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RESEARCH PAPER

Modification of asphalt by dispersing waste polyethylene and carbon fibers in it

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Abstract: Recycled waste packaging polyethylene (WPE) and chopped polyacrylonitrile-based carbon fibers (PAN-CFs) were dispersed in molten asphalt at 170 °C with a shearing machine at 3 800 r/min for 60 min to modify its properties to meet the demands of motorway paving. WPE and PAN-CFs were mixed by three methods before the dispersion: (a) simple blending, (b) first dissolving WPE in xylene, then mixing and evaporating and (c) blending and extrusion to rods of 1mm diameter at 170 °C which were fed directly into the hot asphalt. The PAN-CF content was varied in the range 0 to 0.12 wt% while the WPE content was constant (4 wt%). Results indicate that WPE and PAN-CFs are dispersed in asphalt to form a network structure by the xylene-assisted mixing or blending-extrusion methods. The softening points, penetration degree and ductility are improved with increasing content of PAN-CFs up to 0.1 wt%. Aggregation of the two modifiers occurs beyond 0.12 wt% of PAN-CFs, which degrades the properties of the modified asphalts. A fiber length of 5 mm is optimum for their best dispersion in the asphalt. Segregation of the modifiers from the modified asphalts can be prevented by increasing the content of PAN-CFs. The blending-extrusion method is best to form a fine network structure, which achieves a best performance. A model is proposed to explain the observed dispersion behavior in asphalt.

Key Words: Waste packaging polyethylene; Carbon fibers; Composite modification; Asphalt

1 Introduction

The domestic ordinary asphalt is unable to meet the demands of modern high-speed motorway due to its disadvantages, such as high wax, bad cohesive force, low ductility and large temperature-sensitivity. In order to deal with these problems, many polymers were used to modify the asphalt, such as styrene-butadiene-styrene triblock copolymer (SBS), rubber and polyethylene(PE). At present, the asphalt modified by SBS are broadly used. The properties of the asphalt modified by any single polymer could not be improved comprehensively to meet the demands of modern paving [1-4]. There are different materials that have been employed to reinforce asphalt. Fibers and polymers are two important examples used for this purpose [5-6]. Carbon fibers have many advantages, such as high axial force, high modulus, low density, high temperature resistance in non oxidizing environment, high fatigue resistance, good corrosion resistance and good thermal conductivity[7,8]. Carbon fibers are one class of the important materials used to make composites,owing to their good tensile property and softness. Nowadays, environmental protection, as a social responsibility, has become an important task in all countries. Therefore, the recycled waste packaging polymers and carbon fibers appear to be the attractive modifiers.

Based on the above background, recycled waste packaging polyethylene (WPE) and polyacrylonitrile (PAN) -based carbon fibers (PANCFs) were selected to modify the ordinary paving asphalt instead of the ordinary polymer modifiers. At the same time, three different types of combined modification technologies were studied to reveal the modification mechanism and provide a theoretical basis for the preparation of the low-priced modified asphalt.

2 Methods and experimental

2.1 Materials

The recycled WPE bags whose main component was linear low-density polyethylene (LLDPE) were cleaned and dried. The ordinary industrial asphalt was SK-90 produced in petrochemical factory in Xi'an and its main properties are shown in Table 1. PANCFs are made by Institute of Coal Chemistry, Chinese Academy of Sciences. And the carbon fibers are 6 k and cut into 5mm.

2.2 Specimen preparation

The recycled WPE bags were washed to remove impurities and dried in a vacuum drying oven until the water content was less than 1%. PANCFs were cut into a length

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Table 1 Main properties of ordinary asphalt.

Penetration degree (25°C,100g)/ 1/10mm	Ductility (25°C) /cm	Softening point (ring and ball)/ °C	Solubility/%	Flashing point / °C
60	>100.0	46	96.0	220

Table 2 Compositions of the modified asphalt samples in the experiment.

Samples	WPE content wt%	PANCFs content wt%	Asphalt content wt%
A0	4	0	96.00
A02	4	0.02	95.98
A04	4	0.04	95.96
A06	4	0.06	95.94
A08	4	0.08	95.92
A10	4	0.10	95.90
A12	4	0.12	95.88

about 5mm. The compositions of the samples in the experiment are listed in Table 2.

Before the WPE and short-cut PANCFs were added into the asphalt, they were mixed in the following three methods. In the method A, WPE and PANCFs were weighed separately according to the formulations in Table 2. In the method B, WPE and short-cut PANCFs were added into xylene, heated to 90 °C and stirred by a blender for 100 min. The mixture was flocculated in alcohol, filtered and dried at 90 °C in a vacuum drying oven. In method C, WPE and short-cut PANCFs were mixed, crushed at high speed by double roller and extruded by an extruder at 170 °C.

The asphalt was heated to 170 °C until completely melted. To the melted asphalt, the blends of WPE and PANCFs produced in the above three methods were added in the completely melted raw asphalt at 170 °C in a reaction kettle. Keeping the temperature constant, the mixture was stirred for 30min with a glass stirring rod, and then sheared by a shearing machine at a high-speed of 4000 r/min for 80min.The temperature of the mixture was then reduced to 130 °C and left undisturbed for 50 min for swelling. After fully swelled, the mixture was sheared again by a shearing machine at a high-speed of 3 800 r/min for 60 min until WPE and PANCFs were dispersed uniformly in the asphalt.

2.3 Performance test of the modified asphalts

The softening point, the penetration degree and the ductility degree of the modified asphalts were measured according to the standards of China, GB/T0606-2000, GB/T0604-2000 and GB/T0605-1993, respectively. The penetration degree of the modified asphalts was measured with a GS-IV type automatic asphalt penetrometer (China). The softening point of the modified asphalts was tested with a SLR-C type digital softening point tester (China). The ductility was tested with a STYD-3 type digital ductility testing machine (China). The softening point, the penetration degree and the ductility degree of the modified asphalts were measured three times at different positions and averaged.

Besides, a JSM-6390A scanning electron microscope (Japan) was employed to observe the microstructure of the modified asphalts at 5 kV. The modified asphalt samples were obtained at -5°C, and coated with gold/pallladium alloy before observation. An Olympus CX40-RFL32J fluorescent microscope was used to investigate the microstructure of the modified asphalts. FT-IR spectra were obtained using a Shimazu FTIR-8400S infrared spectrometer with a scanning range of 400- 4000cm^{-1} and a frequency of 20 Hz.

The samples for softening point were prepared according to GB/T0661-2000. First, three kinds of modified asphalts were put into three test tubes. Next, the test tubes were layered for 48±1 h in an incubator at 163±5 °C. The test tubes were first cooled to room temperature, then to -5 °C for 4h [9]. Finally, the softening points of the asphalts were measured. The softening points of the samples were measured three times at different positions to get an average value.

3 Results and discussion

3.1 Softening point

The softening point of asphalt is the temperature when asphalt changes from a state of being uneasy to flow to a liquid state in the presence of some external force and heat, reflecting the high temperature performance of the asphalt[10-12]. Fig.1 shows the softening point of the three types of modified asphalts. It can be seen that high temperature performance of the asphalts modified by WPE and PANCFs was greatly improved. Besides, the modification methods have great effects on the high temperature performance of the modified asphalts. The softening points of the WPE-modified asphalts with the method B and C are higher than that with the