Research on construction technology for orthotropic steel deck pavement of Haihe River Chunyi Bridge

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Abstract. In order to ensure the good service quality of orthotropic steel deck pavement of Haihe River Chunyi Bridge in Tianjin, and to reduce the occurrence of pavement diseases like lateral and longitudinal cracks, the key working procedures such as steel deck cleaning, anticorrosive coating, bonding layer spraying, seam cutting, epoxy asphalt concrete’s mixing, transportation, paving and compaction were studied. The study was based on the main features of epoxy asphalt concrete which is the pavement materials of Haihe River Chunyi Bridge, and combined with the basic characteristics and construction conditions of Haihe River Chunyi Bridge. Furthermore, some processing measures like controlling time and temperature, continuous paving with two pavers, lateral feeding, and improving the compaction method were proposed. The project example shows that the processing measures can effectively solve the technical difficulties in the construction of orthotropic steel deck pavement of Haihe River Chunyi Bridge, can greatly improve the construction speed and quality, and can provide reference for the same kinds of orthotropic steel deck pavement construction.

1. Introduction

Epoxy asphalt concrete (EAC) is an excellent concrete with several decades of application as orthotropic steel deck pavement material. Generally, the aggregate used in EAC is highly processed basalt aggregate with a dense gradation. Epoxy asphalt is consisted of petroleum asphalt and thermosetting acid epoxy [1]. The epoxy asphalt is premixed before being combined with the heated aggregate through epoxy asphalt static mixer.

Previous studies [2-5] have clearly demonstrated that the EAC is a sustainable material with long service life, and has superior waterproofness, fatigue performance, moisture susceptibility and high temperature stability, can apply to serious service conditions in high-cold and high-latitude areas. EAC was first applied to pave the steel deck of the San Mateo–Hayward Bridge in the mid-1960s,
which has exhibited superior performance for many years [6]. From then on, EAC has been widely used as surface material on numerous orthotropic steel decks around the world [7, 8].

With the distinct advantage of superior performance, using EAC does have some downsides. The main one is the difficult in construction of EAC: Once the two separate components of epoxy asphalt are mixed, curing agent and epoxy resin begin an irreversible chemical reaction that increases the strength and stiffness of the EAC. If we don’t finish the paving and compaction of EAC in construction allowable time and specific temperature range, the EAC will become hard to compact and pave and its pavement performance will become very poor [9-11]. Therefore, the mixing temperature and the construction allowable time need to be carefully controlled.

Haihe River Chunyi Bridge using orthotropic steel deck lies in the southeast of Tianjin, China as shown in Figure 1. It is located between the Haijin Bridge and Jizhao Bridge. The span and width of the bridge are 663m and 40m, respectively. The pavement structure of orthotropic steel deck on main bridge is double-EAC. Besides, Haihe River Chunyi Bridge is the final bridge in the upstream of Haihe River since 2002 after overall development of Haihe River. It can cross the Haihe River and ease traffic pressure of Tianjin, and is very important to transportation planning and economic development of Tianjin. Hence the construction of Haihe River Chunyi Bridge got sufficient attention. This paper presents a research on the construction technology for orthotropic steel deck pavement of Haihe River Chunyi Bridge.

![Figure 1. Aerial view of Haihe River Chunyi Bridge.](image)

2. Materials

The technical specifications of the epoxy asphalt used in the paper are listed in Table 1, Table 2 and Table 3. The gradation of the basalt aggregate is presented in Table 4 and the nominal maximum size is 9.5 mm. The basalt aggregate has a compressive strength of 140 MPa and crushing value of 4.2%. The optimum binder content of EAC with was 6.5% determined based on the standard Marshall Mix design procedure.
Table 1. Technical specifications of epoxy resin (component A).

| Technical specification                | Test results | Criteria   | Test Method   |
|----------------------------------------|--------------|------------|---------------|
| Viscosity (23°C, Pa·s)                 | 13           | 11~15      | ASTM D 445 [12]|
| Epoxide equivalent weight              | 188          | 185~292    | ASTM D 1652 [13]|
| Color (Gardner)                        | 3            | ≤4         | ASTM D 1544 [14]|
| Moisture content (%)                   | 0.03         | ≤0.05      | ASTM D 1744 [15]|
| Flash point, Cleveland open cup (°C)   | 247          | ≥200       | ASTM D 92 [16]|
| Specific gravity at 23°C               | 1.165        | 1.16~1.17  | ASTM D 1475 [17]|
| Appearance                             | Transparent amber | Transparent amber | Visual |

