Functions and Installation of Paving Geosynthetics

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ABSTRACT: Geosynthetics 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 geosynthetics, and their design aspects and installation procedures based on the available experiences. The suitability of the geosynthetics as a paving material has also been discussed. Some special cares may be required by the practising engineers for effective utilization of paving geosynthetics. This important aspect has also been discussed in this paper.

1 INTRODUCTION

Pavements are civil engineering structures used for the purpose of operating wheeled vehicles safely and economically. Paved roadways that include the carriageways and the shoulders have been constructed for more than a century. Their basic design methods and construction techniques have undergone some changes, but the development of geosynthetics 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.

Commonly a paved road becomes a candidate for maintenance when its surface shows significant cracks and potholes. 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 subgrade
- 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. Most overlays are done predominantly to provide a waterproofing and pavement crack retarding treatment. A minimum thickness of the asphalt concrete overlay may be required to provide an additional support to a structurally deficient pavement. 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.

Reflective cracks in an asphalt overlay are basically a continuation of the discontinuities in the underlying damaged pavement. When an overlay is placed over a crack, the crack grows up to the new surface. The causes of crack formation and enlargement in asphalt overlays are numerous but the mechanisms involved may be categorized as: *traffic induced*, *thermally induced* and *surface initiated* (Ingold, 1994). Surface cracking in overlays can occur from traffic induced fatigue as a result of repeated bending condition in the pavement structure or shear effect causing the pavement on one side of a crack (in the old layer) to move vertically relative to the other side of the crack during the traffic movement. High axle loads or increased traffic can further increase the stresses and strains in the pavement that lead to surface cracking. In the case of an asphalt overlay, on top of a concrete pavement, cracks may be reflected to the overlay as the concrete slabs expand and contract under varying temperatures. 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. Asphalt mixes have been improved and even modified by adding a variety of materials. In the past a number of potential solutions have also been evaluated including unbound granular base "cushion courses" and wire mesh reinforcement. All have found to be either marginally effective or extremely costly.

The most basic way to slow down the reflective cracking is to increase the overlay thickness. In general, as the overlay thickness increases, its resistance to reflective cracks increases. Limits on the thickness of an overlay are the expense of asphalt and the increase in the height of 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 crack resistance of the overlay can also be enhanced via interlayer systems. An interlayer is a layer between the old pavement and new overlay, or within the new overlay to create an overlay system. The benefits of the geosynthetic interlayer (a.k.a *paving geosynthetic 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;

An effort has been made in the limited length of this single paper to include the present understanding of the functions of paving geosynthetics, design aspects and their installation procedures, based on the available experiences, for the benefits of the users of paving geosynthetics.

2 FUNCTIONS OF PAVING GEOSYNTHETICS

A geosynthetic layer, especially a geotextile 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 geotextile 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 geotextile 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

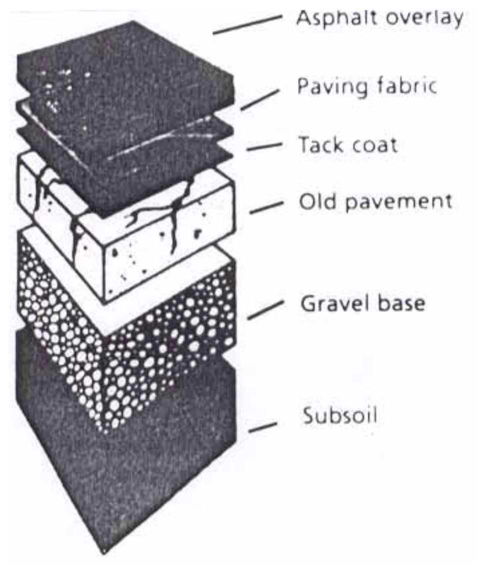

Figure 1. Typical cross-section of a paved road with a paving fabric interlayer (after Barazone, 2000)

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 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 geotextile may be of considerable benefit if the subgrade strength is highly moisture sensitive. In fact, excess moisture in the subgrade is the primary cause of premature road failures. Heavy vehicles can cause extensive damage to roads, especially when the soil subgrade is wet and weakened. The pore water pressure can also force the soil fines into the voids in the subbase/base, weakening them if a geotextile is not used as a separator/filter. Therefore, efforts should be made to keep the soil subgrade at fairly constant and low moisture content by stopping moisture infiltration into the pavement and providing proper pavement drainage.

