Construction and Building Materials 162 (2018) 37–47

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

# Evaluation of cracking resistance potential of geosynthetic reinforced asphalt overlays using direct tensile strength test

V. Vinay Kumar, Sireesh Saride *

*Department of Civil Engineering, Indian Institute of Technology Hyderabad, Telangana 502285, India*

## HIGHLIGHTS

- The geosynthetic reinforcement improves the cracking resistance potential of asphalt overlays.
- The performance of specimens conditioned at lower temperatures are superior to that conditioned at higher temperatures.
- Digital imaging technic effectively provides the crack propagation patterns and the mobilized strains.
- The tensile strains in reinforced specimens are lower than the unreinforced specimens.
- The presence of interlayers could accelerate the delamination of pavement layers, if not addressed properly.

## ARTICLE INFO

*Article history:*
Received 2 August 2017
Received in revised form 16 November 2017
Accepted 29 November 2017

*Keywords:*
Asphalt overlays
Digital image correlation
Direct tensile strength test
Fracture energy
Geosynthetic interlayers

## ABSTRACT

The study aims at evaluation of cracking resistance potential of geosynthetic reinforced two-layered asphalt specimens under direct tensile strength test (DTT), conditioned at different temperatures (20 °C, 30 °C and 40 °C). Apart from determining the tensile stiffness of the asphalt specimens, the DTT is also capable of evaluating the cracking resistance potential through estimating the energy dissipated during cracking. The potential to resist reflection cracking may be improved with the inclusion of geosynthetic-interlayer. To understand the crack propagation patterns and to quantify the resulting strain fields, digital image correlation (DIC) technique was employed. The geosynthetic-interlayers used in the current study consist of a glass-grid composite (GGC), a bi-axial polyester grid coated with polymer modified binder (PE), a biaxial polypropylene grid (PP) and a woven geo-jute mat (GJ).

Results indicate that all the specimens conditioned at a temperature of 20 °C have shown better resistance to the cracking than the specimens conditioned at 40 °C. The specimens with GGC interlayer were effective in controlling the cracks as they could mobilize high tensile strength at a low strain value. The digital image analysis was instrumental in quantifying the tensile strains developed in the pavement layers. It was noticed that the control specimens have developed a tensile (vertical) strain of 6.85% at 20 °C against 2–4% in the specimens with geosynthetic-interlayers.

## 1. Introduction and background

Reflective cracking is the most common failure mode frequently encountered in the hot mix asphalt (HMA) overlays. The reflective cracking is a phenomenon defined as a process of propagation of discontinuities and cracks from an existing distressed pavement surface into the new overlay, due to the horizontal and vertical movements of the overlay [1]. The major factors causing the reflection cracking in overlays are the temperature/seasonal variations of the overlay and the traffic induced wheel loads [2,3]. The temperature variation causes a horizontal movement of the discontinuous bottom layer accumulating tensile stresses in the overlay just above the crack or discontinuity [4]. These accumulated tensile stresses initiate a crack in the overlay, which can be termed as mode-1 cracking [5]. Similarly, the traffic wheel loads applied on the overlay above a crack or a discontinuity, causing a vertical movement of the overlay, initiates the crack, which can be termed as mode-2 cracking [6]. Further, the crack will be propagated into and through the overlay due to the combined effect of mode-1 and mode-2 stresses.

Reflection cracks can cause an early deterioration of overlays and reduce the performance life of the overlays. The deterioration of overlays often results in impairment of the entire pavement

---

* Corresponding author at: 207, Academic Block A, Department of Civil Engineering, Indian Institute of Technology Hyderabad, Kandi, Sangareddy, Telangana 502285, India.

*E-mail address:* sireesh@iith.ac.in (S. Saride).

https://doi.org/10.1016/j.conbuildmat.2017.11.158

system due to frequent moisture ingression into the layers below through the cracks, leading to their strength deterioration, and accelerating the delamination of pavement layers [7,8]. Several researchers [9,10,7,11], through laboratory and field studies on reflection cracking in asphalt overlays, have suggested that the cracking is a complex phenomenon and does not have a complete solution. The researchers have suggested various possible techniques to resist the crack propagation into overlays, which include increasing the overlay thickness, employing polymer modified binders and cut and seal techniques. However, the most effective solution is to provide a geosynthetic interlayer at the interface of old and new layers, due to their stress absorbing and reinforcement functions in improving the performance of pavement system [11–13].

