

Design Aspects and Installation of Geosynthetics

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ABSTRACT: Geo-synthetics are being increasingly used at the asphalt overlay base level to enhance the overall performance of the paved roadways. This paper describes the present understanding of the functions of such paving geo-synthetics, and their design aspects and installation procedures based on the available experiences. The suitability of the geo-synthetics as a paving material has also been discussed. Some special cares may be required by the practicing engineers for effective utilization of paving geo-synthetics. This important aspect has also been discussed in this paper.

KEYWORDS: Pavement deterioration, geo-synthetics, pavement reinforcement, cracks, rutting, durability.¹

I.INTRODUCTION

Pavements are civil engineering structures used for the purpose of operating wheeled vehicles safely and economically. Their basic design methods and construction techniques have undergone some changes, but the development of geo-synthetics in the past three decades has provided the strategies for enhancing the overall performance of the paved roadways. Various levels of government, in most of the countries, devote unprecedented time and resources to roadway construction, maintenance and repair. Efforts are also being made to apply newfound technology to old pavement problems. Cracks in the pavement surface cause numerous problems, including (GFR, 2003):

- Riding discomfort for the users
- Reduction of safety
- Infiltration of water and subsequent reduction of the bearing capacity of the sub-grade
- Pumping of soil particles through the crack
- Progressive degradation of the road structure in the vicinity of the cracks due to stress concentrations.

The construction of asphalt overlays is the most common way to renovate both flexible and rigid pavements. An asphalt overlay is at least 25 mm thick and it is placed on top of the distressed pavement. Overlays are economically practical, convenient, and effective. The cracks under the overlay rapidly propagate through to the new surface. This phenomenon is called *reflective cracking*, which is major drawback of asphalt overlays. Because asphalt overlays are otherwise an excellent option, research and development has focused on preventing reflective cracking. The expansion and contraction of the overlays and upper asphalt layers can lead to tension within the surfacing which can also lead to surface cracking. The stresses are at their maximum at the pavement surface where the temperature variation is the greatest. In this case, the cracks are initiated at the surface and propagate downwards. It should be noted that the term 'reflective cracking' is often used to describe all these types of cracking. Methods for controlling reflective cracking and extending the life of overlays consider the importance and effectiveness of overlay thickness and proper asphalt mixture specification. Limits on the thickness of an overlay are the expense of asphalt and the increase in the height of

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road structure. Asphalt additives do not stop reflective cracking, but do tend to slow down the development of cracks and convert a large crack in the old pavement into a multiple small cracks in the overlay. Mixing glass fibres, metal fibres, or polymers in asphalt prior to paving creates modified or optimized asphalt, which is not always specified because it is much more expensive than unimproved asphalt and the relationship between the investment and the improvement has not been established.

The benefits of the geo-synthetic interlayer (*paving geo-synthetic interlayer*) include the following:

- Waterproofing the pavement;
- Delaying the appearance of reflective cracks;
- Lengthening the useful life of the overlay;
- Added resistance to fatigue cracking; and
- Saving up to 50 mm of overlay thickness;

II.FUNCTIONS OF PAVING GEOSYNTHETICS

A geo-synthetic layer, especially a geo-textile layer, is used beneath asphalt overlays, ranging in thickness from 25 to 100 mm, of asphalt concrete (AC) and Portland cement concrete (PCC) paved roads. The geo-textile layer is generally combined with asphalt sealant, or tack coat to form a membrane interlayer system known as a *paving fabric interlayer*. Fig. 1 shows the layer arrangement in paved roads with a paving fabric interlayer. When properly installed, a geo-textile layer beneath the asphalt overlay mainly function as (Holtz *et al.*, 1997):

- Fluid barrier (if impregnated with bitumen, that is, asphalt cement), protecting the underlying layers from degradation due to infiltration of road-surface moisture; and
- Cushion, that is, stress-relieving layer for the overlays, retarding and controlling some common types of cracking, including reflective cracking.

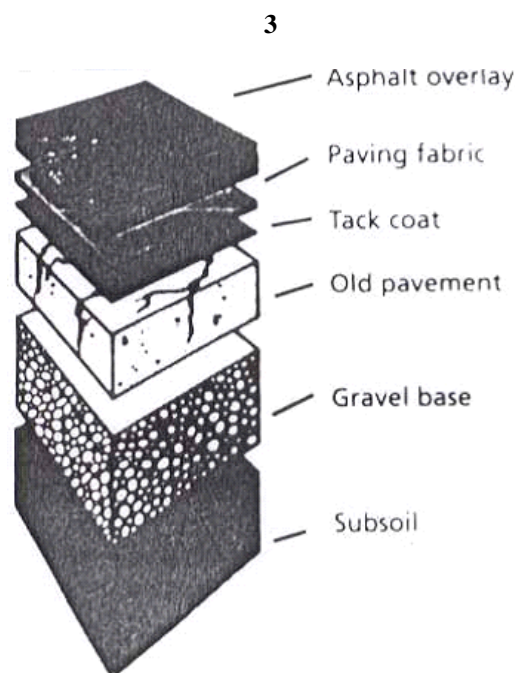


Figure1.2.1. Typical cross-section of a paved road with a paving fabric interlayer

