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Development of a lightweight epoxy asphalt mixture for bridge decks

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HIGHLIGHTS

- We tested granulated and rounded lightweight aggregate to use in epoxy asphalt mix.
- Mix with higher lightweight aggregate percentage necessitates higher asphalt content.
- The mix performance varies with the shapes and percentages of lightweight aggregate.
- An epoxy asphalt mix with 70% rounded lightweight aggregate is proposed.

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ABSTRACT

A lightweight epoxy asphalt mixture (LEAM) was developed by replacing part of the basalt aggregate in an epoxy asphalt mixture with lightweight aggregate. These mixtures were evaluated as alternative to basalt mixes for deck paving of the TianJin bascule bridge in China. Nine different types of LEAM with varying lightweight aggregate shapes and percentages were designed and tested. The results indicated significant variations in performance. This approach was deemed viable based on FEM analyses that indicated significant stress reductions using lightweight material. Based on the findings it is recommended that a LEAM with 70% rounded lightweight aggregate be used to reduce the deadweight of the deck paving and optimize performance in terms of rutting and cracking resistance.

1. Introduction

Epoxy asphalt mixtures have proved to be excellent materials for deck paving on steel bridges [1] and are widely used throughout the world. In China, basalt aggregate is traditionally used in these mixes to provide improved compressive strength and anti-abrasion properties. Some steel bridge structures, such as bascule or drawbridges and long-span bridges, require deck paving materials that not only have acceptable performance but also be as lightweight as possible. To alleviate the additional weight of basalt, epoxy asphalt mixtures using a lightweight variant were evaluated. Lightweight aggregates (LWA), a synthetic material manufactured from waste products, provide an environmentally friendly alternative to basalt, an expensive and dwindling natural resource.

LWA is used extensively in cement concrete [2] but has found limited applications in asphalt concrete, where it is used primarily for surface treatments on low volume roads. Wycoff [3] was the first to study the application of LWA in asphalt concrete and subsequent research has reported adequate performance in highway pavements [4]. Qian et al. [5] report the use of LWA in epoxy asphalt concrete for bridge paving with focus on the performance of the material – a detailed design procedure for the application of LWA in epoxy asphalt concrete is lacking.

This paper reports on the development of a lightweight epoxy asphalt mixture (LEAM) developed specifically for the TianJin bascule bridge, which opens up to 85° as shown in Fig. 1. The LEAM used in deck paving of steel bridges was developed by replacing the basalt aggregate in the epoxy mixture with LWA. Applicable LWAs were sought and categorized by shape as either granulated (GLWA) or rounded (RLWA). Nine different types of LEAM with varying LWA shapes and percentages were designed using the

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(1) Closed state of the bridge (2) Open state of the bridge

Fig. 1. The TianJin Bascule Bridge.

Table 1
Properties of the epoxy asphalt binder.

Property	Test result	Technical requirement[a]	Test method
Tensile strength (MPa)	3.26	⩾1.52	ASTM D638
Elongation at break (%)	242	⩾190	ASTM D638
Absorption (%)	0	⩽0.3	ASTM D4469-11
Viscosity from 0 to 1 Pa s (120 °C, min)	110	⩾50	ASTM D4402

[a] Technical requirements of bridge deck paving for epoxy asphalt [1].

Marshall test. The performance of the LEAMs were tested using the indirect tensile strength test, the Hamburg wheel tracking test and the freeze–thaw splitting test, each of which are used in China for evaluating the performance of hot-mix asphalt. A 3D finite element model of the TianJin bascule bridge with deck paving was established using ABAQUS to investigate the range of stresses the mixture would be subjected to and the stress reductions possible using lightweight aggregate as the deck paving material.

2. Materials

Epoxy asphalt comprises asphalt binder mixed with epoxy, which is added and mixed with graded aggregates. The epoxy asphalt binder used for the study was a popular Chinese epoxy asphalt. It consisted of two components, component A was an asphalt material with curing agent and component B was an epoxy resin. This epoxy asphalt binder was prepared by mixing component A and component B at a fixed ratio of 2.9:1. The properties of the epoxy asphalt binder are listed in Table 1. Asphalt mixes using both basalt and lightweight aggregate were designed and tested. The basalt aggregate typically used for steel bridge paving has a density of 2,920 kg/m^3. The lightweight aggregate was ceramisite and is provided in both rounded and granular or irregular shapes as shown in Fig. 2. In contrast, basalt aggregate is angular in shape. These aggregates meet the Chinese technical requirements for materials used in bridge deck pavements. Table 2 shows the relevant material properties of the lightweight aggregates evaluated. The acronyms RLWA and GLWA are used to distinguish between LWA comprising rounded or granular aggregates respectively. The bulk density of the lightweight aggregates is about 30% of the density of basalt. The grading limit of the mixes is shown in Table 3.

Table 2
Properties of the GLWA, RLWA and basalt aggregate.

Categories index	GLWA[d]	RLWA[e]	Basalt aggregate	Technical requirement	Test method
Density (kg m^{-3})	820	890	2.920	600–900[a]	ASTM C127-88
Compressive strength (MPa)	7.6	7.3	13.8	6.5 Min.[b]	ASTM D7012
Water absorption (%)	3.8	3.6	1.0	8 Max.[b]	ASTM C127-89
Los Angeles abrasion (%)	21.2	18.6	12.7	22 Max. [b]	ASTM C535
Flat and/or elongated (%)	2.4	0.3	3.2	10 Max.[c]	ASTM D4791
Angularity (1 fracture face/2 fracture faces) (%)	99/93	–	99/95	95/90 Min.[c]	ASTM D5821

[a] Chinese national technical standard for lightweight aggregate (GB/T 17431.1-1998).
[b] Technical requirements of bridge deck paving for basalt aggregate [1].
[c] Technical requirements from ASTM (based on severe traffic level and layer position).
[d] Granular light weight aggregate.
[e] Rounded light weight aggregate.

3. Laboratory testing

3.1. Mix design

The Marshall mix design method based on ASTM D6926 [6] and D6927 [7] was used to design and prepare specimens for testing.

(1) RLWA (2) GLWA (3) Basalt aggregate

Fig. 2. Shapes of different coarse aggregate evaluated.