Performance of geosynthetic-interlayered asphalt layers under cyclic loading

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ABSTRACT

The current study aims to evaluate the performance of geosynthetic-interlayered asphalt layers under cyclic loading conditions. In this regard, a control and geosynthetic-interlayered asphalt beam specimens were tested under a cyclic four-point bending test apparatus replicating an equivalent single axle contact pressure of 550kPa. Two different types of geosynthetic-interlayers viz., glass-grid composite (GGC) and bi-axial polyester grid (PET) were adopted. The cyclic four-point bending test results suggest that the geosynthetic-interlayers enhanced the performance life of asphalt layers by about 46-fold and 38-fold, respectively for GGC and PET interlayered specimens with respect to the control specimens. Geosynthetic-interlayers found to initiate delamination of the asphalt layers at the interface. To understand the delamination of the asphalt layers, the interface bond strength properties of control and geosynthetic-interlayered asphalt specimens were evaluated. Results revealed that there is a reduction in the interface bond strengths of about 36% and 16% in the GGC and PET interlayered specimens. Overall, it was found that along with the tensile properties bonding characteristics also important in enhancing the performance life of geosynthetic -interlayered asphalt layers.

Keywords: Cyclic loading; Asphalt layers; Geosynthetics; Performance life; Bond characteristics

1 INTRODUCTION AND BACKGROUND

The performance of a flexible pavement system is often affected by numerous detrimental factors such as traffic, temperature, moisture and other climatic and environmental conditions. Besides, to address their ill effects and enhance the performance life of pavement systems, geosynthetics have proven to be a sustainable and cost-effective solution. This is mainly due to the various type of functions they provide in the pavement system such as reinforcement, stress relieving, separation, and moisture barrier in the pavement system (Khodaii et al. 2009). An important application of geosynthetics is their use as an asphalt reinforcement. The asphalt reinforcements have proven to be an effective solution to an increase in resistance against permanent deformations, fatigue cracking and reflective cracking. In addition, the incorporation of asphalt reinforcements results in a reduction of asphalt layer thickness and an enhanced performance life of pavements. However, the mechanisms responsible for the enhanced performance is still unclear and an important subject of debate.

Researchers have adopted geogrids, and composites in the asphalt layers to study their effectiveness as an asphalt reinforcement. Komatsu et al. (1998) incorporated the geosynthetics in the asphalt layers to enhance their performance life. Similarly, Caltabiano (1990) performed a series of beam tests to study the performance of geogrids and fabric interlayers in restricting the fatigue crack growth in the asphalt layers and found an improvement in the performance life of asphalt layers reinforced with geosynthetic-interlayers.

Kumar and Saride (2017) reported that the inclusion of geosynthetics would retard the rate of modulus degradation in asphalt specimens. Ferrotti et al. (2012), Saride and Kumar (2017, 2019) performed repeated load tests on geosynthetic -reinforced asphalt layers and reported that the presence of geosynthetics retarded the vertical crack growth and redirected them in the horizontal direction.

With this understanding on the performance of geosynthetic-reinforced asphalt layers, the current study aims to better the understanding and evaluate the performance of geosynthetic-interlayered asphalt layers under cyclic loading conditions. In addition, due to the possibilities of delamination between the asphalt layers witnessed during the cyclic load test, the interface bond strength characteristics are also addressed.

2 MATERIALS AND METHODS

2.1 Asphalt

The asphalt concrete mix adopted in the current study is prepared in a mixing plant and transported to the laboratory for specimen preparation. The mix consists of a maximum, and nominal aggregates of 25mm and 13mm sizes, respectively and a PG 60/70 bitumen is adopted as a binder. Marshall Stability tests were performed as per ASTM D6927 (2009) to estimate the optimum binder content (OBC) and were determined to be 5.5% by weight of the aggregates. The maximum stability and flow value for the asphalt concrete mix with 5.5% OBC have found to be 14.25kN and 2.5mm, respectively. The binder tack coat adopted in the current study is a penetration grade (PG) 60/70 bitumen having a penetration value of 66. The tack coat has a specific gravity of 1.01 and a softening point of 52 ^{o}C. The viscosity of the binder is found to be 460cP at a temperature of 60 ^{o}C.