There are numerous test methods available to understand the crack-resisting potential of asphalt mixtures and also to study the effectiveness of anti-reflective cracking systems in pavements. Overlay tester is one such technique designed by Germann and Lytton [14] that replicates the opening and closing mechanism of cracks, which helps to understand the crack initiation and propagation stages. However, it may be difficult to examine the specimens with interlayers using this tester. Similarly, Livneh et al. [15] developed a wheel tracking test, which helps to evaluate the propagation of cracks due to the repeated wheel loads. Recently, Kumar and Saride [16] evaluated the crack initiation and propagation stages, in a geosynthetic-interlayered prismatic specimen using flexural fatigue tests with the aid of digital image correlation (DIC) technic. Similarly, Safavizadeh et al. [17] and Saride and Kumar [11] also evaluated the two-layered pre-cracked (notched) prismatic specimens using flexural fatigue tests and digital image correlation to study the influence of interlayers in restricting the crack propagation into the overlays. There are different techniques available to replicate the temperature and traffic effects on the reflection crack propagation, which include the Texas transport institute (TTI) overlay test [18], the École Nationale des Travaux Publics de l'État (ENTPE) test [19], the Belgian road research center (BRRC) test performed at Belgium Road Laboratory [20] and the combined-load fatigue test [13,21]. The TTI overlay test is an automated version of overlay tester, whereas, the ENTPE and BRRC tests are similar to TTI overlay test with a provision to study the effectiveness of interlayers against reflective cracking. Few test methods such as reflective cracking device and test from the Autun laboratory, can simultaneously apply a slow horizontal displacement and a cyclic vertical load to evaluate the reflective crack resistance of asphalt layers with interlayers [22,23]. Prieto et al. [24] developed a test named reflective wheel cracking, which reproduces simultaneously the effect of bending, tensile and shear stresses, whereas, the thermal effect is replicated by applying repeated load. Similarly, Moreno-Navarro and Rubio-Gamez [25] developed the UGR-FACT test to study the effect of tensile and shear stresses caused due to the traffic loads by simulating them using a single frequency. All these methods have shown mixed results in terms of understanding the reflection cracking phenomenon. The major drawback of these techniques can be attributed to their sophisticated test setup and the testing procedures. However, there are another group of simple tests like semi-circular bending (SCB) test [26], disc-shaped compacted test (DCT) [27] and Fenix test [8,28–30] performed directly on the cylindrical asphalt specimens to evaluate the cracking resistance potential of asphalt mixtures effectively with in a short duration of time. Among these tests, Fenix test is the simpler one, which belongs to the category of Semi-Circular Single-Edge-Notched Tension (SENT) tests [28]. It was developed by the Road Research Laboratory of the Technical University of Catalonia to evaluate cracking resistance potential of asphalt concrete mixtures by calculation of the dissipated energy during the cracking process.

From the literature studies, it can be summarized that there are various test techniques available to study the reflective cracking phenomenon and to quantify the dissipation of energy during the cracking process. However, no information is available on the geosynthetic interlayers and their influence on resisting the reflection cracks based on the proposed equipment. Hence, in this study, an attempt has been made to study the cracking resistance potential of two-layered asphalt specimens with old pavement as the bottom layer and an overlay with and without geosynthetic interlayers placed at the interface. The tests were performed on asphalt specimens conditioned at different temperatures of 20 °C, 30 °C and 40 °C to study the influence of temperature. The digital image correlation (DIC) technique was employed to understand the crack propagation behavior and their corresponding strain fields in the test specimens.

## 2. Materials and specimen preparation

The different materials used in the preparation of two-layered asphalt specimens with and without geosynthetic interlayers are hot mix asphalt concrete, binder tack coat, and the geosynthetic-interlayers. The properties of these materials are discussed in the following sections.

### *2.1. Asphalt concrete and tack coat*

The asphalt concrete mix used as an overlay in the current study consists of a nominal aggregate of 13 mm size, a penetration grade (PG) 60/70 binder with an optimum binder content of 5.5% by weight of aggregates. The hot mix was prepared in the bitumen mix plant and transported to the laboratory for the experimental purpose. The asphalt concrete was tested under Marshall stability testing equipment as per ASTM D6927 [31]. The strength and flow values were found to be 14.25kN and 2.5 mm, respectively. The binder tack coat has a penetration value of 66 and hence, it is classified as PG 60/70 bitumen. The ductility and the softening point of the binder are 100 + cm and 52 °C, respectively. The viscosity of the binder at a temperature of 60 °C is found to be 400 centipoise, as determined by Brookfield viscometer. The binder has a flash point and fire point of 340 °C and 360 °C, respectively.

### *2.2. Geosynthetic interlayers*

In the current study, four types of geosynthetic-interlayers were tested to study the effectiveness of different types of geosynthetic-interlayers with varying ultimate stiffness and strains in improving the crack resistance potential of asphalt overlays. The brief description of geosynthetic-interlayers used is provided in the following sections.

#### *2.2.1. Glass grid composite (GGC)*

The composite interlayer comprises of a knitted glass filaments and continuous non-woven filaments bonded together mechanically to form a grid having a square aperture size of 28 mm and a composite of 3 mm thickness as shown in Fig. 1a. The ultimate tensile strength of the GGC interlayer is 28 kN/m (machine direction) at 2% strain and 25 kN/m (cross-machine direction) at 1.75% strain.

#### *2.2.2. Polyester grid coated with polymer modified binder (PE)*

A high density and high tenacity polyester yarns are knitted together to form a grid with a square aperture of 18 mm and a thickness of about 2 mm as shown in Fig. 1b. The PE interlayers are completely coated with polymer modified binder to enhance the bonding between the interlayer and adjacent layers. The PE