An Asphalt Emulsion Modified by Compound of Epoxy Resin and Styrene-Butadiene Rubber Emulsion

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Abstract: A modified asphalt emulsion with superior performances will be produced after compound of waterborne epoxy resin and styrene-butadiene rubber are mixed in emulsified asphalt. This paper describes the method and technique for preparation of the material as well as the test and research on aspects like adhesion, various performances of evaporation residues and durability, and the results from which reveal that this modified asphalt emulsion shows road performances and indexes better than those of ordinary asphalt emulsion and asphalt emulsion modified by styrene-butadiene rubber latex and will find application in engineering.

Keywords: Water-epoxy resin emulsion; Styrene-butadiene rubber; Asphalt emulsion; Modification; Performances

1 Introduction

Asphalt Emulsion has advantages such as suiting for cold application, strengthening the adhesion and improving the mixture uniformity of asphalt and aggregate, saving 10% ~ 20% of the asphalt materials, extending construction season and reducing environmental pollution, But, since it is only another form of asphalt, it can not extricate itself from the existence of a series of weaknesses in asphalt like easy aging, temperature sensitiveness, etc. [1]. Higher requirements to asphalt emulsion have been raised by modern engineering in aspects like necessary flexibility and plasticity in low temperature conditions, sufficient strength and thermal stability in high temperature, anti-aging ability under conditions of application, bonding strength to surfaces of various work-pieces and structures, and fatigue resistance, therefore, modified asphalt emulsion emerges as the times require. Emulsified asphalt emulsion is a product made from asphalt emulsion that has been modified with polymer emulsion or a product made by means of emulsifying asphalt that has been modified by polymer [2]. Mechanical properties of modified asphalt emulsion all exceed those of emulsified asphalt, such as: its softening point has been increased, film-forming performance, adhesion, resilience behavior and low temperature performance have been improved, while its brittle point has been lowered; it presents a good crack resistance at a temperature much lower than that for application of emulsified asphalt; its fatigue resistance has been markedly improved. Currently in China, water-based modified asphalt emulsion is commonly prepared from butadiene-styrene-styrene block copolymer (SBS)[3], chloroprene rubber (CR) [4], reclaimed rubber[5], styrene-butadiene rubber (SBR) [6], and etc.. However, asphalt emulsion modified by none but SBR can only settle the low-temperature crack resistance performance, but no high temperature performances has been obviously improved; similarly, asphalt emulsion modified by none but water-based epoxy resin emulsion can only greatly increase the high-temperature performance of asphalt, but the low temperature performance has been less improved. This paper propose a method for preparation of the asphalt emulsion modified by compound of water-based epoxy resin emulsion and SBR, which can play the respective advantages of the two in modifying asphalt emulsion; the compound of waterborne epoxy resin emulsion and SBR consists of equal content of the two.

2 Preparation of Asphalt Emulsion

Modified by Compound of Water-Epoxy Resin Emulsion and SBR latex

Adding the polymer into asphalt emulsion is a complex physical and chemical process, and the quality of material properties of the modified asphalt emulsion prepared not only depends on uniformity of the mixture, but also relates greatly to the type, status and nature of modifiers that have been blended in as well as relates directly to the type of emulsifier of asphalt emulsion.

2.1 Modifier

2.1.1 Main Performances and Indexes of Waterborne-Epoxy Resin Emulsion

Water-epoxy resin is a kind of stable resin material prepared by means of dispersing epoxy resin in form of particles or droplets into the dispersion medium based on water as a continuous phase, viscosity of which can be discretionarily adjusted, the operation method whereby to made which is not only convenient but also causes no pollution to the environment and no harm to human body. After adding proper amount of curing/solidifying agent, advantages like high strength, high-temperature resistance, fatigue resistance, and high anti-aging ability will be achieved.

Table 1 Main Performance and Indexes of Water-Epoxy Resin Emulsion

Items	Indexes
Appearance	Milk white
Viscosityviscidity 25□/mPa·S	180
solid content /%	60
pH value	6～7
Storage Stability	>6 months

2.1.2 Main Performance and Indexes of SBR latex

Table 2 Main Performance and Indexes of SBR latex

Items	Indexes
Total solid content /%	≥40±2
coagulum content /%	≤0.001
pH value	3~5
viscidity /mPa·S	≤5
Density,20□/g · cm^{-3}	1.065
Surface tension /mN · m^{-1}	35~55

2.2 Emulsifier

Select the CRS-1 emulsifier (an emulsifier containing 1 amino group) as a major emulsifier. The difference between CRS-1 ionic emulsifier and other ordinary ionic emulsifiers is that two hydrophilic groups are contained in a molecule of CRS-1 emulsifier.

