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Full Length Article

Modified asphalt properties by blending petroleum asphalt and coal tar pitch

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HIGHLIGHTS

- We reported modified asphalt which can be facilely prepared by blending method.
- Modified asphalt is a suitable paving material due to its excellent properties.
- PA properties can be improved by CTP and CTP is compatible to PA.
- For road performance, shearing method is better than mechanical stirring one.
- Small or light composition changes into heavy component during blending process.

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ABSTRACT

Modified asphalt was prepared by mixing coal tar pitch (CTP) and petroleum asphalt (PA), and the effects of blending conditions on the properties of softening point, ductility, penetration, and elastic modulus of CTP-modified asphalt (CTPMA) were discussed. The group compositions of PA and CTPMA were analyzed by Fourier transform infrared spectroscopy (FTIR). Results show that PA properties (i.e., softening point, ductility, and penetration) can be improved by CTP addition because of the formation of large-molecule compounds as polycondensation reaction products from small-molecule materials in the blending process. CTP is compatible to PA, and CTP percent of 15% is proper under the blending conditions. CTP addition can also improve the anti-aging effect and decrease the elastic deformation of asphalt mixture. Experiments verify that the modification of PA by CTP addition is technologically feasible, and modified PA can be used to pave asphalt.

1. Introduction

The rapid development of economy has rapidly increased the number of trucks, cars, and other vehicles in roads all over world, thereby requiring high-quality asphalt materials in paving high-grade highways. Road performance is improved by use of modified asphalt. Addition of modifiers can improve durability of asphalt surface, adhesion of asphalt to aggregate, deformation resistant at great load, and resistance to freezing. Among the existing modifiers, natural and synthetic polymers are widely used to improve the properties of paving asphalt (PA), but such type of modifier presents serious isolation problem that restricts its application in modifying paving asphalt [1–6]. Coal tar pitch (CTP) draws much attention at present because of its high content of resin and asphaltene, and its capability to improve petroleum asphalt (PA) properties [7–12].

CTP is the distillation residue of coal tar produced after coal carbonization. Compared with petroleum pitch, CTP shows better properties of strong permeability, wettability, and tight adhesion to mineral aggregate [7,13,14], so CTP can be used as paving asphalt modifier and contains many active components with S, N, or O element, which can lead to chemical crosslinking and physical swelling behavior between CTP and PA [15–19]. Hence, a new colloid dispersion can be formed, and modified asphalt properties of road consistence, fiction coefficient, load resistance, and driving stability can be changed when CTP is added to PA [20–23].

The modification of asphalt properties can be conducted by changing many influential factors, including CTP particle sizes, CTP percentage, and blending technology conditions (e.g., stirring methods, stirring temperature, stirring time, and stirring speed) [24,25]. Modification mechanisms are still unclear to date because the structure of modified mixture is complicated and contains

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many kinds of substances. In this study, modified asphalt was prepared by blending PA and CTP under different conditions to systematically investigate the performance of CTP-modified asphalt (CTPMA). Group compositions were also studied by FTIR to understand the modification mechanism of CTP.

2. Experimental

2.1. Materials

Mid-temperature CTP was obtained from Taiyuan Chemical Industry Group Co., Ltd. The properties of the material are listed in Table 1. Original petroleum asphalt was obtained from Shenhua petroleum refinery, and the properties of the material are listed in Table 2. The softening point is approximately 80.1 °C for CTP.

2.2. CTPMA preparation

Base asphalt was first heated to melt in a 0.5 L uncovered vessel. Then, CTP was introduced into the vessel and mechanically stirred in XKJ-1 electric agitator at 125 °C for 90 min. Finally, the CTPMA mixture was obtained. The main blending conditions such as CTP particle size and CTP proportions were varied for analysis. AE300L-H shear-emulsifying machine was used for shearing. The thin-film oven test (TFOT) was used to evaluate the capability of asphalt to resist fast aging under hot mixing conditions.

