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Effect of Geotextile and Tack Coat Type on Asphalt Concrete Performance: A Review

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ABSTRACT

The bonding between asphalt concrete layers in flexible pavement is a crucial parameter affecting the mechanical properties of asphalt pavement, mainly influencing stress distribution, structural framework, and mechanisms of distresses resistance. The current study exhibits a comprehensive review of the combined impact of tack coat materials and geotextile interlayers on the performance properties of asphalt concrete, with highlighting Interlayer Shear Strength (ISS), fracture resistance, and durability. Many tack coat types including conventional emulsions, cutback asphalts, hot asphalt binders, trackless systems, and polymer-modified emulsions were assessed by previous studies. The outcomes indicated that trackless and modified with polymer tack coats enhanced ISS by approximately 20 to 50% as compared to conventional emulsions, while epoxy-modified systems demonstrated superior performance especially at high temperatures. Geotextile interlayers substantially improved pavement properties, raising load-carrying capacity by up to 116%, stiffness by 25–31%, and fatigue life by up to four times (Traffic Benefit Ratio (TBR) approximately equals to 4). In addition, reductions of about 25 to 96% in rutting and 28.6 to 74.8% in strain were reported, based on the location of geotextile in the pavement. Geotextiles also minimized the crack propagation by absorbing around 15% of induced stresses, leading to 2 to 3 times increase in asphalt pavement durability. The contact between tack coat and geotextile in pavement is considered a key design factor. Based on the previous studies, the optimum application rates of tack coat typically ranged from 0.6 to 1.2 L/m², corresponding to around 100 to 125% of the geotextile asphalt retention capacity. Excessive amounts can reduce the ISS because of lubrication effects. Furthermore, saturation of geotextiles can enhance moisture resistance by reducing permeability by up to three times. Despite these results, further research is necessary to develop integrated design methods under differing field conditions.

1. Introduction

Asphalt pavements are widely used in transportation infrastructure due to their durability and flexibility under repeated traffic loading. Structurally, Asphalt pavements are composed of multiple layers with varying thicknesses and material characteristics. These layers are typically classified into bound asphalt layers namely the surface (wearing), binder, and base courses which are supported by underlying unbound layers, including the subbase and subgrade [1], [2], [3]. Traffic loads are transferred through the pavement layers, which allows for a reduction in stress intensity by distributing them over a wider area and minimizing excessive deformation

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[4], [5], [6]. However, pavement performance depends not only on the individual properties of the layers but on the behavior between adjoining layers also. Efficient load transfer relies on the ability of the pavement layers to serve as a unified system, and this is primarily controlled by the interface condition. Adequate interlayer bonding facilitates monolithic behavior and enhances structural integrity, whereas inadequate bonding modifies the internal stress distribution and accelerates pavement deterioration [7], [8].

Pavement performance is directly affected by the Interlayer bonding. Poor bonding manifests as distresses such as rutting, fatigue cracking, and slippage [9], [10], [11]. Adequate bonding, on the other hand, improves load transfer and the mechanical response of the pavement, leading to a longer service life [12].

Tack coat materials are used to improve bonding and enhance adhesion between pavement layers. Their effectiveness determines interlayer bond strength and ensures the integrity of the pavement structure [13], [14].

To resist moisture and reduce reflective cracking, the use of geotextile interlayers to modify the interface behavior and improve performance through reinforcement has increased [15], [16], [17], [18], [19]. Both the tack coat and the geotextile are used at the interface, but their roles are different, although they complement each other. The role of the tack coat is to control adhesion, while the role of the geotextile is to influence the mechanical response of the pavement system. The interlayer bond strength of geotextile-reinforced systems is strongly influenced by the type and application rate of the tack coat used to guarantee sufficient bonding at the interface [20].

Despite the recognized importance of interlayer bonding and its effect on pavement performance, most studies have investigated tack coat and geotextile effects separately. Their combined influence on interlayer behavior and pavement performance has not been systematically addressed, limiting the optimization of interface design.

2.Tack Coat in Asphalt Pavements

A tack coat refers to the application of a bituminous material onto an existing pavement surface before placing a new asphalt layer, with the primary objective of ensuring effective bonding between the two layers. Achieving adequate adhesion between pavement layers is critical for the pavement to behave as a unified (monolithic) structure [7]. In the absence of proper bonding between the existing surface and the overlay, delamination may occur, as illustrated in Figure 1. Therefore, to secure sufficient interlayer bonding, the asphalt binder used as a tack coat should be applied in a fluid state, which can be obtained either by heating the binder or by blending it with a solvent to produce a cutback material, or mixing it with water and an emulsifying agent (soap) to make an asphalt emulsion [21]

Figure 1. Delamination interface failure [22]

2.1 Type of Tack Coat Material

Generally, several materials have been applied as tack coats, including cutback asphalt, asphalt emulsion, trackless tack coat and hot asphalt cement; however, the latter is less commonly applied due to environmental concerns associated with its use [7]. Asphalt emulsion is the most commonly used of these materials, and its performance can be greatly improved by adding polymer modifiers and other additives. Within this context, the choice of tack coat material type greatly affects the bonding behavior between layers, due to its direct role in controlling the shear strength generated between the asphalt pavement layers [7], [23], [24]. This observation is further supported by recent findings, which confirmed that variations in tack coat type can significantly alter the interlayer bonding strength [25]

