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DIFFICULTIES ENCOUNTERED DURING THE CONSTRUCTION OF QINGCHUN IRREGULAR-SHAPED FOOTBRIDGE

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Summary

Irregular-shaped footbridge scheme was determined due to urban landscape requirements, the subway constraints under the bridge and crossroad traffic condition. But the deformation and vibration of Irregular-shaped structure will be complicated. To study the static behavior and vibration serviceability of Qingchun irregular-shaped footbridge in Hangzhou, the support reaction under the temperature influence and dynamic performance in pedestrian was calculated by using finite element method. The results of analysis show that the uneven deformation of irregular-shaped structure caused by temperature load will lead to support separation, and this issue can be solved by adding additional weight near the top of the pier; First-order vertical frequency needs to be increased by adjusting the beam height to meet the comfort requirements of Chinese code.

Keywords: irregular-shaped footbridge; temperature load; vibration serviceability; uneven deformation; support separation; vertical vibration

1. Introduction

Qingchun steel box girder footbridge is located in Hangzhou City, Xintang Road and Qingchun Road intersection. The bridge has four section, with a total length of 277.8m, showing a kind of circular curve layout. Each section is a continuous beam in the middle, while simply supported at both ends. The first span of first section beam height is 2.5m, second span beam height is 1.5m, the others are 1.2m. The width of the box girder is 5.3~8.7m. The thicknesses of the top, bottom, and web plates and the diaphragm are all 16 mm. The elastic modulus, Poisson ratio, and density of steel are 2.1×10^5 MPa, 0.3, and 7850 kg/m^3, respectively. The shape of the bridge and bearing layout are shown in Fig. 1. The fourth section with maximum curvature and the first section with maximum span were chose as the object to study the support reaction and dynamic response. Then the conclusions and suggestions were put forward according to the calculation results

2. Design and layout

At the north of the bridge, there is Hangzhou Metro Line 2 under construction and Xinkai river. The choice of pier position is limited, and the curvature of fourth section is larger. The minimum distance between pier and metro is 3.57M. Metro Line 2 has been completed shield construction, the track has not yet laid. In order to reduce the impact on the subway during the pier pile foundation construction, deep casing has been used to cast-in-place bored pile. The bottom height of the steel casing must higher than that of the shield structure at least 5m. During the construction, the monitoring equipment is arranged in the shield.

3. Curved bridge support separation

The deformation of the fourth section of the footbridge is extremely distorted under such load combination, thus causing a highly nonuniform distribution of support reaction. The support reaction in D7-1, D8-1, and D9-1 bearings are negative. To resolve the issue of support separation and enhance the overturning resistance of girders, the method of balance weight is applied in Qingchun footbridge near the top of the pier.

4. Vibration comfort

4.1 Natural frequency

Due to the low stiffness of the long-span footbridge, when the natural frequency of the structure is close to the pedestrian frequency, the bridge deck is prone to generate a significant vibration response. In order to ensure the pedestrian comfort, the vertical vibration frequency should not be less than 3Hz in the upper part of the footbridge in Chinese code (CJJ69-95). The dynamic response of the bridge under crowd load is calculated with the German EN03, as a supplement. Select the first section (55.75m+30.04m) who has the largest span among other sections as the object.

In order to increase the fundamental frequency of box girder, it is necessary to improve the section stiffness. Therefore, Scheme of 2.5m+1.5m has been chosen after comparing the 4 schemes of different beam height. The first order frequency of transverse vibration is 6.04Hz, and it can avoid the sensitive frequency of pedestrian load. The first order vertical frequency is 3.14Hz, which can meet the requirement of CJJ69-95.

4.2 Dynamic response

4.2.1 Single walking load

Referring to the vertical walking load simulation results of X Xu [6], the vertical frequency, weight of single person, and peak of vertical load are2.0Hz, 700kN, and 980kN, respectively, and the load is shown in Fig 7. The load moves on the bridge at 2.2m/s walking speed, and the maximum mid span acceleration is 0.03m/s^2.

4.2.2 Crowd load

Dynamic response of the footbridge under crowd load was checked according to the EN03. The bridge length, width and assuming pedestrian density are 85.8m, 5m, and 1.5 /m^2.Number of the pedestrians on the loaded surface is 643, while the equivalent number of pedestrians are 47 and reduction coefficient ψ=0.25. Under this condition, the dynamic response of mid span history curve is shown in Fig 9.

4.2.3 Assessment of comfort classes

Criteria for pedestrian comfort are most commonly represented as a limiting acceleration for the footbridge. Some codes have the corresponding content on it, in which EN03 is more detailed, as shown in Table 6. The maximum acceleration of first section under single walking load are 0.03m/s^2, and 0.2m/s^2 under crowd load. Qingchun bridge can satisfy the demand of comfort.

5. Conclusions

1) Under the temperature load, the inner bearing of the Irregular-shaped curved bridge will produce the negative reaction, which leads to the bearing separation. The maximum negative support reaction is -342.3kN under the gravity and temperature load, and no negative reaction is observed in any bearing after the balance weight was applied.

2) By adjusting the beam height and increasing the stiffness of the structure, the first order vertical vibration frequency of the first section is increased to 3.14HZ, which meets the requirement of the CJJ 69-95.The dynamic response under single walking load and crowd load is calculated, and the maximum acceleration value is less than 0.5 m/s^2, which meet the CL1 comfort class in EN03, and the comfort is good.