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Review

Alternate uses of epoxy asphalt on bridge decks and roadways

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HIGHLIGHTS

- Epoxy asphalt possesses unique superior properties.
- Epoxy asphalt has wide applications beyond surfacing material for orthotropic deck.
- Epoxy asphalt is a suitable candidate material for long life pavements.
- The high cost of epoxy asphalt may be justified by its long service life.

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ABSTRACT

In the last two decades, epoxy asphalt has seen its wide application as a bond coat and binder for an approximately 50 mm thick dense-graded epoxy asphalt concrete pavement on numerous orthotropic bridge steel decks around the world, particularly in East Asia. Bridges paved with this system include the Sutong Bridge, China's longest main span cable-stayed bridge, the Xihoumen Bridge, China's longest main span suspension bridge, and the new San Francisco–Oakland Bay Bridge in the United States. However, efforts have also been spent to take advantage of the unique properties of epoxy asphalt to solve several other difficult pavement challenges. Some examples of these additional applications of epoxy asphalt include relatively thin dense-graded overlays on concrete bridge decks, durable open-graded surface mixtures on concrete bridge decks or roadways, and dense-graded mixtures for long-life roadway pavements. This paper describes problems faced and solved with epoxy asphalt surfacings on various projects other than the wide spread dense-graded wearing courses on orthotropic decks and discusses the potential application of epoxy asphalt in roadway pavements.

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1. Introduction

Beginning in the mid-1990s, China has undergone a rapid growth in transportation infrastructure construction, and has built numerous long-span bridges across the Yangtze River, Yellow River, and many rivers and bays along the east coast. Due to its light weight, structural efficiency, and good seismic performance, an orthotropic deck has been used on most long-span bridges [1]. An orthotropic deck is a flat, solid steel deck stiffened by a grid of deck ribs welded to framing members like floor beams and girders. This deck structure, coupled with a long span, results in deflections causing localized strains in the deck pavement under traffic and wind loading [1]. With frequent truck wheel overloading and high deck temperatures (up to 70 °C) during prolonged summers, serious early distresses were observed on bridges that used polymer modified asphalt, stone mastic asphalt (SMA), or gussasphalt for deck surfacing. Bridges with noted short-lived wear courses included many critical long-span bridges such as the Humen Cable-stayed Bridge (main span 888 m) [2,3] and the Jiangying Suspension Bridge (main span 1385 m) [3]. As a solution for the premature pavement failure problem, epoxy asphalt was introduced into China and first applied on Nanjing Second Yangtze River Bridge (NSYRB) in 2000. The deck surfacing on NSYRB is 50 mm thick dense-graded epoxy asphalt concrete with a nominal maximum aggregate size (NMAS) of 9.5 mm, and was placed in two 25-mm lifts with an epoxy asphalt bond coat applied to both the zinc primed steel deck plate and in between lifts [4].

Epoxy asphalt is a two-phase chemical system in which a thermosetting acid epoxy (continuous phase) is blended with conventional asphalt (disperse phase) [5]. Before mixing, epoxy asphalt is typically stored in two separate components: epoxy resin (Part A) and curing agent/asphalt blend (Part B). Table 1 shows typical properties of the two components [4,5]. Once the two components are mixed, epoxy resin and curing agent begin an irreversible chemical reaction that increases the stiffness and strength of the mixture. After curing, epoxy resin forms a three-dimensional continuous phase in which asphalt is dispersed [6]. Such a mixture is not only tough but also elastic at typical pavement service temperatures up to 50 °C, providing high fatigue resistance [7–9]. Epoxy asphalt is a thermoset material, does not soften as much as conventional asphalt binders at high temperatures, has good resistance to aging and chemical attack and is impermeable to water and salts, in part due to its low void pavement design [6,10].

After being opened to traffic in 2001, the deck pavement on NSYRB has exhibited superior performance compared to other types of asphalt mixtures placed on other bridges [11,12]. This success spurred a wide application of epoxy asphalt for paving orthotropic steel deck bridges constructed afterwards in China, including some of the very long main span bridges such as the Sutong Bridge (main span 1088 m) and the Xihoumen Bridge (main span 1650 m) [13]. Mix design and pavement structure on those bridges, are all similar to those used on the NSYRB, with slight variations.