2.1.1 Asphalt Binders

Asphalt is mainly composed of high molecular weight hydrocarbons and is classified as a cementitious material, it is black or dark and exists in two states: either naturally or by manufacturing, it is solid, semi-solid, or viscous [26]. In pavement applications, hot asphalt cement, obtained from crude oil distillation, is commonly used as a tack coat material, with typical binder grades including PG 76-22, PG 64-22, PG 58-28, and PG 76-22M [27]. The primary advantage of using straight asphalt binders as tack coats lies in the absence of a curing or breaking time, allowing immediate placement of the overlay. However, this benefit is accompanied by significant limitations, as asphalt binders must be maintained at elevated temperatures to ensure sufficient fluidity for spray application. This requirement not only increases energy consumption but also raises safety concerns when handling and hot spraying materials near workers [7].

2.1.2 Asphalt Cutbacks

Cutback asphalt is identified as an asphalt binder that has been liquefied through the addition of selected petroleum solvents to reduce its viscosity and enable application at lower temperatures [6]. In practical applications such as tack coats and slurry seals, the added solvents evaporate after placement, leaving behind residual asphalt that functions as the primary bonding agent between pavement layers. This evaporation process, commonly referred to as curing, governs the development of adhesion at the interface.

The rate of solvent evaporation depends on both the type of diluent used and the proportion of asphalt binder within the mixture. According to literature and AASHTO [24], [28], [29] , cutback asphalts are classified into three categories based on curing rate: rapid-curing (RC), medium-curing (MC), and slow-curing (SC).

Rapid-curing (RC) cutbacks incorporate highly volatile diluents (e.g., gasoline or naphtha), with typical grades such as RC-70, RC-250, RC-800, and RC-3000 specified under [30].

Medium-curing (MC) cutbacks use diluents of intermediate volatility (e.g., kerosene), including grades MC-30, MC-70, MC-250, MC-800, and MC-3000, as defined in [31].

In contrast, slow-curing (SC) cutbacks contain low volatility oils, with common grades such as SC-70, SC-250, SC-800, and SC-3000.

Although cutback asphalt can provide strong adhesion performance when used as a tack coat, its contemporary use has declined significantly due to health, safety, and environmental concerns associated with the emission of volatile petroleum solvents [6]. As a result, its application is increasingly restricted in many regions, often limited to specific cases such as patching works under cold weather conditions.

2.1.3 Asphalt Emulsions

Emulsified asphalt is manufactured by dispersing asphalt binder within water through the use of an emulsifying agent, which may be either anionic or cationic. Based on setting characteristics, asphalt emulsions are commonly classified into rapid-set (RS), medium-set (MS), slow-set (SS), and quick-set (QS). The SS category includes grades such as SS-1, SS-1h, CSS-1, and CSS-1h, whereas the RS category comprises RS-1, RS-2, CRS-1, CRS-2, CRS-2P (polymer-modified), and CRS-2L (latex-modified) [7].

Compared to hot asphalt binders and cutback asphalts, emulsions are more widely used in tack coat applications due to their ability to be applied at lower temperatures, which promotes uniform distribution while reducing energy consumption and improving safety during construction. Moreover, Asphalt emulsions are free from harmful volatile solvents and are non-flammable, which reduces potential risks to workers' health [8], [29].

From a compositional standpoint, emulsions may be used in different forms. Undiluted emulsion is mainly composed of asphalt binder, water, and an emulsifying agent, whereas diluted bituminous emulsion is obtained by adding extra water, typically at a ratio of 1:1 (one part undiluted emulsion to one part water). After application and setting, the remaining asphalt referred to as residual asphalt typically ranges between 57% and 70% of the original undiluted emulsion [32].

2.1.4 Trackless Tack Coat

Polymer-modified or trackless tack coats have been developed to address one of the primary limitations of conventional tack coat materials, namely the tracking problem Figure 2 demonstrates that.

Figure 2. Tracking problem in asphalt pavement [33]

These materials typically consist of a hard base asphalt blended with polymer modifiers, which enhances their stability during construction and minimizes pickup by construction equipment. The bonding mechanism of trackless tack coats is activated by the heat from the hot asphalt mixture during overlay placement, allowing the material to effectively bond with the newly placed layer [34]. A comparative overview of various tack coat types and their classifications is presented in Table 1.

Table 1: An overview of tack coat types, classifications, and their comparative performance [35]

Hot Asphalt binder	AC-20, AC-30, PG 64-22, and PG 76-22,	Bond strength is high, but difficult to spray, and requires high heating
Asphalt Emulsion	Slow set (SS-1, SS-1h, CSS-1, and CSS-1h) Rapid set (RS-1, RS-2, CRS-1, CRS 2, and CRS-2P)	Personnel safety, ease of handling, savings on energy, and environmental friendliness
Cutback Asphalt	RC 70, RC 250, RC 8000, and VG 10	It is costly, uses more energy, and causes pollution.
Trackless and tack coat additive	modified with Polymer: CRS-2P, Coat, Latex-modified: SS-1h, CRS-2L Polymers types: EVA, PVA, SBS, SBR Latex, and natural rubber	Strong bonds, environmental friendliness, resolving issues, and savings in energy