2.3. Evaluation of modified asphalts

Basic performance tests on CTPMA and PA such as softening point, ductility, and penetration were performed according to Chinese standards GB/T4507-2010, GB/T4508-2010, and GB/T4509-2010, respectively. Solvent extraction was frequently used before group composition of CTPMA was determined [26,27]. The chromatographic column was self-made and was filled with activated Al_2O_3. N-heptane, toluene, chloroform (50%) + anhydrous alcohol (50%), and tetrahydrofuran were used to separate the samples into five fractions. Among the five fractions, four soluble compositions were defined as saturates, aromatics, resins, and asphalt; the rest was considered residue. The contents of the four groups were normalized to 100%. Elastic modulus was characterized by Shanxi Transportation Research Institute. Infrared adsorption spectrum analysis was used to analyze organic compositions. Nicolet iS50 FTIR was employed with wavelength ranging from 400 cm^{-1} to 4000 cm^{-1}. Asphalt samples were ground into powders, prepared by KBr, and sealed for preservation.

The microstructure and uniformity of CTPMA were examined by XDC-10A electronic microscopy (Kalino, Ningbo in China). Prior to observation, slide and cover glasses were pretreated as follows. Slide and cover glasses were cleaned by ultrasonication of the substrates submerged successively in a series of solutions including soap solution, acetone, and deionized water, and dried in hot air oven at 105 °C ± 1 °C for 1 h. The CTPMA samples at a ratio of 15% CTP (1 g, melted state) were dipped on clean slides, and coated by cover glass.

Table 2
The basic properties of PA and CTP.

Material	Penetration (0.1 mm)	Softening point (°C)	Ductility (cm)
PA	77.8	50.1	>100
CTP	5.3	80.1	<0.01

Note: Error bars are the 97.5% confidence limits of the mean of three replicates.

3. Results and discussion

3.1. Effect of CTP proportion on CTPMA properties

In the blending process, the proportion of raw materials significantly affects the properties of the mixture. Therefore, the addition of CTP can significantly influence the performance of CTPMA. The effect of CTP proportion on CTPMA performance was investigated accordingly in this study. The percentages of CTP at particle size of 40–60 mesh added in PA as raw material in the five coal tar contents were denoted as x% in weight. For example, CTP at percentage of 15% means CTP mass accounts for 15% of the total mass of CTP and PA mixture. The effects of CTP on the performance of CTPMA are shown in Fig. 1.

The effect of CTP on softening point value and the penetration value of CTPMA (Fig. 1) shows significantly different trends. 1) The change in ductility value of asphalt mixture with the increase in CTP ratio was divided into three stages: rapid decrease, stable area, and slow decrease. 2) The penetration value of CTPMA with CTP addition slowly decreased first and then reached a stable value with insignificant change, during which the penetration value was nearly constant. 3) The softening point slowly increased with the increase in CTP ratio. The decrease in the penetration and increase in the softening point of modified asphalt mixture indicate that CTP addition can significantly improve the hardness and viscosity of mixed asphalt. Therefore, CTP can enhance the adhesion performance of asphalt mixture. However, when CTP content was more than 15%, the change in penetration value and softening point was insignificant, showing the matching effect of CTP and PA. Compared with petroleum asphalt, the ductility of CTPMA with 10% CTP addition significantly decreased, especially with the increase in CTP ratio. Notably, some CTP particles can be observed from the ductility test sample. These particles can decrease the ductility value. Given that CTP contains residues, CTP and PA cannot be completely dissolved into one system, and the formation of mixed material is not uniform. When CTP was 15%, the ductility value of the mixture was high, implying that the effect of CTP is compatible to that of PA. Thus, 15% CTP ratio was selected as the optimal proportion.

3.2. Effect of CTP particle size on CTPMA properties

The particle size of CTP is also an influencing factor of the performance of CTPMA. Accordingly, different particle sizes of CTP including smaller than 20 mesh, 20–40 mesh, 40–60 mesh, 60–80 mesh, and more than 80 mesh were considered. The CTPMA samples with different CTP particle sizes were obtained after the preparation conditions were conducted in 15% CTP proportion at

Table 1
The group composition (with standard deviation of 2%) of CTP.

Material	Saturates (wt%)	Aromatics (wt%)	Resins (wt%)	Asphaltene* (wt%)	Residue (wt%)
CTP	2.0	25.9	11.5	24.8	35.8

* By difference.