2.2 Geosynthetics

In the current study, the performance of geosynthetic-interlayered asphalt layers is studied under cyclic loading conditions. In this regard, a polyester grid (PET) and glass-grid composites (GGC) are adopted as interlayers.

The glass-grid composite interlayer consists of a fiberglass grid with an aperture of 28mm and continuous non-woven filaments mechanically bonded together as shown in Fig. 1. The bi-axial polyester grid is manufactured by knitting together a high molecular weight and high tenacity polyester yarns. The PET grids have a square aperture of 18 mm as shown in Fig. 1. The working mechanical and physical properties of PET and GGC interlayers are provided in Table 1.

2.3 Specimen Preparation

The specimen consists of two asphalt layers (old and new), a tack coat layer and a geosynthetic -interlayer at the interface of asphalt layers. The old layer was extruded during a highway rehabilitation program and used as a bottom layer in the two-layered asphalt specimen. A tack coat was applied on the surface of old layer at a residual rate of 0.25kg/cm^2 and allowed for emulsion breaking.

Table 1. Properties of geosynthetic-interlayers.

Property	Glass-grid composite (GGC)	Polyester grid (PET)
Ultimate tensile strength (kN/m)	28	40
Strain at ultimate tensile strength (%)	2	18
Thickness (mm)	3	2

A geosynthetic-interlayer was then placed and the hot mix asphalt layer was compacted. Further, the two-layered asphalt slabs were cut into beam specimens of 400mm length, 50mm width and 90mm depth for cyclic load tests.

Fig. 1. Glass-grid composite (GGC) and Polyester grid (PET)

2.4 Cyclic Load Test

A typical four point bending cyclic load test set-up was adopted to evaluate the performance of control and geosynthetic-interlayered asphalt layers. A typical haversine load pattern with 1Hz frequency was adopted to simulate an equivalent single axle contact pressure of 550kPa. The test setup and the load pattern were adopted based on ASTM D7460 (2010).

2.5 Interface Bond Strength Test

The interface bond characteristics between the asphalt layers in control and geosynthetic-interlayered specimens were evaluated under the shear mechanism in a large-scale interfacial shear box measuring 300mm x 300mm size according to ASTM D5321 (2017). The asphalt layers were sheared at a displacement rate of 1mm/min and is repeated for different normal stress values of 30kPa, 60kPa and 120kPa.

3 RESULTS AND DISCUSSION

The cyclic load tests performed in a load-controlled mode helps to understand the performance of control and geosynthetic-interlayered asphalt layers. This understanding would also help to investigate the influence of geosynthetic-interlayers as an anti-reflective cracking system in asphalt layers. The cyclic load test results of the control and geosynthetic-interlayered asphalt beam specimens are presented in Fig. 2, which depicts the variation of vertical deformation (VD) with the number of cycles (N). There is an increase in the vertical deformations with an increase in the load repetitions.

The increase in vertical deformation is very rapid in the case of control specimens. Whereas, at the same number of load repetitions, the geosynthetic -interlayered specimens have undergone lesser vertical deformations. For instance, at a VD of 1mm, the load repetitions resisted by control, GGC and PET specimens are almost same. Whereas, at a VD of about 5mm, the load repetitions are 150, 7000, and 1500 in control, GGC and PET specimens, respectively. These findings confirm that the presence of geosynthetic -interlayers between the asphalt layers has retarded the rate of vertical deformation. From Fig. 2, it is also important to note that the performance of glass-grid composites is better than that of PET grids. The variation in the performance of geosynthetic

-interlayered specimens could be attributed to their working tensile properties under cyclic loading conditions. The glass-grid composites are capable of inducing an ultimate tensile strength of about 28kN/m at a strain level of 2% and hence, it could resist vertical deformations. In contrary, the polyester grids could induce an ultimate tensile strength of 40kN/m only at a failure strain level of 18%. Hence, the rate of increase in vertical deformation is high in PET specimens. In addition, the performance improvement of GGC interlayers is very prominent initially until a VD of 6mm is reached due to the brittleness of the fiberglass. Hence, the glass-grids are highly vulnerable to installation damage and movement of heavy equipment during construction.