3. Comparative Assessment of Tack Coat Materials in Asphalt Pavements

The performance of different tack coat types has been extensively investigated, and the findings consistently indicate that the type of tack coat plays a critical role in controlling interlayer bonding behavior. In general, hot asphalt cement has been indicated to provide higher interface bonding compared to emulsified asphalt; however, achieving uniform distribution requires adequate heating, particularly at low application rates, as insufficient temperature may hinder proper surface coverage [36]

Several studies have focused on modified tack coat systems to enhance bonding performance. Hot-melt coatings incorporating highly polymer-modified asphalt have demonstrated superior interface shear strength compared to solvent-based systems, especially at elevated temperatures [37]. Furthermore, conventional polymer-modified asphalt binders (plastomers or elastomers) typically exhibit thermoplastic characteristics, which can result in excessive deformation at elevated temperatures. To mitigate this limitation, the use of epoxy-modified systems combined with curing agents has been proposed, leading to enhanced mechanical properties. As a result, epoxy asphalt tack coats, along with fiber- or textile-reinforced systems, have demonstrated significantly higher interface shear strength compared to conventional polymer-modified tack coats [37], [38], [39], [40].

With respect to conventional emulsions and cutback asphalts, multiple studies have reported that emulsified asphalt types such as SS-1h and SS-1hP generally provide higher interlayer bonding strength than cutback asphalt RC-70 [28], [29]. Similarly, CRS-1 emulsions have been found to outperform cutback materials such as RC-70 and MC-70 under various temperature conditions [41]. However, other studies have highlighted that cutback materials may exhibit competitive or even superior performance depending on formulation, where RC-250 achieved the highest bond strength, followed by CSS-1, while RC-70 showed the lowest performance [13]. Likewise, by using pull-off tensile strength tests, RC70 has been reported to provide higher tensile strength compared to polymer-modified RC800 and MC70, primarily due to differences in solvent volatility and adhesion characteristics [42].

Trackless (non-tracking) tack coats have received considerable attention due to their enhanced bonding characteristics. Numerous studies have consistently reported that trackless tack coats provide higher interlayer shear strength than conventional emulsions such as CRS-1 and SS-1 [43], [44], [45], [46]. Also, Non-tracking (rapid-setting) tack coat materials have been shown to produce higher interlayer shear strength compared to slow-setting emulsions such as SS-1 and SS-1h, primarily due to the use of a stiffer base asphalt binder [47]. In line with these findings, the comparison of the evaluated tack coat materials indicates that NTSS-1HM (non-tracking) exhibited the highest interlayer shear strength among all tested types. This was followed by CBC-1H and CRS-1HBC, which observed performance comparable to SS-1H and CSS-1H. In contrast, SS-1 demonstrated the lowest interlayer shear strength [48]. In addition, bonding performance of trackless tack coat has been shown to improve at lower temperatures and remain superior to CRS-1 at approximately 40 °C [49]. Moreover, trackless tack coats have been found to achieve the highest interlayer shear strength at both ambient (25 °C) and elevated temperatures (up to 55 °C) compared to other tack coat types [7], [45], [46], [49], [50].

Despite these advantages, some limitations have been reported. Due to their relatively high brittleness, trackless tack coats may exhibit reduced resistance to top-down cracking, particularly in cold regions [51], [52], [53], [54]. In addition, Hakimzadeh et al. reported that, based on shear mode testing, the trackless tack coat provided higher interlayer bond strength compared to SS-1hp. However, at low temperatures, its performance was inferior to that of SS-1hp when evaluated in terms of interface fracture energy [46]. Field evaluations have also shown that polymer-modified tack coats can outperform trackless systems in terms of pavement stiffness, structural response, and overall distress resistance in specific applications such as open grade friction course layers [55].

Polymer-modified asphalt emulsions (PMAE) have also demonstrated significant improvements in bonding and durability. These materials enhance interlayer adhesion by increasing binder concentration at the interface as well as decrease the stress transmitted through the interlayer and improving resistance to top-down cracking [51], [56]. For example, SBS-modified emulsions have shown approximately 20% higher adhesion strength compared to conventional emulsions at optimal application rates [57]. Additionally, polymer-modified emulsions have been reported to provide stronger bonding than conventional tack coats, particularly at low temperatures, with improved fracture energy observed as application rates increase [58].

However, the behavior of tack coat materials is not universally consistent across all conditions. Some studies have reported that the effect of tack coat type on interlayer shear strength may not be practically significant, as similar ISS values were observed among different emulsions under certain surface conditions. In addition, excessive application rates have been shown to negatively affect bonding performance by creating a potential slip plane at the interface [59]. Similarly, surface condition and texture play a key role, as certain emulsions CSS-1h and SS-h maintain superior performance across both new and milled HMA surfaces compared to CRS-2P [60].

Other influencing factors include binder viscosity and composition. Emulsions produced from higher viscosity binders (50/70) penetration grade have been shown to yield higher interlayer shear strength compared to those produced from softer binders (160/200) [61]. Similarly, stiff-residue tack coats have been found to produce higher bond energy compared to soft-residue materials, while all tack coat types generally outperform cases where no tack coat is used [62]

Overall, many studies emphasize the improved interlayer shear strength achieved with trackless and polymer-modified tack coats, the reported outcomes are not entirely consistent across all conditions. The performance ranking of tack coat materials depends on multiple interacting factors, including binder stiffness, application rate, surface condition, and temperature. Therefore, choosing a suitable tack coat type remains essential for attaining optimal interlayer bonding and long-term pavement performance [63].

