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IMPACT FACTORS FOR CURVED CONTINUOUS CFST TRUSS GIRDER BRIDGES

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Abstract. *A finite element model for curved continuous concrete-filled steel tubular (CFST) composite truss girder bridges has been built, and a new iterative process has been proposed for the analysis of the vehicle-bridge coupled system. The vibration modes and impact factors of the curved continuous CFST composite truss girder bridge have been obtained. The effects of parameters on the impact factors, such as the vehicle speed and deck unevenness, have been studied. The results show that the impact factor of the bridge is much larger than the value calculated from the current design code. The resonant critical vehicle speed and the resonant critical loading position are varied for different girder spans. The vehicle speed limit cannot effectively reduce the dynamic impact, and the bridge deck roughness excitation has an amplification effect on the impact factor causing by resonance. The results in this study are useful for design consideration and maintenance of CFST composite truss girder bridges.*

1 INTRODUCTION

The concrete-filled steel tubular (CFST) composite truss girder is widely used in bridge construction as it has a high strength, ductility and large energy-absorbing capacity. In the design of this type of bridges, the vehicle dynamic action is considered in accordance with the impact factor formula provided by the current highway specification [1]. This formula is obtained from traditional steel and concrete bridges, and the spatial characteristics of the complex bridge structure, deck conditions and vehicle conditions are not considered. In practice, the dynamic effect of local components is larger than that from the specification due to the complexity of spatial distribution [2, 3]. Based on experimental and numerical methods, the impact factors of steel and concrete bridges are widely studied. Recently, the impact factors for the CFST arch bridge corrugated steel web composite girder bridge have been studied. However, the study on impact factor of multi-span continuous CFST composite curved truss girder bridges is very rare.

There is a coupled action of the bending and torsion in the curved girder bridge. When the radius of curvature is small and the width of the bridge is large, the static responses of the inner and outer main girders in the multi-girder bridge are significantly different. Similarly, the vibration responses and impact coefficients of the inner and outer main girders or webs of the curved girder bridge are also different. The impact coefficient formula in existing codes is based on the structural

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fundamental frequency that reflects the overall performance of the structure and it is suitable for the multi-girder straight bridge with similar main girder stiffness. It cannot reflect the difference of impact coefficient of each girder in the curved girder bridge.

The superstructure of the Ganhaizi bridge is a double-main girder CFST spatial composite truss girder, and each main girder is an inverted triangle three-limb truss. To ensure stability, several steel pipe truss braces were installed between the two main girders. To authors' knowledge, the dynamic behaviour of the curved CFST bridge subjected to moving vehicles has not been studied. In this paper, the impact factors of main girders of the first united spans of Ganhaizi Bridge are studied based on the vehicle-bridge coupled vibration, considering the influence factors such as the speeds and the road surface roughness.

2 VEHICLE-BRIDGE INTERACTION MODEL

The Ganhaizi bridge in the Beijing-Kunming expressway is a CFST spatial truss composite beam bridge, and the whole bridge is divided into three units. The first unit has the smallest radius of the curve and it is studied in this paper. The first unit of the bridge has a flat curve radius of 356m and a span of 40.9m+9×44.5m+40.9m. The upper structure is an inverted triangular three-limb CFST spatial truss composite beam. The bridge is divided into the left bridge and the right bridge. The center distance of the left and right bridges is 20m to 14m, and the minimum width of the whole bridge is 26m. There are steel tubular truss transverse bracings between the two main girders. One bracing is set at the mid-span position of the first span and the eleventh span separately, and two bracings are set at the mid-span of the second to tenth span separately, and one bracing is set at the positions of the support points separately. The cross-section without transverse bracings is shown in Fig.1.