The more the amount of hydrophilic groups is, the stronger the hydrophilic property is, and therefore, the higher the stability of an emulsion is. The main characteristic of CRS-1-emulsifier is: □ Wide range of application; □ No adverse effects on the nature of asphalt, and under a certain dosage, the ductility is higher than that of the original asphalt; □ Good compatibility With a variety of modifiers. Experimentations reveal that the CRS-1 emulsifier shows perfect compatibility with various latexes containing positive or negative ions.

2.3 Asphalt materials

A sticky thick No.100 petroleum asphalt under Maoming Brand is selected in the experiment, with performances listed in Table.

Table 3 Three Major Indexes of No.100 petroleum asphalt under Maoming Brand

Penetration,25□ /0.1mm	Ductility,25□ /cm	Softening Point /□
96	78	48

2.4 Preparation Process for Asphalt Emulsion Modified by Compound of Water-Epoxy Resin Emulsion and SBR Latex

As the blending method and the order for putting compound of water-epoxy resin emulsion and SBR latex into emulsified asphalt will have important influence on their performances, which must be carefully considered in preparation and should be determined through experiments. A method so-called Liquid Mixing & Blending for preparation of modified asphalt emulsion is divided into three types. The first method is known as Twice Thermal Mixing Method, that is, water-epoxy resin emulsion and SBR latex pass through for two times a thermal mixing and dispersing process. Mix water-epoxy resin emulsion with SBR latex (normal temperature) and hot emulsifier solution (60~70□) by means of an emulsification machine in order to prepare a mixture of water, epoxy resin emulsion and SBR latex and emulsifier, and then, immediately put the mixture and melting asphalt (120~130℃) once again into the emulsification machine for emulsification. During emulsification process, water-epoxy resin emulsion is mixed with and disperses into SBR latex once again, as a result, modified asphalt emulsion is obtained. The second method is known as Single Time Thermal Mixing Method, that is, water-epoxy resin emulsion, SBR latex and asphalt emulsion pass through for one time a thermal mixing and dispersing process. Emulsify hot water solution of emulsifier (60~70℃) and melting asphalt (120~130℃) through an emulsification machine, then, immediately put the asphalt emulsion obtained together with water-epoxy resin emulsion and SBR latex into the emulsification machine for emulsification in order to prepare a asphalt emulsion, after this, immediately put the asphalt emulsion prepared together with water-epoxy resin emulsion and SBR latex (normal temperature) into the emulsification machine for emulsification, as a result, modified asphalt emulsion is obtained. The third method is known as Single Cold Mixing Method, that is, water-epoxy resin emulsion, SBR latex and asphalt emulsion pass through for one time a cold mixing and dispersing process. Mix water-epoxy resin emulsion and SBR latex (normal temperature) with asphalt emulsion (normal temperature) by means of a emulsification machine at a normal temperature, and as a result, modified asphalt emulsion is obtained. Experiment results show that Twice Thermal Mixing Method and Single Time Thermal Mixing Method can reach a good dispersion and therefore achieve a better modification result; Single Cold Mixing Method reach a dispersion inferior to those reached by the foregoing methods and thus achieve a modification effect no as good as those achieved by the former two. But all the said three methods can accomplish the purpose of modification. To simplify the process, reduce equipment and lower costs, the Single Cold Mixing Method is adopted in our experiments and research.

3Performance Evaluation Test of Asphalt Emulsion Modified by Compound of Water-Epoxy Resin Emulsion and SBR Latex

3.1 Adhesion Test

In order to explore the adhesion between emulsion and aggregate, select 3 different types of stone materials: granite, limestone and basalt, which respectively represent acidic stone material, alkaline neutral stone material and similar neutral stone material. The test is based on a so-called Water-Boiling Method in common use, that is, immerse the stone material in water for 1 minute, and then, immerse it in emulsion for l minute, store it at room temperature for 24 hours, then immerse it in water with temperature of 60℃ for 5 minutes, and the index will be based on the finally observed size of the area on the aggregate that is adhered to by the emulsion. Generally, in case that the surface of aggregate is completely covered by asphalt material, the evaluation result will be Excellent; in case of the size of area adhered to is larger than that of shedding area, the evaluation result will be Good; in case of the size of area adhered to is less than that of shedding area, the evaluation result will be Poor.