Finally, the advantages of polymer-modified asphalt emulsions over conventional emulsions can be summarized as improved resistance to rutting and thermal cracking, enhanced fatigue resistance, increased stone retention, faster setting time, and extended service life [64], [65], [66], [67].The main findings reported in previous studies are summarized in Table 2.

Table 2: Overview of Previous Studies on tack coats performance

Reference	**Tack Coat Type(s)**	**Key Finding**
[36]	Hot asphalt cement vs emulsion	Hot asphalt cement provides higher bonding but requires adequate heating for uniform distribution, especially at low application rates
[37]	Hot-melt polymer-modified vs solvent-based	Hot-melt coatings incorporating highly polymer-modified asphalt have higher interface shear strength
[37], [38], [39]	Epoxy asphalt /	Epoxy asphalt / reinforced systems show

	reinforced systems vs conventional polymer-modified	significantly higher shear strength
[28], [29]	SS-1h, SS-1hP vs RC-70	Emulsions provide higher bonding
[41]	CRS-1 vs RC-70, MC-70	CRS-1 showed outperformed at various temperature
[13]	RC-250, CSS-1, RC-70	RC-250 highest, CSS-1 second, RC-70 lowest
[42]	RC70, RC800, MC70	RC70 showed higher tensile strength than polymer-modified RC800 and MC70
[43], [44], [45], [46]	Trackless vs CRS-1, SS-1	Trackless have higher interlayer shear strength
[47]	Non-tracking (rapid-setting) vs SS-1, SS-1h	Non-tracking has higher ISS due to stiffer binder
[48]	NTSS-1HM, CBC-1H, CRS-1HBC, SS-1H ,CSS-1H, SS-1	NTSS-1HM highest ISS and SS-1 lowest
[49]	Trackless vs CRS-1	Trackless has better bonding performance at approximately 40 °C
[7], [45], [46], [49], [50]	Trackless vs other tack coat types	Trackless have highest ISS at both ambient and 55 °C temperatures
[51], [52], [53], [54]	Trackless	High shear strength but reduced resistance to top-down cracking, especially in cold regions
[46]	Trackless vs SS-1hp	Trackless tack coat provided higher interlayer bond strength than SS-1hP but exhibited lower interface fracture energy at low temperatures.
[55]	Polymer-modified vs trackless	Polymer-modified tack coats can outperform trackless systems in stiffness, structural performance, and distress resistance, particularly in open-graded friction course applications.
[51], [56]	Polymer-modified asphalt emulsions	Improve interlayer bonding and durability by enhancing adhesion, reducing stress transmission, and increasing resistance to top-down cracking.
[57]	SBS-modified vs conventional tack coats	~20% higher adhesion compared to conventional emulsions at optimal application rate
[58]	Polymer-modified vs conventional tack coats	Polymer-modified emulsions provide stronger bonding than conventional tack coats, especially at low temperatures, with fracture energy increasing as application rate increases.
[59]	Different emulsions	Tack coat type may not significantly affect ISS under certain conditions, while excessive application rates can reduce bonding by creating a slip plane.
[60]	CSS-1h, SS-h vs CRS-2P	CSS-1h and SS-1h show better performance than CRS-2P on both new and milled HMA surfaces.

[61]	High vs low viscosity binder	Emulsions produced from higher viscosity binder results in higher ISS
[62]	Stiff vs soft residue	Stiff-residue tack coats provide higher bond energy
[63]	General	Proper selection of tack coat is essential for achieving adequate interlayer bonding
[64], [65], [66], [67]	Polymer-modified emulsions vs conventional emulsions	PMAE improved rutting resistance, thermal cracking resistance, faster setting time, and extended service life

4. Effect of Geotextile on Pavement Performance

The effectiveness of geotextiles interlayers in improving the performance of asphalt pavements has been addressed in numerous academic studies, particularly with regard to crack resistance.

[16] indicated that nonwoven polypropylene geotextiles, when used as paving interlayers, have shown positive results in improving resistance to reflection cracking and reducing strain levels in asphalt layers. It was also noted that their effectiveness is significantly affected by the bond between the interlayer and the asphalt mixture. In addition, [68] showed that improvement in resistance to reflection cracking was observed with the geotextile interlayers reinforcement, and pavement durability was increased by approximately two to three times compared to the unreinforced condition. Zamora et al. also found that the bitumen content had a relatively limited effect on performance. Moreover, [69] demonstrated that due to the presence of geotextiles, the loading cycles to failure increased, thus significantly increasing the resistance of the asphalt overlays to reflective cracking and reducing the rate of crack propagation compared to the unreinforced case. Also, sun et al., [70] reported that the role of the geotextile was to reduce the rate of crack propagation and it absorbed 15% of the total stress in the asphalt surface layer.

The previous findings highlighted the important role of geotextile interlayers in limiting the propagation of cracks as well as their initiation under traffic loading conditions.

