Study of experiment in field for long-span cable-stayed bridge

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Abstract. In order to provide the reasonable optimization measures for the construction of long-span steel bridge deck pavement in the alpine area, the actual pavement effect under the real load is studied by simulation simulation with the finite element analysis software relying on the construction of the bridge deck of No.1 Bridge of Haidong Avenue, Ledu District, Haidong city. Through different load positions and loading methods, the control load loading points are determined, and the parameterized analysis is carried out for the elastic modulus, thickness and temperature difference of the pavement, and finally the structural parameters of the pavement suitable for the bridge are obtained; the experimental analysis results show that the theoretical calculation idea adopted is feasible, and the measured value is within the expected range. It can be seen that the construction optimization measures and suggestions are of great significance to the construction of steel bridge deck pavement in the high cold area.

1. Introduction

With the unique advantages of light weight and large span, steel bridge has become the first choice of modern bridges. At the same time, the use of steel in steel bridge solves the problem of excess steel production in China. The deck pavement is a very important part of the steel bridge, and the orthotropic steel deck is generally used for the long-span steel bridge. Because the pavement is located on the orthotropic deck, the deck pavement has higher requirements in construction technology, mechanical properties and durability quality. However, how to effectively combine the flexible deck pavement with the rigid steel deck has been studied by numerous scholars at home and abroad in recent decades, but there is still no good method to effectively solve the steel deck pavement problem of rigid flexible bond between deck and steel deck.

In recent years, the bridge has formed the main girder type of steel box girder and steel truss girder, and the bridge deck pavement type is mainly composed of cast-in-place asphalt concrete + Modified SMA, double-layer epoxy asphalt concrete and double-layer SMA.

It can be seen that no matter which form, the actual stress layer is divided into "upper layer + lower layer". Therefore, in this paper, the simplified finite element model is used to analyze the stress of the three kinds of pavements and get the reasonable pavement parameters. After that, experimental analysis is carried out to verify the correctness of the theoretical research strategy.

2. Engineering survey

The main bridge of No.1 Bridge of Haidong Avenue is a single tower and double cable plane composite girder cable-stayed bridge, with a span of 158.0+45.0+40.0=243.0m, a width of 44.0m and a main span of 158.0m. The steel box girder is adopted, and the bridge deck pavement is planned to
adopt a double-layer system. The overall structure of the bridge is shown in Figure 1.

Figure 1. Main bridge drawing of No.1 Bridge of Haidong Avenue.

3. Brief introduction on experiment
The stress-strain effect of orthotropic steel deck structure is localized obviously under load. Therefore, the research object should be considered as local box girder section (including steel box girder stiffener, pavement, steel plate, diaphragm), rather than the finite element analysis of the whole box girder. When using mechanical model to analyze the mechanical mechanism of steel box girder bridge deck pavement, the structural and material characteristics of the pavement system should be based on the following assumptions:

- It is assumed that the pavement material and steel deck are continuous and uniform isotropic elastomers.
- The interface between the upper and lower layers of the pavement layer, the pavement layer and the steel deck are all in full contact, and the bonding layer is not considered separately.
- Because the pavement is carried out after the completion of the bridge deck, the influence of the self weight of the pavement layer and the steel bridge deck structure is ignored.
- The boundary condition of the model is that the pavement, steel plate and longitudinal stiffener have no horizontal displacement and the diaphragm bottom is completely constrained.

4. Experimental study

4.1. Loading and measuring point layout
Take 9 loading positions in a partition room, the measuring points are arranged symmetrically. Only 1/4 section can be measured. The standard vehicle weight is 40t. The static load of the rear wheel is taken as the loading position. The loading points and measuring points are shown in Figure 2 below. The field test is shown in Figure 3 and 5.

Figure 2. Layout plan of loading and measuring points

Figure 3. Measuring points in the lower layer
4.2. Result analysis

Take the measured data of the upper and lower layers respectively, and sort them out according to the actual situation of each working condition as shown in Table 1 (only the measuring points of the sixth load working condition are listed due to the limited space).

| Measuring point | Upper layer /μm   | Lower layer /μm   |
|----------------|-------------------|-------------------|
|                | transverse portrait | transverse portrait |
| 1              | -340.8 -309.1     | -170.4 -147.2     |
| 2              | 1 982.8 2 147.5   | 1 001.4 1 160.8   |
| 3              | 2 261.5 2 250.5   | 1 142.2 1 216.5   |
| 4              | 1 726.0 1 843.1   | 863.0 877.7       |
| 5              | 1 596.8 1 651.2   | 798.4 786.3       |
| 6              | 1 809.0 2 185.5   | 904.5 1 040.7     |
| 7              | 2 322.5 2 253     | 1 161.3 1 072.9   |
| 8              | 1 656.4 1 414.3   | 828.2 673.5       |
| 9              | Data abnormity    | Data abnormity    |
|                | Data abnormity    | Data abnormity    |
|                | Data abnormity    | Data abnormity    |