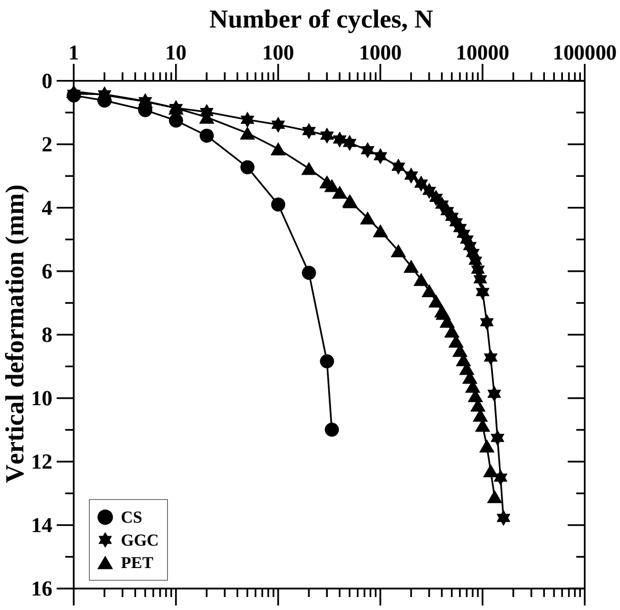

Fig. 2. Cyclic load test results

To further quantify the performance, a non-dimensional factor, improvement ratio (I_R) was introduced. The I_R is defined as a ratio of number of load repetitions sustained by a reinforced specimen to that sustained by a control specimen, at the same vertical deformation level.

Figure 3 presents the variation of improvement ratio (I_R) with vertical deformation for geosynthetic -interlayered specimens and it can be observed that the I_R increases with an increase in the VD. The I_R of GGC specimen increases rapidly from 20 (VD of 2mm) to 40 (VD of 4mm) and thereafter the improvement is gradual. Whereas, the I_R of PET specimen increase gradually up to a VD of 6mm. These observations suggest that the reinforcing mechanism in GGC specimen has initiated as quickly as a VD of 2mm is reached. Besides, the reinforcement and the membrane effects in the PET specimen would initiate gradually. Hence, it can be inferred that the material composition is also one of the important factors influence the performance life of asphalt layers.

An I_R as high as 46 is witnessed in GGC specimen against 10 in PET specimen, at a VD of 6mm. In addition to the improvements in the performance life of asphalt layers, the geosynthetic-interlayers have also resulted in the probable delamination of the asphalt layers. To address the delamination issues in the geosynthetic-interlayered asphalt specimens, the interface bond strength characteristics were studied.