3.2 Evaporation residue Performance Test

The purpose of this test is to identify the differences between the performances of asphalt arising from the residue of asphalt emulsion after its demulsification and water evaporation and the performance of the original asphalt.

3.3 Analysis of Test Results

(1) See Table 4 for the performance and indexes test results of asphalt emulsion modified by compound of water-epoxy resin emulsion and SBR latex.

(2) See Table 5 for the performances and indexes test results of Residues of asphalt emulsion modified by compound of water-epoxy resin emulsion and SBR latex.

(3) See Table 6 and Table 7 for low temperature performance test results of residues of modified asphalt emulsions with different contents of latex

(4) High-Temperature Fluidity Test

Select two porcelain pieces with a size 15×10 cm, respectively coat an area 2.5 cm wide and 7 cm long at one end of each porcelain piece with a 3 mm-thick layer of the evaporation residue of ordinary asphalt emulsion and the evaporation residue of modified asphalt emulsion, then, expose them under the hot sun, when the outside environmental temperature reaches 36□, and the angle between the porcelain piece and the horizontal plane is set to 85□, the test result is as follows: ordinary asphalt emulsion under the sunlight flows a distance of 7 cm, SBR latex modified asphalt emulsion under the sunlight overall declines over a distance of 0.7 cm, water-epoxy resin modified asphalt emulsion under the sunlight overall declines over a distance of 0.3 cm, asphalt emulsion modified by the compound of water-epoxy resin emulsion and SBR latex under the sunlight overall declines over a distance of 0.1 cm.

(5) Durability Test

Coat two glass pieces size 30 cm×30 cm respectively with a certain amount of ordinary asphalt emulsion, SBR latex asphalt emulsion, water-epoxy resin asphalt emulsion and asphalt emulsion modified by the compound of water-epoxy resin emulsion and SBR latex, then, horizontally place and keep them under sunlight until the emulsion is demulsified and the water is completely evaporated and a layer of film is formed. Place the two pieces of glasses simultaneously into a thermostatic oven and heat for 24 hours at a temperature of 60□, then, put them into a refrigerator and cool at a temperature of -20□ for 24 hours. After repeatedly heating and cooling this way for 28 days, the result is found as follows: The film formed from ordinary asphalt emulsion material spreads uniformly with netted cracks, and the surface of film formed from modified material shows tiny netted wrinkles; when cutting the film surface with a blade at a low temperature, asphalt powder is cut out from the former, while flower-like flake is cut out from the latter; again, after repeatedly heating and cooling for 60 days, cracks on the film formed form ordinary asphalt emulsion material continuously get deepened, while no netted cracks have been found on the surface of films formed from SBR latex asphalt emulsion, water-epoxy resin asphalt emulsion and asphalt emulsion modified by the compound of water-epoxy resin emulsion and SBR latex.

The above-mentioned test results reveal that: asphalt emulsion modified by the compound of water-epoxy resin emulsion and SBR latex shows a low-temperature anti-cracking performance superior to that of the ordinary asphalt emulsion, SBR latex modified asphalt emulsion and water-epoxy resin emulsion modified asphalt emulsion; in the aspect of high temperature stability, softening point of residue from compound-modified asphalt emulsion has been increased and is 9□ higher than that of ordinary asphalt emulsion, and is obviously higher than those of SBR latex modified asphalt emulsion and water-epoxy modified asphalt emulsion. In the aspects of high-temperature fluidity and adhesion, experiments and tests also revealed that it presents performances exceeding those of ordinary asphalt emulsion, SBR latex modified asphalt emulsion and water-epoxy resin emulsion modified asphalt emulsion.

4 Mechanism of Asphalt Emulsion Modification by Compound of Water-Epoxy Resin Emulsion and SBR Latex

It is generally believed that in the preparation process of polymer modified asphalt, the main role of the polymer in asphalt is to absorb the small-molecule oil in asphalt and get swollen, no chemical reactions occur basically. In some modification processes, strong polar materials may be added in so that the polymer getting swollen in the asphalt may crosslink with the asphalt, as a result, a modified asphalt with stable performance will be obtained.

