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Performance evaluation of modified asphalt based trackless tack coat materials

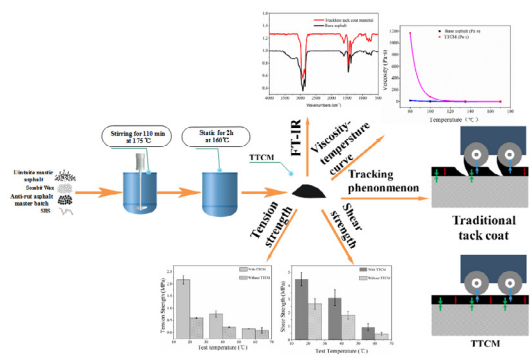
Dianhao Hou [a], Meizhao Han [a], Yaseen Muhammad [b,c], Yu Liu [d], Fenglei Zhang [a], Yuhua Yin [a], Shaochan Duan [a], Jing Li [a,c,*]

[a] Guangxi Colleges and Universities Key Laboratory of New Technology and Application in Resource Chemical Engineering, School of Chemistry and Chemical Engineering, Guangxi University, Nanning 530004, China
[b] Insitute of Chemical Sciences, University of Peshawar, 25120, KP, Pakistan
[c] Guangxi Key Laboratory of Petrochemical Resource Processing and Process Intensification Technology, Guangxi University, Nanning 530004, China
[d] Guangxi Communication Investment Technology Co. Ltd, China

HIGHLIGHTS

- Trackless tack coat materials (TTCM) were successfully prepared.
- TTCM exhibited enhanced softening point, PI, shear strength and track resistance.
- Adhesive bond TTCM were stronger than cohesive forces within asphalt mixture.
- The bonding mechanism and interaction of tack coat with tyre was discussed.

GRAPHICAL ABSTRACT



Performance Evaluation of Modified Asphalt Based Trackless Tack Coat Materials

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ABSTRACT

In this study, a modified asphalt based trackless tack coat material (TTCM) was prepared by adding styr ene–butadiene–styrene, uintaite mastic asphalt, anti-rut asphalt master batch and Sasobit wax to 50# base asphalt (penetration grade). Mehcnaimcal properties like track resistance, shear strength, pull-off strength, and rheological as well as temperature performance of TTCM were studied. Results showed that the adhesive bond strength of TTCM was greater than cohesive forces within hot mix asphalt layer, track-free time was less than 1 min and it did not deteriorate upon contact with tyres at 60 °C. Furthermore, bonding mechanism of TTCM was proposed. Surface morphology and functional group characterization were achieved using SEM and FTIR, respectively. The present approach utilizing routine raw materials and ease of operation for the synthesis of novel modified asphalt based TTCM with enhanced performance can be effectively applied on industrial level production for practical applications.

1. Introduction

Pavement conditions and performance have been highly emphasized and many improvements have been made recently [1]. Different materials have been developed over the years, among

* Corresponding author at: Guangxi Colleges and Universities Key Laboratory of New Technology and Application in Resource Chemical Engineering, School of Chemistry and Chemical Engineering, Guangxi University, Nanning 530004, China.
E-mail address: lijingsophia1234@163.com (J. Li).

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which modern asphalt pavement based on a multi-layer system has earned a vital position attributed to its stronger bond strength between pavement layers which can affect lifetime and performance of applied coat [2–7]. As adjacent layers in a multilayer system has different modulus, strength, structure, etc. thus good bonding between layers can ensure the whole material work as homogeneous composite layer and can more effectively absorb the load of heavy traffic. On the contrary, poor bonding will result in premature distress such as de-bonding, delamination, slippage, fatigue cracking or peeling, resulting in reduced pavement service life [7–9]. These factors make the interface bonding of critical importance and must be carefully considered in designing both materials as well methods for pavement selection [10]. As a simple, economical and efficient process, applying tack coat could strengthen bonding between pavement layers and can minimize the aforementioned pavement related problems [11]. Generally, tack coat is either a base or modified liquid asphalt, or an emulsified asphalt [12]. However, traditionally modified or base asphalt has poor bond strength [12] attributed to poor or non-uniform dispersion of tack coat and low compatability with the base asphalt. Moreover, improperly designed and applied or irregular tack coat is vulnerable to heavy construction traffic tyres and hence can be removed from the existing pavement surface, leading to debonding [13–15]. In a survey conducted by Mohammad et al. [16], 38% of the respondents favored the application of tack coat material before haul trucks are allowed over the roads to reduce tracking problem. Trackless tack coat materials (TTCM) have been recently introduced to the paving industry [17]. The tack coat layer is applied in hot liquid state which hardens with the passage of time upon cooling. At ambient temperatures, the tack coat is non-tracking and non-adhesive, which bonds with newly applied hot mix asphalt (HMA) in liquid state [13,18]. As a relatively new tack coat material, the TTCM has superior bonding strength [19–21] and short track-free time [12,14,20].

