



Influence of water-borne epoxy resin content on performance of waterborne epoxy resin compound SBR modified emulsified asphalt for tack coat

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HIGHLIGHTS

- The optimal content of SBR latex in emulsified asphalt was determined through the adhesion and DSC tests.
- The calculation and evaluation of conventional asphalt adhesion tests were improved.
- The curing time and shear strength tests were added to evaluate the performance of tack coat material.
- The effects of waterborne epoxy resin content on the properties of SBR modified emulsified asphalt were studied.

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ABSTRACT

In order to improve the performance of emulsified asphalt for tack coat, waterborne epoxy resin was blended with styrene-butadiene rubber (SBR) to prepare epoxy SBR modified emulsified asphalt by using an emulsification and then a modification process. The contents of SBR latex and epoxy resin in modified emulsified asphalt were determined by several evaluation indexes. The SBR latex content was determined by the adhesion and non-isothermal differential scanning calorimetry (DSC) experiment. The general content range of the waterborne epoxy resin was determined through storage stability test at first. Brookfield Rotational Viscometer was employed to test the viscosity of modified emulsified asphalt with the passing of time. Then the epoxy resin curing reaction time was determined and used to guide the modified emulsified asphalt evaporation residue experiments. The modified emulsified asphalt was employed as bonding material in a rolled composite plate and an 45° oblique shearing tests were taken on the core samples. The performance evaluation results have been compared with specification standards. It was found that the addition of SBR latex and epoxy improve the high and low temperature properties and shear strength of asphalt significantly. Particularly, under the optimum SBR and epoxy resin content, the modified emulsified asphalt shows better physical thermal property and therefore better storage stability. The optimal contents of SBR and waterborne epoxy resin are all determined as 3%.

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1. Introduction

Pavement adopts layered construction. Adjacent layers of pavement tend to have slippage failure because they may have different properties as strength and modulus [1,2]. The slipping faulting weakens the integrity and load carrying capacity of the pavement. Matrix asphalt is generally chemically modified using high polymers, because it is almost impossible for the matrix asphalt itself to meet the performance requirements of the tack coat. Magdy studied the interaction characteristics of asphalt with Crumb Rubber Modifier (CRM) using performance testing recommended by SHRP and provided an understanding of the property development as asphalt interacts with CRM [3]. Zhang et al. prepared modified asphalt by adding MMT (montmorillonite) into SBR and incorporating the mix into the asphalt. They reported that SBR/MMT modified asphalt formed an ideal fine network structure, which improved the viscoelastic properties of the asphalt, resulting in enhancing its rutting resistance at high temperature [4]. However, modified asphalt shows too large viscosity at air temperature. It has to be heated to 160 °C or higher to have better fluidity. This prevents it from being used as a tack coat material. It is inconvenient for field operation and can bring environmental problems because the asphalt has to be heated before being sprayed.

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Therefore, for the convenience and safety of tack coat spraying, it is necessary to emulsify the asphalt before it is utilized as tack coat material [5,6]. Styrene-butadiene-styrene (SBS) and Styrene-Butadiene-Rubber SBR) modified emulsified asphalt is generally employed as tack coat material due to its strong film-forming property and high viscosity [7–9]. However, the bonding performance of SBS or SBR modified emulsified asphalt needs further improvement under modern traffic condition. A new research trend is to compound epoxy resin, rubber powder or other material with SBS or SBR to produce new type modified asphalt emulsion [11]. Water-based epoxy resin can be solidified at air temperature and humid environment, and the solidified product has excellent high temperature stability. Composite modified emulsified asphalt using water-based epoxy resin has good prospect because the performance of which, especially the bonding performance, has been greatly improved than that of SBS or SBR modified emulsified asphalt [10]. Zhang et al. proposed an approach for preparation of the asphalt emulsion modified by compound of water-based epoxy resin emulsion and SBR. Properties like adhesion, durability of the compound, performances of evaporation residues were tested. The results reveal that the modified asphalt emulsion shows better road performances than those of the original asphalt emulsion and the asphalt emulsion modified only by SBR latex [12]. Li et al. improved the direct shear test and torsional shear test method, and tested the shear fatigue properties of three kinds of tack coat material including emulsified asphalt, SBS modified emulsified asphalt and epoxy resin through shear fatigue test under repetitive loads at an angle of 45°. Their study indicates that epoxy resin material shows a remarkably superior shear fatigue performance when compared with the other two [13].