In addition to its crack resistance performance, numerous studies have also confirmed improvements in structural capacity and mechanical properties. [71] reported that in comparison with the control mixture, the load-carrying capacity of asphalt concrete reinforced with geotextiles increased by up to 116%, and its stiffness improved by 25-31%. From these results, it was concluded that geotextiles are beneficial in enhancing the sustainability of asphalt concrete. Furthermore, [72] found that adding geotextiles has a positive effect on pavement performance and significant potential for extending the service life of the pavement system. The geotextile-reinforced wearing layer exhibited longer fatigue life compared to unreinforced mixtures. Also, the results showed that temperature impacts performance, with the geotextile interlayer performing inferior behavior at low temperatures (5°C) compared to moderate or warmer temperatures (20°C and 30°C) as show in Figure 3.

In addition to improving pavement properties, the effect of geotextiles on deformation control and stress distribution has also been investigated. [73] demonstrated that when nonwoven geotextile is placed in the pavement structure, it reduces the transfer of stresses to the lower layers, especially when the tire contact pressure is low or medium. In this research, the geotextile was added in two locations, the surface-base interface, where both layers are composed of asphalt, and also in the mid-depth of the asphalt surface layer. The geotextile acted as reinforcing layer that improved load distribution and reduced stress levels in both cases. However, its effectiveness decreased with high tire contact pressures. Similarly, [17] showed that strain reduction is clearly achieved through reinforcement with woven and non-woven geotextiles, and their placement location significantly impacts their effectiveness. When placed within the wearing layer, the strain reduction rate ranges between 45.7% and 28.6%. However, when placed at the interface between the wearing layer and the base layer, the reduction rate is higher, between 74.8% and 66.5%. This indicates that their presence results in higher resistance to dynamic loads. In addition, [74] reported that permanent deformation decreased and stress distribution improved after the use of geotextile reinforcement. The reduction in rutting reached 25.2%, the location of the geotextile and its modulus of elasticity affected its efficacy. After its use, it is feasible to lower the thickness of the base layer by up to 30% without weakening the structural system. Moreover, [75] indicated that when geotextile reinforcement was used at the interface between the wearing and binder layers, and using Traffic Benefit Ratio (TBR) for evaluation, there was a significant increase in TBR value of 4, which indicates an almost fourfold increase in service life as illustrated in Figure 4. The study also used geotextile reinforcement under each surface-binder-base pavement course, and this had a significant result in reducing rutting by up to 96%. The study recommended that geotextile reinforcement is an effective approach to reducing permanent deformation, especially in regions with high temperatures.

Despite all the potential improvements mentioned above, some studies have shown that the effectiveness of the geotextile interlayers relies on the conditions of interfacial bonding. [76] indicated that the prospect and rate of slippage cracking development may increase if the bond among the geotextile interlayer and the overlying asphalt is inadequate. Finally, [77] showed that when using several common types of tack coat, the best performance was generally achieved when using SBS asphalt modified as tack coat between the asphalt overlay and geotextile interlayer, temperature had little effect on the adhesion performance of geotextile interlayer, but water immersion had a more effect. A considerable number of studies have examined the influence of geotextiles on pavement performance, particularly with respect to rutting resistance, fatigue life, and crack mitigation. A summary of these studies is presented in Table 3.

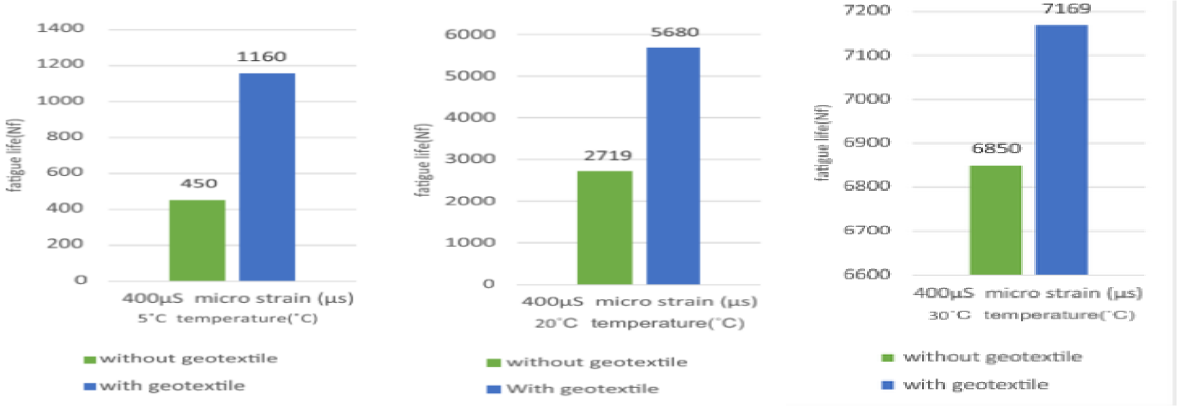
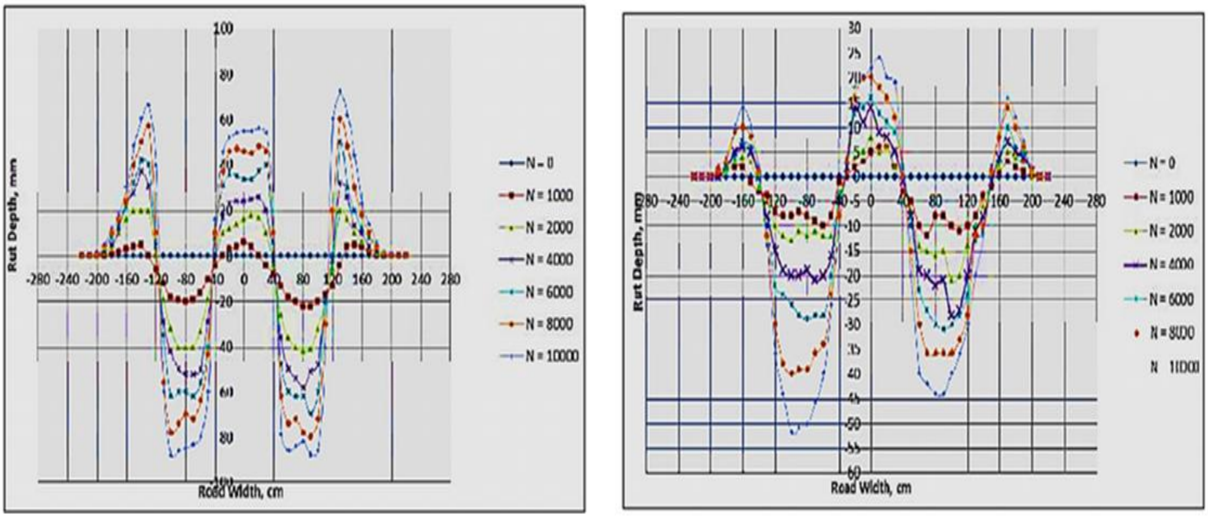