Asphalt material mainly consists of three components, i.e. oil, colloid and asphalt. When the polymer is mixed in asphalt and under the action of mechanical force, polymer particles absorb the oil content in asphalt and get swollen, as a result, the asphalt component partially recover the nature of raw rubber, and the original tight structure becomes a relatively loose floc-like structure, moreover, the particles of swollen polymer prepared can more evenly disperse and suspend in asphalt, and the base asphalt becomes thick and sticky because some oil contents have been absorbed. Getting swollen (or swelling) is an important link in modification of asphalt by polymer. Swelling can create an adsorption layer or interlayer with a certain thickness on the interface between asphalt and polymer, which is equivalent to enlarging the size of a particle and greater interaction will also among particles of the swollen polymer. After the oil content has been absorbed by the polymer network, the number of macromolecule in asphalt increase relatively, moreover, polymer disperses in asphalt in form of particles and get close to each other due to aggregation action, therefore, some of them create crosslink or form a network structure. Strong interaction between networks restricts the relative movement of asphalt molecule, increases the capacity to resist external forces, and also increase the viscosity of the modified asphalt and road-purpose performance.

Research on asphalt emulsion modified by compound of water-epoxy resin emulsion and SBR latex reveals that， along with the increase in used amount of water-borne epoxy resin emulsion SBR latex, and due to good viscidity/stickiness of water-epoxy resin as well as good flexibility of SBR latex, the strong interaction between the space networks formed by them restrict the displacement of emulsified asphalt particles and flow of emulsified asphalt colloid, improve the cohesion and flexibility of emulsified asphalt, and substantially increase the flexibility and viscosity of emulsified asphalt.

Research found that, along with the increase in amount of SBR latex and water-epoxy resin that have been added, the concentration of SBR latex and water-epoxy resin in asphalt will increasingly get high, for example, particles of SBR latex and water-epoxy resin can splice with each other and form space network in asphalt, and make the asphalt present excellent performances belonging to rubber and resin themselves. Asphalt and SBR latex as well as modified asphalt materials after epoxy resin not only maintain main physical and mechanical natures of the base asphalt material and recover part of the flexibility and plasticity of raw rubber and epoxy resin, but also change the base asphalt material's physical characteristics like temperature sensitivity, elasticity, viscidity and durability, therefore, a modification result is achieved.

5 An Engineering Application Example

In the maintenance for Zhaoqing section of the State Highway 321, asphalt emulsion modified by compound of water-epoxy resin emulsion and SBR latex was ever used as prime coat. Before construction of lower seal coat of asphalt concrete, poured the prime coat on the surface of base layer. The prime coat was based on modified PC-2 asphalt emulsion, and the modifier consisted of water-epoxy resin emulsion and SBR latex, the compositions were added and mixed into in accordance with proportion as bellow: asphalt emulsion 100, water-epoxy resin 2, solidifying agent equal to 20% of water-epoxy resin, SBR latex 2. the used amount of PC-2 asphalt emulsion equals to 1.5kg/m^2. The modification is realized on site when carrying out construction.

Poured a layer of modified asphalt emulsion on the base layer, which may penetrate a certain depth into the cement stabilization gravel of the base layer, and the depth is generally 5mm-10mm. in the penetrated area, organic material (asphalt and epoxy resin and SBR) filled in the gap of inorganic materials, and formed a special structure layer, which is called the coupling layer. Coupling layer, which contains organic materials like water-epoxy resin good viscosity and SBR latex with good flexibility, made it perfectly adhere to flexible pavement and achieved a good effect of flexibility, at the same time, coupling layer itself acted as an integral part of the semi-rigid roadbed, and thus can completely resolve the problems in connection with adhesion and anti-deformation and flexible pavement and semi-rigid bond roadbed. Under the action of load, the road pavement consisting flexible materials only plays a role of transferring load and resisting deformation, what play the role of bearing the load and resisting the pressure is the roadbed. Coupling layer is based on semi-rigid roadbed material incorporating with flexible materials. As its toughness and viscidity are much better than that of the roadbed, it show a certain degree of anti-deformation capacity, which is equivalent to an increase in the thickness of the flexible structure layer, and therefore plays a certain role in improving the anti-deformation ability of the road payment. Coupling layer is formed by means of filling in the gaps on the surface of roadbed with flexible materials, which facilitate the of the roadbed to show a good water-tightness, and therefore can prevent the surface water from penetrating into and causing erosion to the roadbed and avoid the underground capillary water from rising, which, in case of use in combination with waterproofing layer (lower seal coat), not only can solve the problem involved in viscidity of waterproof layer (lower seal coat), but also can achieve a better waterproof effect. Thanks to the coupling layer's waterproof feature, internal moisture in the roadbed is not easy to evaporate in hot weather and thus sprinkling maintenance is needed to be taken into account, as a result, maintenance cost saving becomes possible.