Table 2. Technical specifications of mixture of curing agent and petroleum asphalt (component B).

| Technical specification                | Test results | Criteria   | Test Method   |
|----------------------------------------|--------------|------------|---------------|
| Viscosity at 100°C (Pa·s)              | 0.18         | ≥0.14      | ASTM D 2983 [18]|
| Acid Value (mg, KOH/g)                 | 52           | 40~60      | ASTM D 664 [19]|
| Flash point, Cleveland open cup (°C)   | 255          | ≥200       | ASTM D 92 [16]|
| Specific gravity at 23°C               | 1.00         | 0.98~1.02  | ASTM D 1475 [17]|
| Color                                  | Black        | Black      | Visual        |

Table 3. Technical specifications of epoxy asphalt (mixture of component A and component B).

| Technical specification                | Test results | Criteria   | Test Method   |
|----------------------------------------|--------------|------------|---------------|
| Time (Viscosity from 0 to 1000 mPa·s, min) | 51           | ≥50        | ASTM D 4402 [20]|
| Tensile strength (23°C, MPa)           | 2.22         | ≥1.52      | ASTM D 638 [21]|
| Fracture elongation (23°C, %)          | 462          | ≥190       | ASTM D 638 [21]|

Table 4. Grading limits and design value.

| Sieve size (mm) | 0.075 | 0.15 | 0.3  | 0.6  | 1.18 | 2.36 | 4.75 | 9.5  | 13.2 |
|-----------------|-------|------|------|------|------|------|------|------|------|
| Percentage passing (%) |       |      |      |      |      |      |      |      |      |
| Upper limit     | 14    | 23   | 32   | 40   | 55   | 70   | 85   | 100  | 100  |
| Lower limit     | 7     | 14   | 21   | 28   | 39   | 50   | 65   | 95   | 100  |
| Design value    | 10.8  | 16.7 | 23.8 | 35.9 | 48.4 | 59.7 | 75.2 | 96.9 | 100  |

3. Construction

3.1. Steel deck cleaning
The oil, salt and other dirt in the deck were cleaned through detergent. The appearance of the steel bridge deck was checked to ensure that there was not splash, pinhole and burr in the deck.

3.2. Anticorrosive coating
The deck was descaled through using a portable automatic dust-free sand machine, the grinding material in machine was steel shot and grit, and the mix ratio of steel shot and grit was 7:3. The roughness of deck must reach the requirement of 50-100μm before coating anticorrosive and the
relative air humidity must be less than 85% when coating anticorrosive. Epoxy zinc-rich paint widely used as an anticorrosive material was coated in the deck through high-pressure airless spraying method. The thickness of epoxy zinc-rich paint was 60-80μm.

3.3. Bonding layer spraying

As the middle layer in composite pavement structure, the bonding layer should play an important role in connecting EAC and orthotropic steel deck, that is to say, the bonding layer should have a great adhesive performance in maintaining the continuity of each layer under the action from the external load. Hence the procedure of spraying bonding layer is very important to the integral pavement performance of orthotropic steel deck. The bonding layer was sprayed through special spreader combined with artificial coating as shown in Figure 2. The spraying volume is about 0.5 L/m².

![Figure 2. Bonding layer spraying.](image)

3.4. EAC mixing

The procedures of EAC mixing were as follows: Firstly, the epoxy asphalt was prepared by mixing component A and component B at a fixed ratio of 1:2.45, when component A was heated to 87°C and component B to 133°C, then blended the epoxy asphalt with basalt aggregate when basalt aggregate was heated to 120-125°C. The final temperature of EAC should be controlled at 110-130°C. A faster chemical reaction of epoxy asphalt caused by a higher temperature would shorten the construction allowable time of EAC, while a lower temperature cannot ensure sufficient drying of aggregates. The properties of EAC are presented in Table 5.