Figure 3. Relationship between geotextile present, temperature, and fatigue life [72]



(a)

(b)

Figure 4. Rutting depth (a) control section (b) geotextile between wearing and binder layers [75]

Table 3. Summary of studies on the effect of geotextile on pavement performance

Reference	Geotextile Effect	Key Findings
[16]	Crack resistance & strain reduction	Improved resistance to reflection cracking and reduced strain in asphalt layers, effectiveness depends on interlayer bond
[68]	Durability & cracking	Increased pavement durability by 2–3 times, improved reflection crack resistance, bitumen content had limited effect on performance
[69]	Fatigue & crack propagation	Increased loading cycles to failure and reduced crack propagation rate
[70]	Stress absorption & cracking	Reduced crack propagation and absorbed 15% of total stress
[71]	Structural capacity & stiffness	Load capacity increased up to 116% and stiffness improved by 25–31%
[72]	Fatigue & service life	Improved pavement performance and extended service life and longer fatigue life
[73]	Stress distribution	Reduced stress transfer to lower layers, however effectiveness decreases at high tire pressure
[17]	Strain reduction & location effect	Strain reduction 28.6–45.7% (within wearing layer); 66.5–74.8% (interface placement between wearing and base layer)
[74]	Rutting & stress distribution	Rutting reduced by 25.2%; improved stress distribution; base thickness reduced up to 30%
[75]	Rutting & service life	TBR increased to 4; fourfold increase in service life; rutting reduced up to 96%
[76]	Bond dependency	Inadequate bonding between the geotextile interlayer and

		asphalt may increase the likelihood and rate of slippage cracking.
[77]	Tack coat types & geotextile	SBS-modified tack coat generally provides the best performance among common types, especially between asphalt overlay and geotextile interlayers.

5. Interaction Between Geotextile and Tack Coat

Regarding the effect of the tack coat application rate and residual bitumen content on geotextile systems and their performance, this has been addressed in academic studies. [78] A scope of geotextiles and emulsifiers were used at varying emulsion quantity, and the results indicated that the optimal residual bitumen content that achieved the best performance was varied from 0.35 to 0.50 kg/m². [79] indicated that the choice and application rate of the tack coat material is a crucial factor in the effectiveness of the geosynthetic interlayer. Several problems can arise in practice related to the application of the tack coat, such as leakage and blockage of spray nozzles, lack of temperature control and excessive or insufficient application distribution.

Geotextile impregnation plays a role in improving the strength and stiffness properties, so in general the mechanical performance of asphalt pavement. [80] demonstrated that due to the interaction between the geotextile and the asphalt binder as tack coat, the mechanical performance, including tensile strength, fatigue resistance and stiffness is improved when the impregnated geotextile is incorporated into asphalt mixtures.

To assess the potential benefit of geotextile impregnation on the mechanical characteristics of reinforced asphalt mixtures, [81] study four cases of geotextile impregnation with hot bitumen (0.36 L/m^2) were studied, impregnation on both sides, impregnation on the top only, impregnation on the bottom only and a control sample without impregnation. The results indicated that impregnation of the geotextile on the top side only was the most effective compared to the other cases. However, through experiments all impregnation cases achieved a higher mechanical response than the control sample. Also,[82] The study showed based on the type of geotextile and the properties of the emulsion, the asphalt retention capacity ranges approximately from 0.54 to 1.11 L/m^2. This indicates that non-woven geotextiles require relatively a large quantity of asphalt to achieve impregnation. Under the influence of simulated Installation damage and different loading types, no reduction in the mechanical characteristics of the geotextile was observed; rather, impregnation increased the stiffness and tensile strength of the geotextile.