While many studies have evaluated the performance of tack coat [22–27], comprehensive evaluation of preparation and mechanism of bonding strength in TTCM are rare.

In the current study, TTCM based on modified asphalt were prepared. The prepared TTCM was evaluated for track resistance, bond strength, rheological properties. Apart from these, thermal properties tests *i.e.* track-free time test, track resistance test at 60 °C, shear test, pull-off test, dynamic shear rheometer (DSR) frequency sweep test and thermogravimetry/digital thermogravimetry (TG/DTG) analysis were performed. Beside, the materials were characterized by Scanning Electron Microscopy (SEM) and Fourier Transform Infrared Spectroscopy (FTIR) which further helped in structural and compositional elucidation of the materails and proposing mechanism for the tracking process.

2. Experimental

2.1. Materials

YH-134 SBS is linear polymer containing 30 wt% styrene, with an average molecular weight of 10^4 g/mol, obtained from Baling Petrochemical Co. Ltd. Hunan, China. Uintaite mastic asphalt, 100-mesh was obtained from Guangzhou Zhonggu Construction Material Co. Ltd, Anti-rut asphalt master batch, was supplied by Sinopec Luoyang, China. H5 Sasobit wax was provided by Wax China Dotcom Shanghai, China. 50# base asphalt (physical properties shown in Table 1) was supplied by China National Petroleum Corporation.

2.2. Preparation of TTCM

For the preparation of TTCM, the base asphalt was dried in vacuum at 135 °C for 1 h while the four different modifiers:SBS, uintaite mastic asphalt, anti-rut asphalt master batch, Sasobit wax were dried at 50 °C for 2 h. Then, the fluid base asphalt was heated to 175 ± 5 °C followed by the addition of 2 wt% SBS, 4 wt% uintaite mastic asphalt, 8 wt% anti-rut asphalt master batch and 6 wt% Sasobit wax (base asphalt quality as a benchmark) and mixed for 50 min with a rotating rate of 5000 rpm in LME100LT high-shear mixer. In the final stage, mixing was performed for 1 h at 175 ± 5 °C in BME100LT-N high-speed stirrer to obtain TTCM. Both, High-shear Mixer and High-Speed stirrer were supplied by Shanghai AIDONG Electromechanical Equipment Co. Ltd.

Table 1
Physical properties of 50# base asphalt.

Property	Standard requirement	Test values	Test method
Penetration (25 °C, 5 s, 100 g)/(1/10 mm)	40–60	55	T0604-2011
Penetration index (PI)	−1.5 to +1.0	−0.6	T0604-2011
Softening point (R&B)/(°C)	≥49	48	T0606-2011
Motive viscosity (60 °C, Pa·s)	≥200	187	T0620-2011
Ductility (15 °C, cm)	≥80	>100	T0605-2011
After TFOT aging			
Mass loss/%	−0.8 to 0.8	0.072	T0610-2011
Penetration ratio/%	≥63	67	T0604-2011
Residual ductility (15 °C, 5 cm/min)/cm	10	18	T0605-2011

2.3. Characterization

2.3.1. Determination of physical properties

To evaluate physical characteristics of rejuvenated asphalt binders, penetration index (PI), softening point and Brookfield rotational viscosity were measured via standard methods JTG E20 T0604, JTG E20 T0606, JTG E20 T0625 respectively.

2.3.2. Tracking resistance test

The "track-free time" is the time at which tack remains intact, which is highly dependent on temperature *i.e.* higher temperature leads to easy deterioration of tack and can be picked up and skimmed from the surface with tyres. As the standard rutting test temperature of asphalt mixture is 60 °C in JTG E20-2011 (Standard Test Method of Bitumen and Bituminous Mixture for Highway Engineering), tracking resistance in this study was tested at 60 °C. A modified no-pick-up time test based on JT/T 280-2004 (Pavement Marking Paint for No-Pick-Up Time of Traffic Paint) was used in this test. The stainless steel roller used was 15.6 ± 0.2 kg and fitted with rounded rubber gaskets. The tack sample was 30 cm × 8 cm in size while an unused A4 paper was used as tracking paper. The device was rolled across the tack sample at an interval of 15 s.

2.3.3. Mechanical test

2.3.3.1. Shear strength. The shear test performed for TTCM spanned to about 10 s which was calculated from the start of applying load (50 mm/min) till the specimen was broken. The shear test was conducted using the WAW-300B electronic universal testing machine controlled through a computer simulated software, produced by Zhejiang Chenxin Machinery Co. Ltd. as shown in Fig. S1. A pictorial representation of the device is shwn in Fig. 1. Its maximum load was 300 kN. The specimen used was a cylinder of 10 cm in height and 5 cm in diameter which is shown in Fig. S2.

2.3.3.2. Tension strength. Tension strength of the prepared material was tested in a self-designed tension device shown in Fig. 2. A bond specimen is glued to tension device by epoxy resin and is pulled in tension with WDA-20A electronic universal testing machine