Dense-graded epoxy asphalt concrete has also been used in other parts of the world for paving or resurfacing steel bridge decks [14]. For example, the Westgate Bridge in Australia was paved with epoxy asphalt concrete in 1978 [15]; the Erskine Bridge in Scotland was surfaced with epoxy asphalt mastic concrete in 1994 [16]; the Humber Bridge in the U.K. was resurfaced with an epoxy asphalt sand system in 2001–2002 [17,18]; and the Lions Gate Bridge was surfaced with a 38 mm thick layer of epoxy asphalt concrete in 1975, and re-decked and resurfaced with epoxy asphalt concrete in 2002 [19]. More project examples can be found in the literature [20,21].

Over the last two decades, numerous research and technical papers have been published on various aspects of applying the dense-graded epoxy asphalt mix on orthotropic bridge decks, ranging from mix design modification, mechanistic analysis, construction details, structural analysis, performance evaluation, and maintenance techniques [22–36]. A quick survey of these papers may provide the impression that paving orthotropic bridges in dense-graded mixes is the only area of application of epoxy asphalt. However, this is not the case.

The first application of dense-graded epoxy asphalt on roadways was in the mid-1960s by the California Bay Bridge Authority. A product originally developed by Shell (EPON-Epoxy Asphalt) was used to pave the steel deck of the San Mateo–Hayward Bridge in 1967, has been performing extremely well [22] and is still in service today, 47 years later. As a superior binder material, epoxy asphalt is not solely limited to dense graded epoxy asphalt concrete deck surfacings, but provides significant benefits in other asphalt mixture types and applications. Over the years, engineers have successfully taken advantage of the unique properties of epoxy asphalt to solve difficult pavement problems. Examples of additional applications of epoxy asphalt include:

- Airfield and port pavements where high strength, durability and chemical resistance are essential needs.
- Thin dense-graded overlays on concrete bridge decks to provide waterproofing and skid resistance. The surfacing of the San Francisco–Oakland Bay Bridge in the U.S. used this system that has remained in service since 1976.
- Epoxy asphalt chip seals approximately 10 mm thick applied on orthotropic steel decks in the shop before installation of the deck system on the bridge for use as a long lived (up to 10 years) temporary wearing surface prior to paving. This method has been used on the orthotropic steel deck replacement of the old concrete decks of the Golden Gate Bridge in the U.S. and the Lions Gate Bridge in Canada.
- Either field or shop applied 25–35 mm thick dense graded first layer used as a permanent waterproofing and stiffening layer for orthotropic steel decks to be surfaced with a sacrificial wearing surface. The Ben Franklin Bridge in Philadelphia in the U.S. paved in 1984 is an example.
- Open-graded overlays on concrete bridge decks or roadways with severe skid problems to eliminate hydroplaning. Severe skid and hydroplaning problems on an area of the San Francisco–Oakland Bay Bridge were eliminated with this treatment.
- Long-lived wearing courses for high priority strategic roadways.

This paper describes the problems faced and solved with epoxy asphalt surfacings on various projects other than the dense-graded wearing courses on orthotropic decks, and discusses the potential application epoxy asphalt in roadway pavements.

Table 1
Typical properties of epoxy asphalt components [5].

Property	Value	Test method
Resin (Part A)		
Viscosity at 23 °C, Pa·s	11–15	ASTM D 445
Epoxide equivalent weight	182–292	ASTM D 1652
Color, Gardner, max.	4	ASTM D 1544
Moisture content, % max.	0.05	ASTM D 1744
Flash point, Cleveland open cup, °C, min.	200	ASTM D 92
Specific gravity at 23 °C	1.16–1.17	ASTM D 1475
Appearance	Transparent amber	Visual
Asphalt and hardening agent (Part B)		
Viscosity at 100 °C, Pa·s, min.	0.14	Brookfield
Specific gravity at 23 °C	0.98–1.02	ASTM D 1475
Color	Black	Visual
Acid value, mg KOH/g	40–60	ASTM D 664
Flash point, Cleveland open cup, °C, min.	200	ASTM D 92