Analysis on Preparation and Properties of Waterborne Epoxy Emulsified Asphalt Mixture

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Abstract: asphalt pavement construction and maintenance at normal temperature is one of the key research and development directions in highway construction. The development and application of emulsified asphalt mixture for pavement not only conform to the development trend of asphalt pavement technology, but also conform to the requirements of national environmental protection. The traditional asphalt mixture is hot-mix asphalt mixture, which uses viscous asphalt as binder, and needs to heat asphalt and aggregate to a high enough temperature before mixing. This not only consumes and wastes a large amount of energy and produces various wastes that pollute the environment, but also seriously damages the health of constructors. Water-based epoxy resin can be cured at room temperature or in a humid environment. It has the characteristics of safety, environmental protection and low cost. Compared with the performance of hot-mixed asphalt mixtures, water-based epoxy resin modified emulsified asphalt mixtures have superior high-temperature performance, insufficient low-temperature performance and fatigue performance, and basically maintain consistent water stability. Based on this, the preparation and performance of water-based epoxy emulsified asphalt mixtures are discussed in this paper.

1. Introduction

With the development of economy, driving comfort has been paid more and more attention. The traditional cement concrete pavement is easy to be damaged, resulting in a large amount of maintenance costs [1]. Asphalt pavement has been widely used in urban roads and expressways and has become the main trend of highway construction. With the rapid growth of traffic volume, the requirements for pavement quality are increasing day by day. However, the traditional hot mix asphalt mixture has insufficient high temperature performance, large emissions and serious pollution during mixing, which cannot meet the quality requirements of the existing traffic load on the pavement [2]. The traditional asphalt mixture is hot-mix asphalt mixture, which uses viscous asphalt as binder, and needs to heat asphalt and aggregate to a high enough temperature before mixing [3]. This not only consumes and wastes a large amount of energy and produces various wastes that pollute the environment, but also seriously damages the health of constructors [4]. Epoxy resin has high viscosity, chemical stability and high strength after curing. Adding water-based epoxy resin into emulsified asphalt to modify emulsified asphalt can improve the pavement performance of the mixture, such as high temperature stability, low temperature crack resistance, water stability, wear resistance and so on, and is convenient for wide application in engineering [5]. Strengthening the research on the maintenance and repair technology of asphalt pavement and extending the service life of asphalt pavement will have a good market prospect [6].

As china gradually builds a reasonable layout and complete function of the highway network, the focus of highway development has gradually shifted from planning and construction to improving maintenance methods, standardizing and improving management, improving service quality, and improving supporting facilities [7]. Water-based emulsified asphalt technology is a new idea to improve the inherent defects of emulsified asphalt by adding different substances to meet its technical requirements in asphalt pavement maintenance and maintenance [8]. In order to adapt to the new trend of highway construction and development, the direction of construction development must be changed. From the past, the main development direction of infrastructure construction was gradually changed to new project construction, maintenance of completed projects, facility

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management, and equal emphasis on improving services. Management and service work [9]. Water-based epoxy resin can be cured at room temperature or in a humid environment. It has the characteristics of safety, environmental protection and low cost, and is well compatible with emulsified asphalt. Normal temperature asphalt mixture, also known as cold mix, is an asphalt mixture that is mixed and paved at normal temperature with emulsified asphalt or liquid asphalt and minerals [10]. Compared with the performance of hot-mixed asphalt mixtures, water-based epoxy resin modified emulsified asphalt mixtures have superior high temperature performance, insufficient low temperature performance and fatigue performance, and basically have the same water stability performance [11]. Based on this, the preparation and performance of water-based epoxy emulsified asphalt mixtures are discussed in this paper.