A stress-relieving interlayer retards the development of reflective cracks in the overlay by absorbing the stresses induced by underlying cracking in the old pavement. The stress is absorbed by allowing slight movements within the paving fabric interlayer inside the pavement without distressing the asphalt concrete overlay significantly. In fact, the addition of a stress-relieving interlayer reduces the shear stiffness between the old pavement and the new overlay, creating a buffer zone (or break layer) that gives the overlay a degree of independence from movements in the old pavement. Pavements with paving fabric interlayers 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.

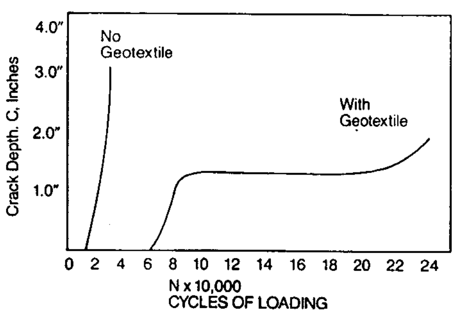

Figure 2. Fatigue response of asphalt overlay (after IFAI, 1992)

Geogrids and geogrid-geotextile 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 geogrid, 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 geogrid 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 geosynthetic reinforcement. The stiffness of the geogrid and its interlocking with the asphalt concrete contribute to the restraining effect.

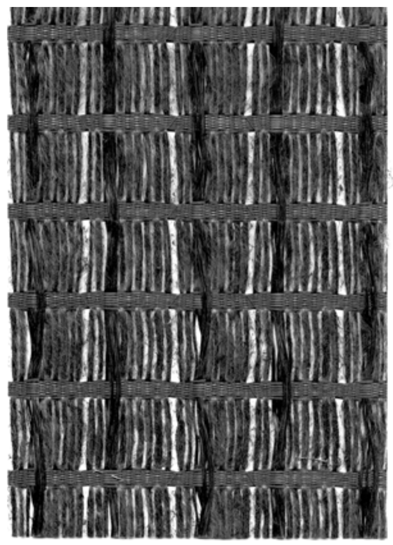

Figure 3. Asphalt reinforcement geogrid

3 SUITABILITY OF GEOSYNTHETICS AS A PAVING INTERLAYER

Geotextiles 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. Geotextiles 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 geotextile 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 leveling 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 selection of a geosynthetic for use in asphalt overlays is complicated by the variable condition of the existing roadway systems. The deterioration may range from simple alligator cracking of the pavement surface to significant potholes caused by failure of the underlying subgrade. 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 geosynthetic 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 geosynthetics are lightweight needlepunched nonwoven geotextiles, with a mass per unit area of 120 to 200 g/m^2. Woven geotextiles 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 135 ^{0}C for 30 min. Specimens are then hung to drain in the oven at 135 ^{0}C 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, R_B, is calculated as follows (ASTM D 6140-00):

$$R_B = \frac{W_{sat} - W_f}{\gamma_B A_f} \tag{1}$$

where, W_{sat} is the weight of saturated test specimen in kg; W_f is the weight of paving fabric in kg; A_f is the area of fabric test specimen in m^2; and γ_B is the unit weight at 21 ^{0}C in kg/l. The average bitumen retention of specimens are calculated and reported in l/m^2.

Paving fabrics precoated 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 precoated paving fabrics are good.

Heavy-duty composites of geosynthetic and bituminous membrane are commercially used, especially over cracks and joints of Portland cement concrete pavements that are overlaid with asphalt concrete.

4 DESIGN ASPECTS

The fluid barrier function of geosynthetic 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 subgrade, can cause pavement deterioration by:

- Softening the soil subgrade
- Mobilizing the soil subgrade into the road base stone, especially if a separation/filtration geosynthetic is not used at the road base and subgrade 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 geosynthetic 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):

$$Q_d = 0.36 + Q_s + Q_c \tag{2}$$

where, Q_d is the design tack coat quantity (kg/m^2); Q_s is the saturation content of the geotextile 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).

Table 1. AASHTO M288– 00 paving fabric geotextile property requirements (see Note 1)

Property	ASTM test methods	Units	Requirements
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 and 3
Melting point	D 276	^0C	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.

