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A pothole patching material for epoxy asphalt pavement on steel bridges: Fatigue test and numerical analysis

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HIGHLIGHTS

- A fine gradation patching material is developed for epoxy asphalt pavement.
- The generalized Maxwell model is used to analyze the viscoelastic response.
- The patching interfaces are vulnerable to cyclic load due to stress concentration.
- The increase of viscoelastic difference causes worse stress state on patching interface.

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ABSTRACT

Various patching materials and field procedures have been studied for pothole repairing on highway asphalt pavements. However, only a few publications have focused on patching materials for epoxy asphalt pavement on steel bridge decks. Considering the requirements of steel deck pavements, a patching material was developed using a fast cure thermosetting binder and a fine gradation. Then, to evaluate the fatigue performance of patched structure, a three-point bending fatigue test was conducted on three types of composite beams under four different stress ratios. After that, the Prony series presentation of the generalized Maxwell model was used to analyze the viscoelastic response of different patched beams and the effect of viscoelastic difference. The results showed that the fatigue test performed well on exposing the vulnerable parts of patched structures. The developed patching material had a smaller dynamic modulus and performed better in fatigue resistance than commonly used epoxy asphalt mixture. Nevertheless, with the growth of viscoelastic difference between patching material and original material, the stress state on vertical patching interface becomes worse, and the interface becomes easier to fracture under cyclic load.

1. Introduction

Epoxy asphalt concrete (EAC) has been proved as a better pavement material for steel bridge pavement than other conventional asphalt mixtures [1]. Due to its good performance in durability, high temperature stability and waterproofness, EAC has been widely used on the steel bridges in China recently. However, according to the investigations [2], distresses caused by various factors still appear in the EAC layers of some steel bridge pavements. Among all the distresses, potholes are bowl-shaped holes existing on the surface of EAC layers [3]. Because of the poor field construction quality, fatigue failure or falling objects from vehicles, part of the EAC pavement surface would break into pieces and be pulled up by travelling wheels, thus a pothole could form on the pavement surface. In addition, the water inside the potholes would cause more damage under the vehicle load and accelerate the pothole development. Pothole significantly reduces pavement performance level and service life, and is one of the most aggravating pavement distresses for traffic safety.

Pothole has been a common distress on highway asphalt pavements. Various materials and field procedures for pothole repair have been studied and used by researchers and highway agencies. The Strategic Highway Research Program (SHRP) [4,5] evaluated the performance of different patching materials and various repair techniques by field experiment and investigations. It was found that bituminous hot mixtures have higher quality but limited applicability under different weather conditions while cold-mixed mixtures have lower quality but are workable under most weather conditions. New Jersey Department of

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Transportation [6] tried the blade resistance test and rolling sieve test to evaluate the workability and the cohesion of patching materials. Fragachan [7] proposed an accelerated testing procedure for evaluating pavement patching materials under the simulation of traffic loading and environmental conditions. Dong et al. [8] investigated and modified special laboratory procedures to evaluate the bonding, freeze-thaw resistance and rutting potential of the patching materials. Yuan et al. [9] identified a polymeric material, dicyclopentadiene (DCPD) resin to become an ultra-tough material for pothole repair. Li et al. [10] evaluated the performance of a rapid patching material which combines magnesium phosphate cement and emulsified asphalt.

For pothole repair on steel bridge pavements, only a few studies have been published. Luo et al. [11] investigated the performance of EAC pavement on the Second Nanjing Yangtze River Bridge and pointed out that the dynamic water pressure in the early cracks would decrease the fatigue life of EAC and contribute to the development of potholes. Huang et al. [12] analyzed the pavement damages of the Jiangyin Bridge and then evaluated the performance of EAC pavement and “gussasphalt mixture + epoxy asphalt mixture” structure by laboratory tests as well as field tests. They suggested the EAC to be used for the pavement overhaul on the bridge.

To determine the semi-permanent patching material and field procedure on EAC pavement, the differences from highway pavements in pavement structure, pavement materials and work conditions should be considered. The thickness of EAC pavement on steel bridges usually ranges from 50 to 60 mm which is much thinner than highway pavements, and the aggregate gradation with a 9.5 mm nominal maximum size is also finer than that for highways. Moreover, the work conditions of steel bridges require the EAC pavement patching materials to perform well in workability, rutting resistance, waterproofness, adhesion and durability.