Among them, except for No.9 measuring point, which cannot be read because of abnormal data, other measuring points are analyzed as follows after preliminary sorting of data and removing obvious abnormal values:

- In the double deck system, the longitudinal and transverse strain ranges of the bridge deck are basically the same, which also means that for the orthotropic bridge deck, the longitudinal and transverse deformation differences of the pavement under the action of vehicle load are small, which can be considered as isotropy in the same partition.
- Under the action of 40 t vehicle load, the stress concentration area is eliminated, and most of the strain distribution areas are concentrated in the range of 1500-2500 μm, which meets the use requirements, without excessive deformation.
- The situation of each index only reflects the current situation. For possible environmental factors, such as rainstorm, temperature sudden change and overload, close observation shall be conducted according to the operation situation. If necessary, finite element simulation shall be conducted to feed back all data to the model for long-term monitoring.
The fatigue effect is not considered in this test, but the fatigue problem of pavement under alternative load is more prominent. This study mainly focuses on static load, and carries out construction scheme optimization and test from the perspective of structural stress. For long-term operation, it is suggested to conduct a comprehensive study combined with fatigue effect.

5. Conclusion

The larger the modulus of the pavement is, the larger the shear stress between the pavement and the steel plate is. The growth rate of the transverse stress is greater than the longitudinal stress. In most cases, the transverse shear stress is 2 or 3 times of the longitudinal shear stress. Therefore, increasing the modulus of the pavement can increase the rigidity of the bridge surface system, reduce the transverse tensile stress of the top surface of the pavement, and reduce the possibility of crack damage. In addition, in the design document, there are strict requirements for the total thickness of pavement, so how to determine the thickness of the upper and lower layers under the condition of ensuring the structural requirements is the difficulty and key point of construction.

Considering the large temperature difference effect of the alpine region itself, this study considers the ideal temperature difference. In fact, there must be a single cycle effect that the lower layer always keeps low temperature, while the upper layer has strong sunshine at noon and returns to low temperature in the evening. From the above study, it can be concluded that the effect of the interlayer temperature difference in the alpine region is a model that can't be predicted simply.

When the deck pavement adopts double-layer structure design, it is recommended that the pavement thickness of the upper layer is between 30-35 mm and that of the lower layer is between 40-45 mm. The total thickness of the pavement should be 7-8 cm; the recommended elastic modulus of the upper layer of the bridge deck pavement is 1200-1800 MPa, and that of the lower layer is 1600-2000 MPa.

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References
[1] Lu Z, Liang C, Zhang Z. (2000)Steel deck pavement of Xiamen Haicang Bridge. Foreign highway, 1:40-43.
[2] Wang X, Cheng G, Huang W. (2001)Study on performance of epoxy asphalt concrete. Journal of Southeast University, 6:10-12.
[3] Qian Z, Huang W, et al. (2002)Analysis of mechanical properties of Orthotropic Steel Deck Pavement. Journal of transportation engineering, 9:44-47.
[4] Hu G, Qian Z, Huang W. (2001)Structural optimization design of the second system of working orthotropic steel box girder bridge deck. Journal of Southeast University, 5:102-108
[5] Huang W. (2008)Theory and Method of Steel Deck Pavement Design for Long-span Bridges, China Architecture Press.
[6] Gu X. (2002)Mechanical Analysis and Structural Design of Asphalt Pavement on Suspension Bridge Deck. PhD dissertation of Southeast University.
[7] Huang P, Ren H, Guo Q. (1994)Study on the performance of asphalt concrete on steel bridge decks of main roads. Journal of Civil Engineering, 27:67-74.
[8] Hu G, Huang W, Zhang W. (2002)Mechanical Analysis of Steel Deck Pavement of Runyang Bridge. Journal of Highway and Transportation Research and Development, 19:1-3.
[9] Li C Li Y. (2000)Study on Strain Change Law of Asphalt Pavement on Steel Bridge Deck. Journal of Highway and Transportation Research and Development, 17:1-4.
[10] Tong L, Shen Z. (1997) Static test and finite element analysis of orthotropic steel bridge deck. Journal of Tongji University, 25 : 617-622.