According to situation and feedback information from the construction site, prime coat made of the asphalt emulsion modified by compound of water-epoxy resin emulsion and SBR latex shows a road-purpose performance much better than those of ordinary asphalt emulsion and asphalt emulsion modified by SBR latex.

6 Conclusions

Study and research on the performances of the asphalt emulsion modified by compound of water-epoxy resin emulsion and SBR latex show that, in the aspects like low-temperature cracking, high temperature stability, adhesion and durability, it obviously exceeds ordinary asphalt emulsion, SBR latex modified asphalt emulsion and water-epoxy resin modified asphalt emulsion. Generally speaking, asphalt emulsion modified by compound of water-epoxy resin emulsion and SBR latex has advantages as follows:

(1) Obviously increase the softening point of asphalt; increase in softening point can improve the wear resistance under high temperature and meanwhile maintain a good ductility at low temperatures, therefore, it can acclimatize itself to an application region where the climate varies greatly.

(2) Improve the mechanical property of asphalt: modified asphalt can reduce or even eliminate permanent deformation cause by pressure induced by the wheels.

(3) Capability of self-draining: modified asphalt shows a high adhesion. Even though contact area between large stones is very small, asphalt material is enough to bond them firmly together and maintain a certain degree of flexibility so that it can quickly restore the original shape after action by stress. Rain can pass through the porous structure on the top layer of rough and un-tight road pavement formed by large-sized uniform gravels and penetrate into the roadside drains.

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Table 4 Performances and Indexes of asphalt emulsion modified by compound of water-epoxy resin emulsion and SBR latex.

Sorts	weight of screen residue /%	Electric charge	Storage stability /%	Viscidity /Pa·s	Adhesion		
					Granite	Limestone	Basalt
Emulsified asphalt (Asphalt emulsion)	0.30	+	3.0	18.6	Good	Good	Excellent
Water-epoxy emulsified asphalt	0.20	+	2.7	38	Good	Excellent	Excellent
SBR latex emulsified asphalt	0.20	+	2.7	32	Good	Excellent	Excellent
Emulsified asphalt modified by compound	0.18	+	2.6	40	Excellent	Excellent	Excellent

Table 5 Performances and indexes of residues of asphalt emulsion modified by compound of water-epoxy resin

emulsion and SBR latex.

Sorts	Penetration,25□ /0.1mm	Softening point /□	Ductility,5□ /cm
Emulsified asphalt (Asphalt emulsion)	99	46	Brittle Fracture
Water-epoxy emulsified asphalt	81	53	4.3
SBR latex emulsified Asphalt	74	49	8.4
Emulsified asphalt modified by compound	62	55	9.7

Table 6 Ductility test of residues of modified asphalt emulsions with different contents of latex

Amount of modifier mixed in /%		0	2.0	4.0	6.0
5□ Ductility /cm	SBR latex emulsified asphalt	0.8	6.1	8.4	18.5
	Water-epoxy resin emulsified asphalt	0.2	2.6	4.3	8.3
	Emulsified asphalt modified by compound	1.2	7.8	10.2	21.3

Table 7 Brittle point test of residues of modified asphalt emulsions with different contents of latex

Amount of modifier mixed in /%		0	2.0	4.0	6.0
Brittle point /□	SBR latex emulsified asphalt	-9.2	-15.8	-20.6	-23.1
	Water-epoxy resin emulsified asphalt	-6.2	-9.4	-14.2	-16.5
	Emulsified asphalt modified by compound	-11.4	-17.1	-24.7	-26.4