2. Preparation Technology and Properties of Epoxy Resin Modified Emulsified Asphalt

2.1 Raw Materials and Their Properties

The kinds of raw materials and their technical properties have great influence on the properties of the binder and its mixture. Waterborne epoxy resin is a liquid phase system material with epoxy resin particles as dispersed phase and water as continuous phase. It can be cured at room temperature and in humid environment, while retaining the characteristics of good thermal stability, high strength and strong adhesion of epoxy resin. According to the hardness of modified waterborne epoxy resin, waterborne epoxy resin can be divided into rigid waterborne epoxy and flexible waterborne epoxy. Rigid waterborne epoxy has good storage stability and is not easy to demulsify. Flexible storage stability is poor and easy to delaminate after long-term storage. Emulsion state can be restored by stirring without affecting the quality of waterborne epoxy itself. Epoxy resin has strong bonding ability, which can consolidate loose aggregate and improve the waterproof performance of pavement. The combination of the two will improve the flexibility and weatherability of the system [12]. Using waterborne epoxy resin as modifier of emulsified asphalt can improve the high temperature performance of emulsified asphalt. The addition of cement has a certain influence on the demulsification of emulsified asphalt and the working performance of waterborne epoxy emulsified asphalt cement. Due to the polar difference between waterborne epoxy resin and emulsified asphalt, cement is needed in waterborne epoxy emulsified asphalt mucilage to connect emulsified asphalt and waterborne epoxy resin. The selection of cement conforms to the technical indexes shown in table 1.

Table 1 Technical Indicators Of Cement

Type	Setting time/min		Rupture strength/MPa		Compressive strength/MPa	
	Initial setting time	Final setting time	3d	28d	3d	28d
Cement A	60	120	6.2	10.5	47	59
Cement B	25	40	5.8	9.4	29	49

2.2 Preparation and Technology of Waterborne Epoxy Emulsified Asphalt

Cationic emulsified asphalt contains a large amount of water, which requires demulsification and film formation to form strength in use. In this paper, two cationic emulsified asphalts with 59% theoretical solid content are selected, and the actual solid content of emulsified asphalt A is 55.2% and the solid content of emulsified asphalt B is 49.8% through the performance test of raw materials. Considering the solid content and long-term storage performance of emulsified asphalt, emulsified asphalt A is preferred as the emulsified asphalt material in this paper. Water-based epoxy resin system A, both components have relatively low solid content, ranging from 40% to 50%, is easy to stir in the stirring process and has good working performance. General waterborne epoxy curing system consists of waterborne epoxy resin soluble in water and corresponding curing agent. There are many kinds of raw materials for preparing waterborne epoxy resin and curing agent, and there are also many preparation methods. This makes water-based epoxy resin curing system have many combinations, different kinds of water-based epoxy resin and curing agent combination form, the nature of the reaction products are also very different. The solid content of the two components in

the water-based epoxy resin system B is above 80%, which has good compatibility with emulsified asphalt. The construction process of waterborne epoxy emulsified asphalt requires a certain holding time, which will destroy the setting process of cement in the compaction process. Therefore, the cement with a later setting time should be selected. The cement selected in this paper is Type A cement.

Water-based epoxy system (10%, 20%, 30%) and cement (10%, 20%, 30%) with different proportions are added into emulsified asphalt with fixed quality, and consolidation time, homogeneity and tensile test are carried out in turn. While testing the consolidation time of water-based epoxy emulsified asphalt, record the mixing difficulty of water-based epoxy emulsified asphalt with different proportions and record the test results as shown in Table 2.

Table 2 Consolidation Time Test Results of Waterborne Epoxy Emulsified Asphalt

Water-borne epoxy resin content	Cement content	Difficulty of mixing	Consolidation time/min
10%	10%	Easy to stir	320
20%	10%	Easy to stir	220
30%	10%	It's hard to stir	50
10%	20%	Easy to stir	290
20%	20%	Easy to stir	100
30%	20%	It's hard to stir	40
10%	30%	Easy to stir	110
20%	30%	It's hard to stir	50
30%	30%	It's hard to stir	30