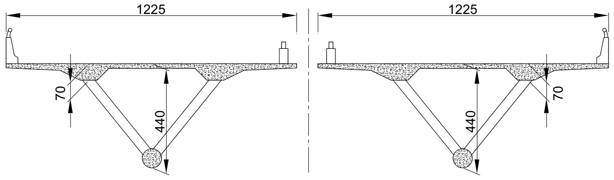

Figure 1: Cross section of truss girder

3.1 Bridge model

The bridge model is built by the comercial software ANSYS. To analyze the effect of piers on the dynamic behaviour of superstructure, the whole bridge model and the superstructure model are built separately. The connection between the bridge deck and the CFST truss is regarded as a complete shear connection. The bridge deck is discretized into longitudinal and transverse grillage elements, and the quality of the virtual transverse beam is zero, and the rigidity is taken from the actual rigidity. The longitudinal beam corresponding to the position of the upper chord is simulated as steel reinforced concrete component, and other longitudinal beams are simulated by common reinforced concrete members. The bottom chords and web members of the truss, the piers are simulated as steel tubular and CFST components. The elastic modulus of the CFST members is calculated using the unified theory. Rigid beam element is adopted for the pier-beam consolidation, and spring element is adopted for the bearing. As the foundation includes piles and pile caps, and the foundation stiffness is large. The bottom of the pier is simulated as consolidation. The whole bridge model is set up as shown in Fig.2.

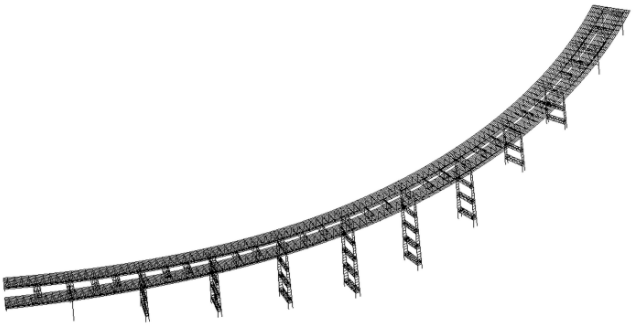

Figure 2: The bridge model

3.2 Vehicle model

A two-axle three dimensional vehicle model with seven degrees of freedom (DoFs) is used. The seven Dofs are the vertical displacement of the body “Z_v”, the turning of the body around the transverse axis “θ_{yv}”, the turning of the body around the longitudinal axis “θ_{xv}”, and the vertical displacement of left suspension of the front axle “z_{sL1}”, and the vertical displacement of the right suspension of the front axle “z_{sR1}”, and the vertical displacement of the left suspension of the rear axle “z_{sL2}”, and the vertical displacement of the right suspension of the rear axle “z_{sR2}”. The vehicle model is established by ANSYS software, and the vehicle body is simulated as mass and rigid rods, and the vehicle suspensions and tires are simulated as damped linear springs. It is assumed that the suspension and tire mass are concentrated on the axle and the tire is always in contact with the bridge deck. The vehicle model is shown in Fig.3.

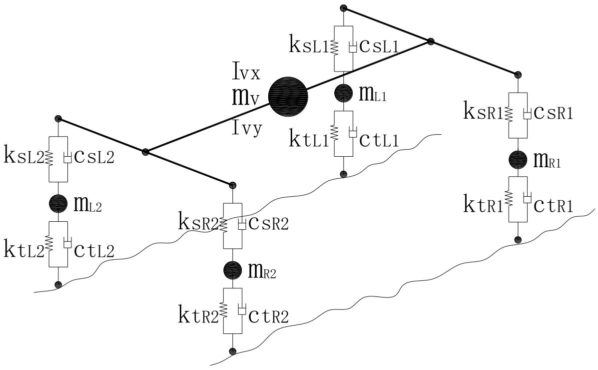

Figure 3: Cross section of truss girder

4 DYNAMIC IMPACT FACTOR

4.1 Effect of the vehicle speed

When the vehicle moves along the right upper chord of the right bridge, the impact factors of the lower chord nodes are as shown in Figure 4. When the speed is 60 km/h, the impact factor of the lower chord in the 1st span reaches its peak value 0.436, but that of the lower chord in the 5th span is always a smaller value.