The quantity of tack coat is critical to the final membrane system. Too much tack coat will leave an excess between the fabric and the new overlay resulting in a potential sliding failure surface and potential bleeding problems, while too little will fail to complete the bond and create the impermeable membrane. In fact, the misapplication of the tack coat can make the difference between paving fabric installation success and failure. The asphalt tack coat forms a low permeability layer in the fabric and bonds the system to the existing pavement and overlay. The fabric allows slight movement of the system, while holding the tack-coat layer in place and maintaining its integrity.

The actual quantity of tack coat will depend on the relative porosity of the old pavement and the amount of bitumen sealant required to saturate the paving fabric being used. The quantity of sealant required by the existing pavement is a critical consideration. The saturation content of the fabric depends primarily on its thickness and porosity; that is its mass per unit area. It is to be noted that the more the mass per unit area of the geotextile, the more tack coat is required to saturate the fabric. For typical paving fabrics in the 120-135 g/m^2 mass per unit area range, most manufacturers recommend fabric-bitumen absorption of about 900g/m^2, or application rates of about 1125 g/m^2. For the full waterproofing and stress-relieving benefits, the paving fabric must absorb at least 725 g/m^2. The remaining part of the applied bitumen helps in bonding the system with the existing pavement and the overlay. Additional tack coat may be required between the overlap to satisfy saturation requirements of the fabric.

A review of projects with unsatisfactory paving fabric system performance shows the importance of the tack coat to the whole system. Evidence from records of 65 projects, which took place over a 16-year period, indicates that the tack coat application was too light (less than 725 g/m^2) in an overwhelmingly high percentage of failure cases. This is shown graphically in Fig. 4. In the laboratory tests it has been observed that the waterproofing benefit of paving fabric is negligible until the fabric absorbs at least 725 g/m^2 of tack coat. Inadequate tack coat may result in rutting, shoving or, occasionally, complete delamination of the overlay. It has been found that the structural problems such as overlay slippage and delamination begins to occur where the tack coat quantity absorbed by the fabric is less than about 450 g/m^2.

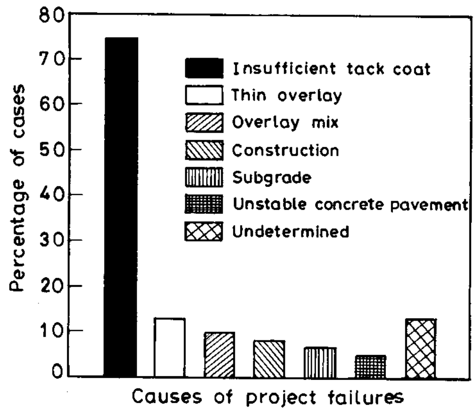

Figure 4. Causes in 65 project failures investigated in the United States between 1982-1997 (after Baker, 1998).

In addition to low application amounts of tack coat, there can be another set of conditions that may result in a low tack amount in paving fabric. Inadequate rolling or, low overlay temperatures may create conditions in which the tack may not be taken up by the fabric. In fact, overlays less than 40 mm thick are seldom recommended with paving fabric, in part, because of their rapid heat loss.

The controlled studies have shown that an overlay thickness designed to retard reflective cracking can be reduced by up to 30 mm for equal performance, plus the additional waterproofing advantage if a paving fabric interlayer is included in the system (Marienfeld and Smiley, 1994). Equations are available that enable the designer of a geosynthetic-reinforced overlay to design an appropriate overlay thickness and corresponding geosynthetic. The major drawback to currently available design techniques is that they allow us to address the potential failure modes (traffic load induced, thermally induced, and surface initiated) separately but not together. In reality, all three modes occur together – a condition that can only be evaluated using sophisticated finite element modeling (Sprague and Carver, 2000). For routine applications, the thickness of the overlay may not be reduced with the use of a geosynthetic interlayer, and one can design the overlay as per the guidelines in design standards on overlays without geosynthetic interlayer. This is mainly because the major purpose of introducing a paving fabric is to enhance the performance of the pavement, not to reduce the thickness of the overlay.

5 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.

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 geosynthetic interlayer. Surface preparation is followed by the application of tack coat, installation of the geosynthetic, 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 leveled, dry, and free of dirt, oil and loose materials. Cracks, 3 mm 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 leveling 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. The surface on which a moisture barrier interlayer is placed must have a grade which will drain water off the pavement.