3. Factors Affecting Curing of Waterborne Epoxy Resin

The curing agent in the waterborne epoxy resin is dissolved in water, and the epoxy resin is dispersed in water in the form of dispersed phase. After long-term storage, part of the water in the waterborne epoxy emulsion volatilizes, the ratio of epoxy to water changes, and the dosage ratio of curing agent also changes. With the evaporation of water, the epoxy resin latex particles contact each other to form a tightly packed structure, and the residual water and curing agent molecules are located at the gaps of the dispersed phase particles of the epoxy resin. With the increase of temperature, the demulsification and curing speed of waterborne epoxy are significantly improved. In the emulsion type waterborne epoxy resin system of curing agent, the surface of epoxy resin is coated with a layer of curing agent. Because the molecular structure of curing agent is modified, its properties are hydrophilic and lipophilic. When the concentration of waterborne epoxy resin continues to increase, waterborne epoxy resin particles will form a network structure through association of macromolecules, and the network structure is interconnected and intertwined, thus increasing the viscosity of the system. When the amount of water-based epoxy resin is continuously increased, the concentration of epoxy resin reaches a certain degree, and the epoxy resin will undergo local flocculation, segregation and floating, thus the mass difference of emulsified asphalt residues taken out from the upper and lower regions of the stability tube will be reduced. In terms of curing and bonding effect, the rigid epoxy film is not easy to scrape off, has strong adhesion to the surface, and has higher hardness.

For the problem of local or even overall white color of rigid waterborne epoxy after curing, it should be caused by incomplete volatilization of water in rigid epoxy. To prove this problem, a weighing step was added during the test to calculate the mass loss after curing of waterborne epoxy. The results are shown in Table 3.

Table 3 Mass Loss Ratio after Curing of Waterborne Epoxy At Different Temperatures

Epoxy type	Normal temperature	45℃	65℃
Rigidity	7.6%	39.8%	46.4%
Flexible	47.5%	48.3%	50.2%

Demulsification of waterborne epoxy and volatilization of water are not only related to temperature, but also the thickness is an important factor. For rigid waterborne epoxy, which is

difficult to demulsify, samples of 0.5mm, 1.0mm and 1.5mm are respectively prepared and cured at three temperatures, and the mass loss is weighed and calculated. The results are shown in Table 4.

Table 4 Mass Loss Ratio of Rigid Epoxy with Different Thickness At Different Temperatures

Film thickness	Normal temperature	45℃	65℃
0.5mm	6.8%	36.7%	45.3%
1.0mm	31.9%	47.5%	48.2%
1.5mm	45.6%	49.1%	49.8%

The adhesion of flexible epoxy to the surface of substrate is relatively weak, especially on the surface of glass, and the cured film has certain toughness. For different surfaces, the demulsification and curing speed of waterborne epoxy also changes. The concrete surface is relatively fast, while the glass and metal surfaces are relatively slow. When the content of water-based epoxy resin is low, the long chains in the epoxy resin molecular structure adsorbed on the surface of asphalt particles can be simultaneously adsorbed on the surfaces of other asphalt particles, thus generating a bridging effect between the asphalt particles. The concentration of emulsified asphalt in the lower part of the stability tube will increase and the stability value will increase as the tendency of flocculation and agglomeration of asphalt particles increases. Water continues to evaporate, the concentration of curing agent increases, the curing agent diffuses into the dispersed phase under the push of chemical sites, and curing reaction occurs at the interface and inside of the dispersed phase particles of epoxy resin.

4. Conclusion

Waterborne epoxy emulsified asphalt mixture is an asphalt-based material for normal temperature mixing construction. The higher the curing temperature, the faster the curing speed and strength of waterborne epoxy resin will increase. An increase in the amount of waterborne epoxy resin will greatly shorten the consolidation time of the mortar. Excessive amount of waterborne epoxy resin will cause poor performance of the mortar and even rapid agglomeration. The effect of temperature on the adhesive force of waterborne epoxy-emulsified asphalt is mainly reflected in the growth rate of curing stage. When waterborne epoxy-emulsified asphalt is completely cured, the effect of temperature gradually weakens. Epoxy emulsified asphalt mixture has excellent high temperature performance, which is far better than emulsified asphalt mixture and hot mix asphalt mixture. No matter cement surface or asphalt surface, the final bonding strength of waterborne epoxy-emulsified asphalt to the surface increases with the increase of the content, and the growth rate changes from urgent to slow. Epoxy resin is a thermosetting material, which solidifies at high temperature and becomes brittle at low temperature. Compared with hot mix asphalt mixture, the high temperature performance of waterborne epoxy resin modified emulsified asphalt mixture is significantly improved, but the low temperature performance and fatigue performance are decreased, and the water stability performance is basically the same. Therefore, it is suggested that the waterborne epoxy resin modified emulsified asphalt mixture should be used in high temperature and rainy areas.

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