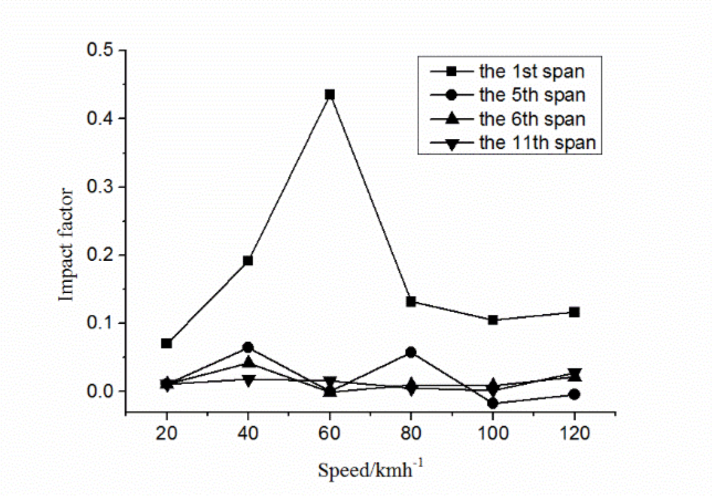

Figure 4: Impact factors of bottom chords of the right girder with different vehicle speeds

4.2 Effect of road surface roughness

Considering the deck roughness as the input, the impact factors of the low chord in the right bridge are calculated based on vehicle-bridge coupled vibration analysis. The results are shown in Figure 5. In the analysis, the vehicle speed is 20km/h. The results show that the impact factor increases with the class level of bridge deck roughness. The impact factor of the 5th span is smallest compared with other spans. With the deterioration of the bridge deck, the impact factors of the main girder in the 1st, 6th, 11th spans are increasing. The influences of deck roughness on the impact factor of the 1st, 5th, 6th, 11th span suggest that, when the vehicle frequency is close to the vertical bending frequency of the bridge, the impact of vehicle vibration is stronger than that of bridge deck roughness excitation. When the frequency of vehicle vibration is far away from that of the bridge, the impact of vehicle vibration is weaker than that of bridge deck roughness excitation. The roughness excitation can further amplify the impact factor caused by resonance.

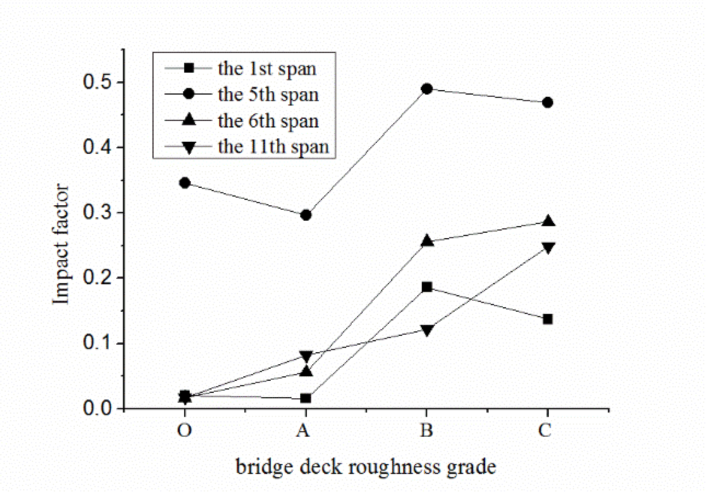

Figure 5: Impact factors of bottom chords of the right girder with different deck roughness

5 CONCLUSIONS

The vehicle-bridge coupled vibration analysis for the double-main girder curved CFST truss girder bridge has been conducted and the following conclusions can be obtained,

(1) For this bridge, the special mechanic characters are remarkable, and the resonant critical vehicle speed and the resonant critical loading position are different for different bridge spans. The

resonant critical vehicle speed is 60 km/h for the 1st span of the right bridge, while it is 20 km/h for the 5th span of the right bridge, so the speed limit is not reliable for reducing the impact factor.

(2) The bridge deck roughness excitation can further amplify the impact factor. For the resonant parts of this bridge, the magnification factor of impact factor is about 1.4 at the roughness level B to C, and for the non-resonant parts, the magnification factor is about 12. So, keeping the bridge surface smooth can effectively reduce the impact factor during the operation period.

REFERENCES

[1] JTG D60-2015. *General Specifications for Design of Highway Bridges and Culverts*. Beijing: China Communications Press (2015).

[2] Zhu X. Q. and Law S. S. Dynamic load on continuous multi-lane bridge deck from moving vehicles. *Journal of Sound and Vibration*, 251(4): 697-716 (2002).

[3] Deng L., Yu L., Zou Q. And Cai C.S. State-of-the-art review of dynamic impact factors of highway bridges. *Journal of Bridge Engineering ASCE*, 20(5): 04014080 (2015).