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 10^0C 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 140 ^{0}C and 160 ^{0}C, 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 - Geosynthetic Placement: The paving fabric is placed prior to the tack coat cooling and loosing 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. Today most paving fabric is applied using tractor-mounted rigs. Slight tension can be applied during paving fabric installation to minimize wrinkling. However, stretching is not recommended, because it will reduce the thickness, changing the bitumen retention properties of the fabric. Too little elongation may result in wrinkles. Too much elongation produces excessive stretch, thinning the geosynthetic so that it may not be thick enough to absorb the tack coat, leaving excess that may later bleed through the bituminous concrete on a hot day. Wrinkles and overlaps can cause cracks in the new overlay if not properly handled during construction process.

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. Paving multiple lanes has inherent installation problems. It is best to install in one lane and pave it for traffic prior to installing in another lane. Leave 150 mm of fabric unpaved for overlap on the adjacent panel of fabric to be installed.

A paving reinforcement geogrid is installed into a light asphalt binder or it may be attached to the existing pavement by mechanical means (nailing) or by adhesives, preventing the geogrid from being lifted by paving equipment passing over it. When a composite of geogrid and geotextile is installed, the tack coat is applied the same as a paving geotextile alone.

Installing geosynthetic around curves without producing excessive wrinkles is the most difficult task for installers of paving synthetics. However, with the proper procedures, it can be accomplished with ease. Attempt should not be made to roll the geosynthetic around a curve by hand. It will wrinkle too much. Placing fabric around a limited curve with machinery is preferable. Some minor wrinkles may occur. Grids have low elongation and thus do not stretch in curves. In most cases, the grid will need to be installed by hand or in short sections by machine to avoid wrinkles (Barazone, 2000).

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 geosynthetic 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 geosynthetic placed are paved on the same day. In fact, asphalt concrete overlay construction should be done immediately after the placement of paving geosynthetic. 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.

The temperature of asphalt concrete overlay should not exceed about 160 ^{0}C to avoid damage to the paving fabric. Overlays should not be attempted with its temperature less than 120 ^{0}C and air temperature less than 10 ^{0}C. Adequate overlay thickness, if used, generates enough heat to draw the tack coat up, into and through the paving fabric, thus making a bond. In fact, the heat of the overlay and the pressure applied by its compaction force the tack coat into the paving fabric and complete the process. If sufficient residual heat after compaction is not present, the bonding process is disrupted, the results being slippage and eventual overlay failure. 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. In cold weather, a thicker overlay may be necessary to achieve the same objective.

A paving fabric interlayer can also be used beneath seal coat or other thin surface applications. In such applications, there is not sufficient heat applied to reactivate the asphalt sealant. Therefore, the installed paving fabric must be trafficked or rolled with a pneumatic roller to push the fabric completely into the asphalt sealant. Sand can be applied lightly to avoid bitumen tackiness during trafficking. Once the paving fabric has absorbed the asphalt sealant, the seal surface treatment is applied exactly as it would be over any road surface.

It is suggested that the first-time users of paving fabric interlayer should obtain help from the paving fabric manufacturers, keeping in view the site and material variables.

It should be noted that choosing proper application sites for the paving geosynthetic is a function of the existing pavement’s structural integrity and crack types – not its surface condition. For successful performance, proper installation must occur on a pavement without significant vertical or horizontal differential movement between cracks or joints and without local deflection under design loading (Marienfeld and Smiley, 1994).

6 CONCLUSIONS

When properly installed, the paving geosynthetic interlayer at the overlay base level of the paved roadway keeps the water out of the road base for maximum pavement life. It may be very useful for wide pavements, including airfields and parking lots, where the path to under drains or edge drains can be distant. In fact the waterproofing is one of the basic functions of the paving geosynthetics. Other functions of paving geosynthetics include cushioning (stress relief) and reinforcement depending on whether the geosynthetic is nonwoven geotextile or geogrid. For effective utilization of paving geosynthetics, particularly geotextiles, 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 geosynthetic is generally to enhance the performance of the pavement, not to reduce the thickness of the overlay. Both air temperature and asphalt overlay mix temperature are needed to be maintained as per the discussion made in this paper.

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