A paving fabric, in general, is not used to replace any structural deficiencies in the existing pavement. However, the above functions combine to extend the service life of overlays and the roadways with reduced maintenance cost and

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increased pavement serviceability. The pavements typically allow 30 – 60 % of precipitation to infiltrate and weaken the road structure. The fluid barrier function of the bitumen impregnated geo-textile may be of considerable benefit if the sub-grade strength is highly moisture sensitive. In fact, excess moisture in the sub-grade is the primary cause of premature road failures. Heavy vehicles can cause extensive damage to roads, especially when the soil sub-grade is wet and weakened. The pore water pressure can also force the soil fines into the voids in the sub-base/base, weakening them if a geo-textile is not used as a separator/filter. Therefore, efforts should be made to keep the soil sub-grade at fairly constant and low moisture content by stopping moisture infiltration into the pavement and providing proper pavement drainage. Pavements with paving fabric inter layers also experience much less internal crack developing stress than those without. This is why fatigue life of a pavement with a paving fabric interlayer is many times that of a pavement without, as shown in Fig. 2. A stress-relieving interlayer also waterproofs the pavement, so when cracking does occur in the overlay, water cannot worsen the situation.

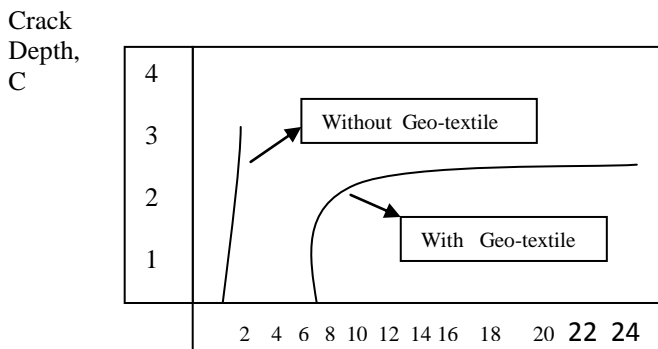


Figure 1.2.2. Fatigue response of asphalt overlay

Geo-grids and geo-grid-geo-textile composites are also commercially available for overlay applications to function as *reinforcement interlayer* for holding the crack, if any, together, and dissipating the crack propagation stress along its length. It has been reported that the reinforcement geo-grid, as shown in Fig. 3, if used beneath the overlay, can reduce the crack propagation by a factor of up to 10 when traffic induced fatigue is the failure mechanism (Terram Ltd., UK). The study conducted by Ling and Liu (2001) shows that the geo-grid reinforcement increases the stiffness and bearing capacity of the asphalt concrete pavement. Under dynamic loading, the life of the asphalt concrete layer is prolonged in the presence of geo-synthetic reinforcement. The stiffness of the geo-grid and its interlocking with the asphalt concrete contribute to the restraining effect.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 3, March 2015