**Table 5. Properties of EAC.**

| Technical specification             | Test results | Criteria | Test Method          |
|------------------------------------|--------------|----------|----------------------|
| Density (g/cm³)                    | 2.566        | -        | JTG E20-2011 T0705  |
| Air void (%)                       | 2.0          | 1.5~3.0  | JTG E20-2011 T0705  |
| Voids in the mineral aggregate (%) | 17.5         | ≥17      | JTG E20-2011 T0705  |
To guarantee the favorableness and quality of construction, the method of controlling time and temperature was proposed as shown in Table 6. The construction allowable time was determined by marshall molding state and strength developing rule measured in a mass of Marshall Stability tests. The time from mixing epoxy asphalt to the beginning of paving EAC must be more than the shortest construction allowable time, while the time from mixing epoxy asphalt to the finish of compacting EAC must be less than the longest.

Table 6. Construction allowable time of EAC at different temperatures.

| Temperature (°C) | Shortest Construction Allowable Time (min) | Longest Construction Allowable Time (min) | Construction Allowable Time Range (min) |
|-----------------|-------------------------------------------|------------------------------------------|----------------------------------------|
| 110             | 45                                        | 96                                       | 51                                     |
| 111             | 43                                        | 91                                       | 48                                     |
| 112             | 41                                        | 86                                       | 45                                     |
| 113             | 39                                        | 82                                       | 43                                     |
| 114             | 38                                        | 79                                       | 41                                     |
| 115             | 37                                        | 77                                       | 40                                     |
| 116             | 36                                        | 74                                       | 38                                     |
| 117             | 35                                        | 71                                       | 36                                     |
| 118             | 35                                        | 69                                       | 34                                     |
| 119             | 35                                        | 70                                       | 35                                     |
| 120             | 34                                        | 69                                       | 35                                     |
| 121             | 34                                        | 68                                       | 34                                     |
| 122             | 34                                        | 67                                       | 33                                     |
| 123             | 34                                        | 66                                       | 32                                     |
| 124             | 34                                        | 66                                       | 32                                     |
| 125             | 33                                        | 64                                       | 31                                     |
| 126             | 33                                        | 63                                       | 30                                     |
| 127             | 33                                        | 63                                       | 30                                     |
| 128             | 33                                        | 62                                       | 29                                     |
| 129             | 33                                        | 62                                       | 29                                     |
| 130             | 33                                        | 61                                       | 28                                     |

3.5. EAC transportation
In order to reduce the time spent for transportation of EAC and guarantee the temperature, some measures were taken, including covering canvas and quilt on the top of lorry, formulating the shortest travel path, arranging dispatchers for lorries.

3.6. EAC paving
To prevent the pollution of lorries on bonding layer which had not paved, the lateral feeding machine
was used in paving EAC as shown in Figure 3. Continuous paving with two pavers could be adopted to avoid the longitudinal seam as shown in Figure 4. The distance and speed of two pavers was about 10 m and 2 m/min, respectively.

![Lateral feeding machine](image1)

**Figure 3.** Lateral feeding machine.

![Continuous paving with two pavers](image2)

**Figure 4.** Continuous paving with two pavers.

### 3.7. EAC compaction

The compaction method of EAC was improved as shown in Table 7. Vegetable oil was smeared constantly on the wheels of rollers when compacting. Moreover, Diversion, head back and emergency brake were forbidden. Artificial hammer and handheld vibration rammer were adopted to compact the pavement where the roller could not compact.
Table 7. Compaction method.

| Compaction stages | Preliminary | Next | Final |
|--------------------|-------------|------|-------|
| Roller kinds       | Oller       | Oller| Steel wheel |
| Compaction times   | 4           | 4    | 4     |
| Compaction temperature (°C) | ≥82 | ≥72  | ≥65  |

3.8. Seam cutting
The lateral construction se am was cut at angle of 90°, its position should be the middle of adjacent diaphragm plates.

4. Conclusions
There were no any diseases like cracks occurred on the orthotropic steel deck pavement of Haihe River Chunyi Bridge after in service for three years. The excellent operations quality shows that the EAC with construction technology above has a long service life with superior low temperature crack resistance, high temperature stability, moisture susceptibility and fatigue performance.

The project example shows that the processing measures can effectively solve the technical difficulties in the construction of orthotropic steel deck pavement of Haihe River Chunyi Bridge, can greatly improve the construction speed and quality, and can provide reference for the same kinds of orthotropic steel deck pavement construction.

Acknowledgments
This study was sponsored by the National Natural Science Foundation of China (No. 51178114, 51378122). This funding is greatly appreciated.

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