Determining the optimum tack coat level depends on the geotextile ability to retain the asphalt, and this topic represents one of the trends in scientific studies. [83] researchers studied three application rates of CRS as tack coat with the geotextile, including 0.6 L/m2, asphalt retention capacity and 10-20% above it. They found that increasing the tack coat rate led to an improvement in mechanical performance such as stiffness and tensile strength, but after the asphalt retention capacity of the geotextile, there was a decrease in mechanical performance. Also, when impregnating with 0.6 L/m2, a significant decrease in hydraulic permeability was observed, and no significant reduction occurred after this application. Similarly, [84] Using the same type of emulsion and the same tack coat rate mentioned in the previous study, they found that increasing the application rate of the tack coat from 0.6 L/m² to values close to the asphalt retention capacity improved tensile strength and stiffness by 62%. They also indicated that the improvement did not continue with increasing application rates; rather, optimal performance is achieved at approximately 1.1 L/m², which represents the amount of asphalt cement that can be retained within the geotextile.

Furthermore, [85] studied the interface bonding and fracture-related behavior of asphalt reinforced with a geocomposite composed of glass fibers and non-woven geotextiles. The system's asphalt retention capacity was 421 g/m², and using PG64-22 as tack coat, and the optimum tack coat rate was 125% of the asphalt retention capacity, which was achieved highest interface shear strength, interface shear fracture energy, cross-shear strength, and cross-shear fracture energy.

The literature also reported significant decrease in permeability as a result of impregnating the geotextile with asphalt. [86] The study showed that impregnation of non-woven geotextiles leads to a significant decrease in the permeability coefficient, when using a residual asphalt application rate of 0.6 l/m^2 of the emulsion, it may be adequate to substantially reduce permeability, and raising the application to approximately 1.1 l/m^2 resulted in a further decrease in permeability, depending on the type of material used as can be seen in Table 4.

Similarly, [87] indicate that a residual spray rate of 0.6 L/m2 was sufficient to significantly reduce the permeability values, for Nonwoven polyester and polypropylene geotextiles. Also, [19] demonstrated when samples were reinforced with non-woven geotextile fabric and an asphalt binder as tack coat at a rate of approximately 1.2 L/m2, no water flow was observed in the reinforced samples, confirming the effectiveness of the waterproofing.

Table 4. Permeability characteristics of impregnated nonwoven geotextiles[86]

Material	**Permeability (cm/s)**		
	0.60 L/m²	**0.90 L/m²**	**1.10 L/m²**
PET-1B	2.77×10^{-9}	2.54×10^{-9}	1.73×10^{-9}
PET-2B	4.80×10^{-10}	3.77×10^{-10}	1.68×10^{-10}
PP-1B	1.28×10^{-9}	1.27×10^{-9}	1.22×10^{-9}
PP-2B	9.60×10^{-10}	5.96×10^{-10}	2.17×10^{-10}

Furthermore, [88] found that using asphalt cement as tack coat at a range of 1.04 to 1.13 L/m2 with paving fabric interlayer, reduces the permeability of the pavement system by one to three orders of magnitude and this reduction in permeability helps to protect the subgrade, subbase, and base layers from moisture.

In addition, [89] reported that nonwoven geotextile is relatively impermeable to both cross-plane and in-plane flow when impregnated with asphalt.

However, not all studies have found a significant effect of the tack coat within the selected sample range. [68] reported that the impact of the tack coat content on the geotextile interlayers and its performance was relatively low within the investigated range.

In addition to what has been mentioned, there are broader improvements in paving performance associated with the use of geotextiles and tack coats. [90] reported that the CBR value increased by up to 277%, the transmissivity (in-plane flow) increased by 20%, the permeability (cross-plane flow) decreased by up to 60%, and the rutting depth decreased by up to 70% when latex-backed jute geotextiles are utilized as reinforcement in flexible pavements in comparison with unreinforced systems.

Moreover,[77] This study examined the interfacial adhesion characteristics and pavement performance of asphalt overlays incorporating a geotextile interlayer. The experimental program enabled several conclusions to be drawn based on layer-parallel direct shear, bending fatigue, long-term rutting, and SCB tests. The results indicated that the bonding performance of the geotextile interlayer initially increased with increasing tack coat application rate, followed by a subsequent decline. The corresponding optimum application rates were identified as 1.2 kg/m² for emulsified asphalt, 0.9 kg/m² for penetration grade 70/80 virgin asphalt, and 0.8 kg/m² for SBS-modified asphalt, respectively. As presented in Figure 5. Finally, proper installation practices were also highlighted as an important factor influencing bonding performance. [91] To enhance the bond between the geotextile and the asphalt concrete, and to ensure a uniform distribution of asphalt cement within the mixture, the geotextile strip was coated in advance with a layer of liquid asphalt (tack coat) before being placed into the specimen. Several studies have investigated the interaction between geotextile interlayers and tack coat materials, particularly in terms of impregnation, bonding, and overall pavement performance. A summary of these findings is presented in Table 5.