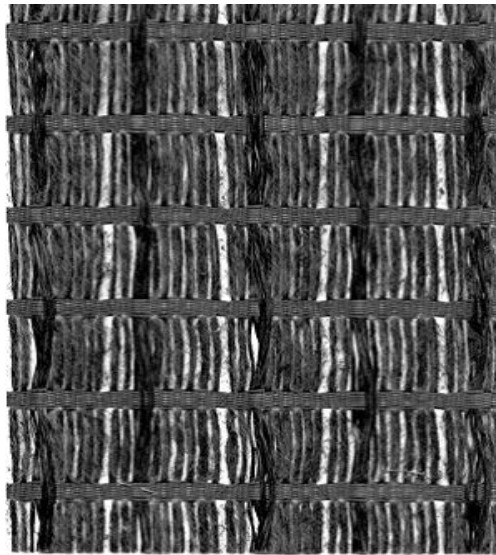


Figure 1.2.3. Asphalt reinforcement geo-grid

III.SUITABILITY OF GEOSYNTHETICS AS A PAVING INTERLAYER

Geo-textiles generally have performed best when used for load-related fatigue distress, e.g. closely spaced alligator cracks. Fatigue cracks, mainly caused by too many flexures of the pavement system, should be less than 3 mm wide for best results. Geo-textiles used as a paving fabric interlayer to retard thermally induced fatigue cracking, caused by actual expansion and contraction of underlying layers, mostly within the overlay, have, in general, been found to be ineffective. For getting the best results on existing cracked pavement, the geo-textile layer is laid over the entire pavement surface or over the crack, spanning it by 15 to 60 cm on each side, after placement of an asphalt levelling course followed by an application of tack coat, and then asphalt overlay is placed above (Figure 1). This construction technique is adopted keeping in view that much of the deterioration that occurs in overlays is the result of unrepaired distress in the existing pavement prior to the overlay. The deterioration may range from simple alligator cracking of the pavement surface to significant potholes caused by failure of the underlying sub-grade. It is important to note that an overlay system as well as a paving fabric interlayer will fail if the existing deficiencies in the existing pavements are not corrected prior to the placement of overlay and/or paving fabric. The selected paving grade geo-synthetic must have the ability to absorb and retain the asphalt tack coat,

sprayed on the surface of the old pavement, to effectively form a permanent fluid barrier and cushion layer. The most common paving grade geo-synthetics are lightweight needle punched nonwoven geo-textiles, with a mass per unit area of 120 to 200 g/m². Woven geo-textiles are ineffective paving fabrics because they have no interior plane to hold asphalt tack coat and so do not form an impermeable membrane. They also do not perform well as stress-relieving layer to help reduce cracking. Tests should be performed to determine the bitumen retention of paving fabrics for their effective application. In the most commonly used test procedure, after taking weights individually, test specimens are submerged in the bitumen at a specified temperature, generally 135⁰C for 30 min. Specimens are then hung to drain in the oven at 135⁰C for 30 min from one end and also 30 min from the other end to obtain a uniform saturation of the fabric.

Upon completion of specimen submersion in bitumen, and draining, the individual specimens are weighed and asphalt/bitumen retention, RB, is calculated as follows (ASTM D 6140-00):

$$R_B = \frac{W_{sat} - W_f}{\gamma_B \cdot A_f} \dots\dots\dots(1)$$

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 3, March 2015

where, W_{sat} is the weight of saturated test specimen in kg; W_f the weight of paving fabric in kg; A_f the area of fabric test specimen in m^2 ; and γ_B is the unit weight at $21^\circ C$ in kg/l . The average bitumen retention of specimens are calculated and reported is l/m^2 . Paving fabrics pre-coated with modified bitumen are also available commercially in the form of strips. These products perform the same functions of waterproofing and stress relief as the field impregnated paving fabrics; however, they are more expensive. Their applications are economical if only limited areas of the pavement need a paving fabric interlayer system. For waterproofing and covering the potholes, the pre-coated paving fabrics are good.

IV.DESIGN ASPECTS

The fluid barrier function of geo-synthetic should be achieved in field application, keeping the fact in view that the water (coming from rain, surface drainage or irrigation near pavements), if allowed to infiltrate into the base and sub-grade, can cause pavement deterioration by:

- Softening the soil sub-grade.
- Mobilizing the soil sub-grade into the road base stone, especially if a separation/filtration geo-synthetic is not used at the road base and sub-grade interface.
- Hydraulically breaking down the base structures, including stripping bitumen-treated bases and breaking down chemically stabilized bases.
- Freeze/thaw cycles.

The selected paving grade geo-synthetic should meet the physical requirements described in Table 1. Prior to laying paving fabric, the tack coat should be applied uniformly to the prepared dry pavement surface at the rate governed by the following equation (IRC: SP: 59-2002):

$$Q_d = 0.36 + Q_s + Q_c \dots\dots\dots (2)$$

Property	ASTM methods	test	Units	Req
Grab strength	D 4632		N	450
Ultimate elongation	D 4632		%	>50
Mass per unit area	D 5261		g/m^2	140
Asphalt retention	D 6140		l/m^2	Notes 2
Melting point	D 276		$^\circ C$	150

Note 1 – All numeric values represent MARV in the weaker principal direction.
Note 2 - Asphalt required to saturate paving fabric only. Asphalt retention must be provided in manufacturer certification. Value does not indicate the asphalt application rate required for construction.
Note 3 – Product asphalt retention property must meet the MARV value provided by the manufacturer certification.

where, Q_d is the design tack coat quantity (kg/m^2); Q_s is the saturation content of the geo-textile being used (kg/m^2) to be provided by the manufacturer; and Q_c is the correction based on tack coat demand of the existing pavement surface (kg/m^2).