On the basis of above considerations, a fine gradation epoxy asphalt pavement patching material (EAPP) is proposed in this research. This patching material was prepared using a fast cure thermosetting binder, limestone filler and basalt aggregates. In order to evaluate the fatigue performance of EAPP, three types of composite beams were fabricated and tested in three-point bending fatigue test. In addition, the Prony series presentations of the generalized Maxwell model for different materials were obtained and used to analyze the viscoelastic response of patched beams.

2. Experimental program

2.1. Raw materials

The EAPP is composed of epoxy asphalt binder, limestone filler and basalt fine graded aggregates. The epoxy asphalt binder is composed of TAF-EPOXY and 70# asphalt. TAF-EPOXY is a mixture of epoxy resin and curing agent. It cures fast thus can reduce the traffic control time after patching. The 70# asphalt is a type of asphalt binder usually used for heavy traffic in China with a penetration value from 60 to 80 (25 °C, 5 s, 100 g) [13]. The basic information of the epoxy asphalt binder is provided in Table 1.

Table 1
Technical index of epoxy asphalt binder.

Technical indexes	Criteria	Test method
Mass ratio (TAF-EPOXY:70# asphalt)	1:1	
Tensile strength (MPa, 23 °C)	⩾2.0	ASTM D638
Fracture elongation (%, 23 °C)	⩾100	ASTM D638
Viscosity 170 °C × 1 h (mPa · s)	⩽2000	ASTM D4402

With considerations on workability, water resistance and adhesion performance, the patching material should have low air-void content, easy handling, and a strong interface bonding with the original pavement. Therefore, a fine aggregate gradation was selected for the patch material as shown in Fig. 1. The asphalt content was determined as 9.8% by conducting the Marshall test on specimens.

The EAC has been widely used on the pavements of steel bridges such as the 2nd Yangtze River Bridge, the Runyang Cable Stay and the Sutong Bridge. In this study, the asphalt binder of EAC was 2910-type local epoxy asphalt and the asphalt content is 6.5%. The details about the binder and the mix design of EAC can be found from [14].

2.2. Fatigue test method

2.2.1. Specimen fabrication

Composite beams were fabricated to evaluate the performance of EAPP in patched EAC pavement structure. Firstly, a 50 mm-thick EAC layer was filled and compacted in a 300 mm × 300 mm mold. After curing, a groove (25 mm deep × 100 mm wide) was cut in the middle of the specimen. The surface of the groove was cleaned and brushed with epoxy asphalt adhesive layer. After that the EAPP was poured into the groove and compacted manually. After curing for 24 h at 25 h, the specimen was cut into three types of composite beams sized 300 mm × 40 mm × 50 mm as shown in Fig. 2. Beam I consists of two 25 mm-thick EAC layers. Beamα is made up of an upper EAPP layer and a lower EAC layer. In Beamβ, the middle part of the upper layer is EAPP while the other parts are EAC.

2.2.2. Test condition

The fatigue test was conducted on a three-point bending fatigue test system as shown in Fig. 3. The test temperature was set at 15 h according to local conditions. The test was carried out in load control using a sinusoidal load with a 10 Hz frequency, and the stress ratios (the ratio of applied peak load to the bending failure load) were selected as 0.3, 0.4, 0.5 and 0.6. The load was applied in the middle of the beam and the span of the beam was 250 mm. The stiffness modulus (tensile stress divided by tensile strain at middle transverse section) was recorded at every load cycle until the beams were completely destroyed. Fatigue failure is defined at 50% reduction with respect to the initial stiffness of the composite beams and the corresponding number of load cycle is defined as fatigue life.

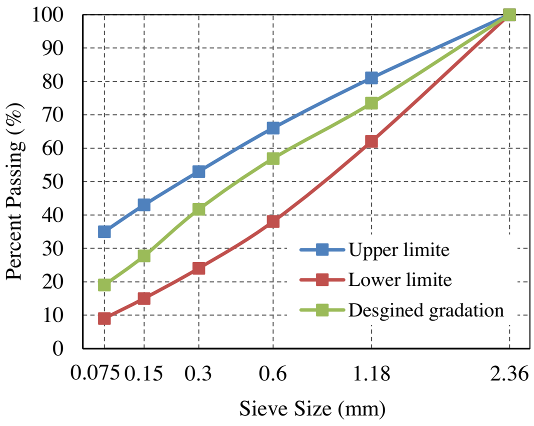

Fig. 1. Aggregates gradation of EAPP.