self-healing capability of bond strength [53]. While interface issues, by and large, show the absence of embedment or friction between the layers depending on the state of aggregate as well as on the type of geosynthetic interlayer. The most popular tack coat material is emulsified asphalt or asphalt emulsion. The recommended type of tack for geosynthetic interlayer application is asphalt cement rather than emulsion. Debonding of AC layers during windy days and slower rate of bond strength development makes the field application of emulsion as secondary option for the geosynthetic interlayer systems [13]. The difference in the type of tack exhibits different interface shear strengths for similar interlayer systems [44,54].

The tack coat application rate during the installation of paving fabric depends on its retention capacity and is a vital property that affects the interface bonding. The absorption capacity of geosynthetic products depends on its type, weight, and the thickness of the material. The absorption capacity of a standard paving fabric is 0.91 ℓ/m<sup>2</sup> [3]. The use of tack coat above the ideal quantity could produce an interface slip plane. Bleeding of pavement can lead to difficulty in geotextile installation [13,26]. Apparently, less tack coat can allow the dust to accumulate at the interface to hinder adhesion [8,12,49].

Evaluation of the rate of tack coat application is a challenging task. It is also influenced by the texture and condition of the interface [56]. Collop et al. [18] found that the gradation of the upper and lower mixes brought critical influence on the interface shear strength. The presence of rounded and water-sensitive aggregates increases the danger of a weak interface bond [31,49]. Wet or dusty interfaces reduce the interface shear resistance. Therefore, it is recommended to use the tack coat material on a cleaned and dried paving surface before resurfacing to attain good bond strength with the overlay [56]. Studies carried out on textured and non-textured field samples reported that textured interfaces were three

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