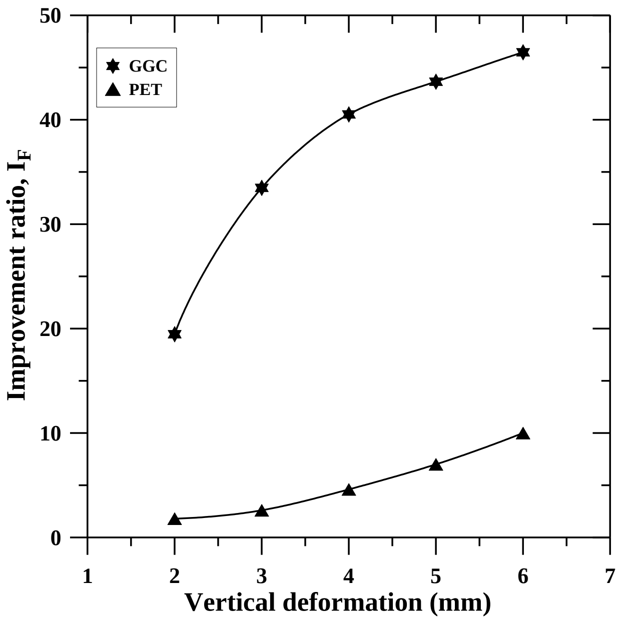

Fig. 3. Variation of improvement ratio with deformation

The peak and residual state interface bond strength envelopes obtained for different interface conditions were recorded, which depicts the variation of shear stress with the applied normal stress. The interface shear strength between the asphalt layers is high for the control interface condition, due to their cohesive nature against geosynthetic interlayer at the interface. Instead of cohesion, the bonding between the asphalt layers and the geosynthetic-interlayers was completely dependent on the adhesion property of the geosynthetic-interlayer. In addition, the apertures in grid would also facilitate an aggregate interlocking and create a through-hole bonding mechanism resulting in an enhanced interface bond strength. For this reason, the interface bond strength of PET specimens is superior than that of GGC specimens. In addition, the PET grids are completely coated with a polymer modified binder to enhance their bonding ability with the adjacent asphalt layers. The above conditions were witnessed by Ferrotti et al. (2012) and Saride and Kumar (2017).

Besides, a performance parameter was introduced to study the reduction in bond strength (RBS). The RBS can be defined as a ratio of difference between the interface bond strength of geosynthetic-interlayered and control specimen to the interface strength of control specimen. Figure 4 presents the variation of RBS with different geosynthetic-interlayers at peak and residual states. The GGC interlayered interface condition has the highest reduction in interface shear strength of about 38% and 36% at peak and residual states, respectively. The reason could be the absence of apertures in GGC interlayer, hence, no direct contact between the pavement layers. Though there is a reduction in interface shear strength of 17% in PET interlayered specimens, the interfacial properties are much superior than the GGC specimens. The polymer modified binder coated on the PET interlayers help to improve their interface bond characteristics. Also, the presence of apertures further helps to enhance the interface shear characteristics with the through hole bonding mechanism.

Overall, it can be witnessed that the inclusion of geosynthetic-interlayers between the asphalt layers have enhanced the performance life of asphalt layers by about 46-fold and 38-fold, respectively for GGC and PET interlayered specimens with respect to the control specimens. In addition, a reduction in the interface bond strengths of about 36% and 16% in the GGC and PET interlayered specimens with respect to the control specimens were also witnessed. Based on these observations, it can be incurred that along with the tensile properties of the geosynthetic-interlayers, their bonding characteristics also an important parameter affecting the performance life of the asphalt layers.

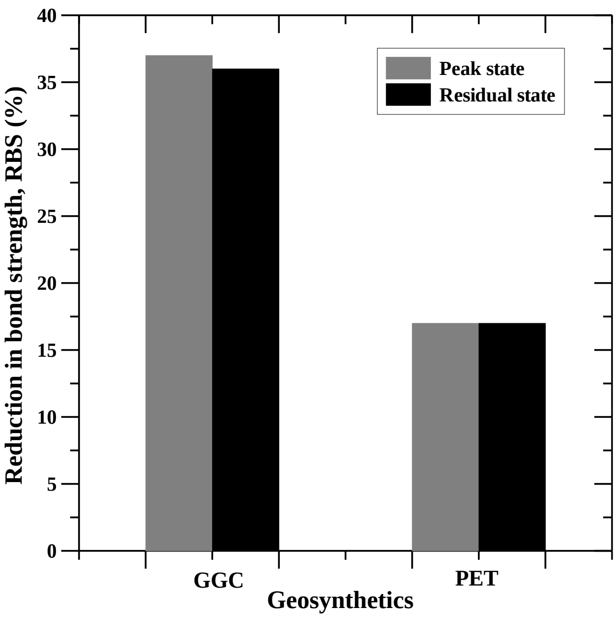

Fig. 4. Reduction in bond strengths

4 CONCLUSIONS

The performance of control and geosynthetic -interlayered asphalt layers were evaluated under cyclic loading conditions. The inclusion of geosynthetic -interlayers enhances the performance life of asphalt layers by 46-fold and 36-fold in GGC and PET specimens, respectively.

The geosynthetic-interlayers were also witnessed to accelerate the delamination of asphalt layers and a reduction in bond strength of 36% and 17% was witnessed in GGC and PET specimens, respectively.

The fatigue performance of GGC specimens are superior to that of PET specimens, whereas, the bond strength characteristics of PET specimens are superior to that of GGC specimens.

Overall, it can be incurred that along with the tensile properties of the geosynthetic-interlayers, their bonding characteristics, material composition and their physical properties are as well an important parameter affecting the performance life of asphalt layers.

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