V.INSTALLATION OF PAVING GEOSYNTHETCS

A paving fabric interlayer system is looked upon as an economical tool, which effectively solves general pavement distress problems. It is easy to install and readily complements any paving operation. The ideal time to place a paving fabric interlayer system is in the very early stages of hairline cracking in a pavement. It is also appropriate in new pavement construction to provide a waterproof pavement from day one.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 3, March 2015

The installation of a paving fabric generally follows the same pattern wherever it is used. There are four basic steps in the proper installation of an overlay system with a geo-synthetic interlayer. Surface preparation is followed by the application of tack coat, installation of the geo-synthetic, and finally the placement of the overlay (Marienfeld and Smiley, 1994; IRC: SP: 59 – 2002; GFR, 2003). These steps along with general guidelines are described below, incorporating the experiences of the authors as a consultant.

Step 1: Surface Preparation

The site surface is prepared by removing loose material and sharp/angular protrusions, and sealing cracks, as necessary. The prepared surface should be levelled, dry, and free of dirt, oil and loose materials. Cracks, 3mm wide or greater, should be cleaned with pressurized air or brooms and filled with a liquid asphalt crack sealant. This will prevent the tack coat from entering the cracks and reducing available tack for saturation of the fabric. Very large cracks should be filled with a hot or cold asphalt mix. Commercial crack filler can also be used. Cracks should be level with the pavement surface and not overfilled. If the quality of the existing pavement is poor, a levelling course of asphalt concrete is placed over it prior to the placement of the paving fabric interlayer system. On existing cement concrete pavements, a layer of asphalt concrete should be provided before laying the fabric.

Step 2: Tack Coat Application

Proper application of tack coat is crucial; mistakes can lead to early failure of the overlay. Straight paving-grade bitumen is the best and the most economical choice for the paving fabric tack coat. Cutbacks and emulsions which contain solvents should not be used for tack coat; if they are used, they must be applied at a higher rate and allowed to cure completely. Minimum air and pavement temperature should be at least 10⁰C or more for placement of tack coat (IRC: SP: 59 – 2002). The temperature of tack coat should be sufficiently high to permit a uniform spray pattern. It should be spread at between 140⁰C and 160⁰C, to permit uniform spray and to prevent damage to paving fabric. The target width of tack coat application should be equal to the paving fabric width plus 150 mm. Tack coat should be restricted to the area of immediate fabric lay-down. Besides proper quantity, uniformity of the sprayed asphalt cement (bitumen) tack coat is of great importance. Application of hot bitumen should be done preferably by means of a calibrated distributor spray bar for better uniformity. Hand spraying and brush application may be used in locations of fabric overlap. When hand spraying, close attention must be paid to spraying a uniform tack coat.

Step 3: Geo-synthetic Placement

The paving fabric is placed prior to the tack coat cooling and losing tackiness. The paving fabric is placed onto the tack coat with its fuzzy side down leaving the smooth side up using a mechanical or manual lay-down equipment capable of providing a smooth installation without wrinkling or folding. Overlaps and all overlapped wrinkles for fabric and grid composites should have an additional tack coat placed. Tack must be sufficient to saturate the two layers and make a bond. If not done correctly, a slip plane may exist at each overlapped joint, resulting in a possible crack of the asphalt from the fabric. Overlaps should be no more than 150 mm on longitudinal and transverse joints. This is different for grids, and each manufacturer has its own recommendations for overlaps. Excess tack coat, which bleeds through the paving fabric, is removed by spreading hot mix, or sand should be spread over it. Any traffic on the geo-synthetic should be carefully controlled. Sharp turning and braking may damage the fabric. For safety reasons, only construction traffic should be allowed on the installed paving fabric.

Step 4: Overlay Placement

All areas with paving geo-synthetic placed are paved on the same day. In fact, asphalt concrete overlay construction should be done immediately after the placement of paving geo--synthetic. Asphalt can be placed by any conventional means. Compaction should take place immediately after dumping in order to ensure that the different layers are bonded together. Thickness of the asphalt overlay should not be less than 40 mm. Compacting the asphalt concrete immediately after placement helps to concentrate the heat and supply pressure to start the process of the bitumen moving up into and through the fabric. This is very important when using a thinner overlay as it cools more rapidly.

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 4, Issue 3, March 2015

VI. CONCLUSIONS

When properly installed, the paving geo-synthetic interlayer at the overlay base level of the paved roadway keeps the water out of the road base for maximum pavement life. For effective utilization of paving geo-synthetics, particularly geo-textiles, the construction of the tack coat layer in the paving fabric system must be done properly in terms of quantity as well as surface distribution. The thickness of the asphalt overlay should not be less than 40 mm. It should be kept in mind that the major purpose of introducing a paving geo-synthetic is generally to enhance the performance of the pavement, not to reduce the thickness of the overlay.

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