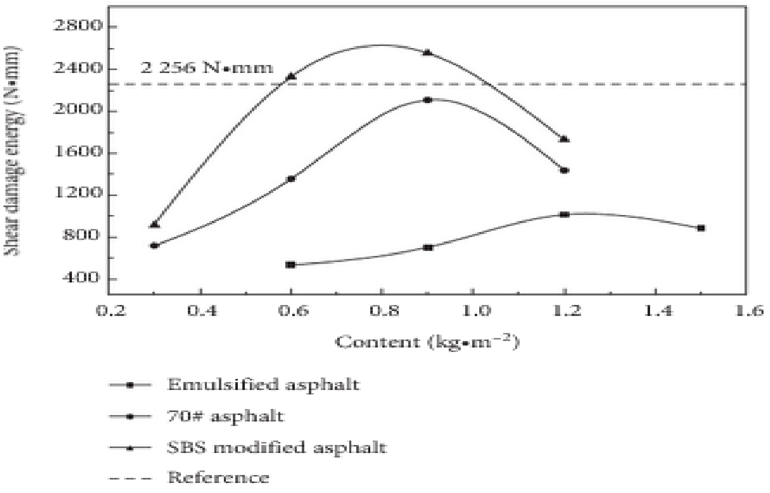


Figure 5. Influence of tack coat application rate on the adhesion of a geotextile interlayer at 25°C [77]

Table 5. Overview of studies on the interaction between geotextile and tack coat in asphalt pavements

Reference	**Topic**	**Key Findings**
[78]	Residual bitumen content	Optimal residual bitumen ranged from 0.35–0.50 kg/m² for geotextile best performance in asphalt mixtures
[79]	Tack coat & geosynthetic	Tack coat type and rate are crucial effectiveness of the geosynthetic
[80]	Geotextile–tack interaction	Impregnated geotextiles improve mechanical performance, including tensile strength, fatigue resistance, and stiffness.
[81]	Impregnation method	Top-side impregnation was most effective, all cases outperformed control
[82]	Asphalt retention	Asphalt retention capacity ranges from 0.54 to 1.11 L/m² depending on geotextile type and emulsion

		properties; impregnation increased stiffness and tensile strength of the geotextile
[83]	Application rate	Increasing rate improved performance up to retention capacity, then decreased; permeability reduced significantly at 0.6 L/m²
[84]	Optimal tack rate	Increasing rate improved strength up to ~1.1 L/m²; beyond that performance decreased
[85]	Optimal rate & bonding	Optimum rate = 125% of retention capacity; highest ISS and fracture energy achieved
[86]	Permeability	Residual asphalt 0.6 L/m² significantly reduced permeability and further reduction at ~1.1 L/m² residual
[87]	Permeability	Residual asphalt 0.6 L/m² sufficient to significantly reduce permeability
[19]	Waterproofing	At ~1.2 L/m² of asphalt binder as tack coat no water flow observed
[88]	Permeability reduction	Tack coat at a range of 1.04–1.13 L/m² reduced permeability by 1–3 orders of magnitude
[89]	Impermeability	Impregnated geotextile becomes impermeable to cross-plane and in-plane flow
[68]	Tack coat effect	Effect of tack coat content on the geotextile interlayers was relatively low within studied range
[90]	Overall performance	When using latex-backed jute geotextiles as reinforcement in flexible pavement, CBR ↑277%, transmissivity ↑20%, permeability ↓60%, rutting ↓70% compared to the unreinforced system
[77]	Optimal application rate	Bond increases then decreases with rate; optimum: 1.2 kg/m² (emulsion), 0.9 kg/m² (Penetration grade 70/80 virgin asphalt), 0.8 kg/m² (SBS-modified asphalt)
[91]	Installation practice	Pre-coating geotextile with tack coat prior to its insertion into the specimen, improves bonding

6. Conclusions

1. The strength of bonding between pavement layers is an important factor influencing pavement performance. Premature distresses involving rutting, fatigue cracking, and slippage can occur because of insufficient bonding.

2. The type of tack coat profoundly impacts ISS, wherein: Polymer-modified emulsions enhance adhesion by roughly 20% compared to standard emulsions. Trackless tack coatings reliably yield superior ISS at temperature ranges of 25 to 55 °C. Epoxy-modified systems demonstrate superior bonding properties, especially in elevated temperature environments.

3. The tack coat application rate is essential in interlocking between asphalt layers, with best values often between 0.6 and 1.2 L/m². Optimum functioning of pavement is attained at approximately 100 to 125% of the geotextile's asphalt retention capacity. Excessive application amount results in a

loss in bonding caused by the forming of a lubricating interfacial layer.

4. Pavement performance is noticeably amended by reinforcing the bonding between layers by means of geotextiles, encompassing increase in load-carrying ability by up to 116%, enhancement of stiffness by 25 to 31%, and rise in fatigue life of up to four times.
5. Based on literature review, significant decreases in pavement distresses are attained by using geotextiles, comprising, a reduction in rutting ranged from 25 to 96%, and strain drop of about 28.6% to 74.8% contingent upon placement location (between layers) compared to in-layer placement (28.6 to 45.7%), and mitigation of crack propagation through pavement layers, achieving stress absorption of about 15%.
6. Geotextile saturation significantly reduces permeability by up to 3 times of magnitude, thus improving moisture resistance and durability.
7. The performance of asphalt pavement modified with geotextiles is notably affected by the condition of bonding; insufficient adhesion may raise a probability of slippage cracking, despite the reinforcing advantages.
8. Environmental and operational considerations, such as temperature, traffic load, and surface texture, considerably affect the influence of tack coat and geotextile.
9. Many studies have been done on asphalt concrete pavement modified with coat and geotextile. Although, a significant research gap persists, especially in field applications. Further studies should concentrate on developing mechanistic–empirical models and performance-based specifications adjusted for climatic conditions similar to those in Iraq and comparable areas.

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