Requirements of tack coat in the Standard Test Methods of Bituminous Mixtures for Highway Engineering (JTG E20-2011) of China are needle penetration (40 mm–100 mm), softening point (>53 °C), 5 °C ductility (>20 cm), solid content (>50%), spray amount (0.6–1.0 kg/m²) and storage stability (≤1% after 1 day).

In this paper, the emulsified asphalt was modified by water-borne epoxy resin and SBR latex compositively. First, the storage

stability of the modified emulsified asphalt was investigated to determine the general content range of the waterborne epoxy resin. Secondly, the curing reaction time of the modified emulsified asphalt evaporation residue is obtained to characterize the strength formation period needed by the tack coat material. Then, the modified emulsified asphalt with different waterborne epoxy resin content was tested to determine the optimal waterborne epoxy resin content so as to produce modified emulsified asphalt with better performance. The modified emulsified asphalt was used for the tack coat, and the shear test at a loading angle of 45 °was carried out to examine its performance as bonding material.

2. Materials and equipments

2.1. Raw materials

Asphalt used in the experiment is Binhua 70# heavy traffic asphalt. Its properties are shown in Table 1. Emulsifier selected is slow crack type cationic emulsifier MQK-1M, which was produced by the MeadWestvac, U.S. Polyvinyl alcohol and anhydrous ammonium chloride were used as stabilizers. The solvent used is distilled water, which is colorless, transparent, clean, with pH value ranging between 6 and 8 and hardness less than 8°. Hydrochloric acid was used as the emulsion pH regulator. The bituminous content within the emulsified asphalt is 52%. Properties of SBR latex are reported in Table 2. Water-based epoxy resin was produced using 618 resin, and the chosen curing agent is modified alicyclic amine water-based epoxy curing agent. Their technical properties are shown in Tables 3 and 4.

According to the principle of first emulsification and then modification, SBR modified emulsified asphalt was prepared beforehand. Then, the water-based epoxy resin and water-based epoxy curing agent were mixed into the beaker with a prescribed proportion. Start the high-speed shear emulsifier, slowly adjust the speed to 350 r/min, shearing the mixture for 5 min and then the weighed SBR modified emulsified asphalt was added into the beaker. Restart the shear machine and set the speed to 550 r/min, continue to agitate the mix for 10 min to make it a homogeneous system.

2.2. Equipments

FM 300-type laboratory high shear dispersing emulsifier, asphalt penetration tester, ductility tester, softening point tester, RVDV-II + Brookfield Rotational Viscometer, MTS universal testing machine, DSC ceremony, and etc. were employed in the research.

Table 1
Properties of the matrix asphalt.

Item	Value	Standard index (70#)	Test method
Penetration (25 °C, 100 g, 5 s)/(0.1 mm)	68.9	60–80	T0604
Softening point (Ring-and-ball method)/°C	48.1	≥45	T0606
Ductility (5 cm/min, 15 °C)	>115	≥100	T0605
Density (15 °C) g/cm ³	1.025	Actual inspection	T0603
Paraffin content/%	1.8	≤2.2	T0615
Solubility (Trichloroethylene)/%	99.8	≥99.5	T0607

Table 2
Properties of SBR latex.

Material	State (25 °C)	Density (20 °C) (g/cm ³)	Flashing point (°C)	pH (25 °C)	Solid content (%)	Proportion (25 °C)	Viscosity (20 °C)/ (mPa·s)	Surface tension/ (mN/m)
SBR PC-1468	Milky white liquid	0.982	145	5.3	66	0.95	35–45	65–75

Table 3
Properties of water-borne epoxy resin.

Item	Standard index	Value	Test method
State	Milk white uniform liquid	–	–
Viscosity, mPa·s, 25 °C	100–900	156	GB/T 11175-2002
Stability, 4000 rpm, 60 min	Unstratified	No delamination	Centrifuge
PH	7 ± 0.5	7.0	GB/T 8325-1987
Dispersion particle size, μm	≤1	0.75	Laser particle analyzer
Epoxide equivalent, g/mol	200–220	210	GB/T 13657-2011

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