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Dynamic analysis of a large span specially shaped hybrid girder bridge with concrete-filled steel tube arches

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ABSTRACT

In the present study, the dynamic property of a specially shaped hybrid girder bridge with concrete-filled steel tube (CSFT) arches is investigated based on experimental and numerical methods, especially under moving vehicles. Before the inauguration of this bridge, a dynamic field test was conducted. A refined three-dimensional finite element model is built to represent the complex structural mechanic property of the bridge. The vehicle-bridge coupled vibration (VBCV) model with a 16 DOF vehicle model is established to simulate the dynamic behavior of the bridge with moving vehicles. The FE model is updated, and the VBCV model for the bridge is verified, taking advantage of the aforementioned measured data. The result indicates that the proposed VBCV numerical model can closely reproduce the measured response and can be used to simulate the dynamic behavior of the bridge under various conditions. The impact effect, ride and pedestrian comfort, and related parameters analysis for the bridge with moving vehicles are studied by numerical simulations and experimental tests. The results indicate that the impact factor formula from design standards significantly underestimates the dynamic impact effect, which may result in an unfavorable influence on the bridge safety. Several conclusions are drawn for this bridge, and further research that is needed for this new bridge type is discussed.

1. Introduction

In recent years, a new type of concrete-filled steel tube (CFST) arch bridges with specially shaped multi-arch ribs have been successfully constructed in certain cities in China, such as the Longjiang bridge in Zhangzhou, the Donggang bridge in Changzhou, the Jiubao bridge in Hangzhou, the Yingzhou bridge in Luoyang, and the Changfeng bridge in Ningbo [10]. This bridge type, one with a strong spanning ability and a unique configuration style, is a good candidate for constructing medium and large span urban bridges. The structural features of this bridge type differing from typical CFST arch bridges can be described as following: its arch ribs are composed of main and auxiliary ribs, and all ribs are concentrated fixed in the same skewback; the auxiliary arch ribs are outward-inclined in transversal space, and the transverse braces and inclined braces are used to link different arch ribs; the girder and arch ribs are connected with vertical or inclined suspensors (a typical bridge example is shown in Fig. 1). The special and complicated configuration of this new bridge type leads to its particular mechanical features, such as a higher center of gravity, more degrees of indeterminacy than regular arches, and a different integrated anti-torsion system composed of an arch rib, girder and suspensors from traditional CFST arch bridges. All of the aforementioned complex and distinct structural characteristics of the bridge type may also induce a large difference in dynamic performance from regular CFST arch bridges, especially with moving vehicles. The results of several initial simplified numerical analyses also verify the above observations [47,28].

For regular CFST arch bridges, related studies on vehicle and bridge coupled vibration (VBCV) have achieved a number of meaningful results in the past decade. A simplified impact factor formula is suggested based on numerical analysis for half-through CFST arch bridges with a span less than 200 m [19]. Taking a CFST arch bridge with a pedestrian deck suspended under the girder as an example, the natural vibration properties and dynamic response analysis under moving vehicles is carried out, and the effect of moving vehicles on the pedestrian and bridge is researched [45]. Another impact factor formula is proposed by statistically analyzing the data from field tests for regular CFST arch bridges [33].

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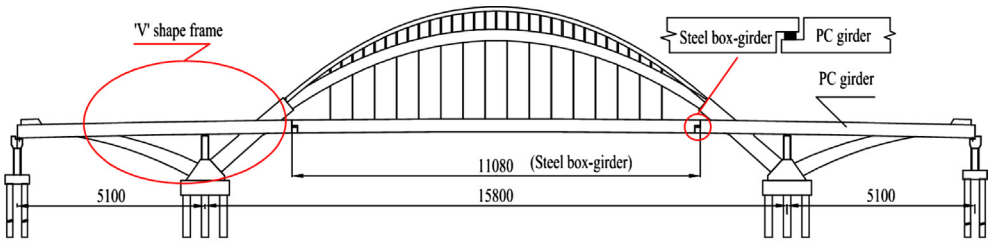
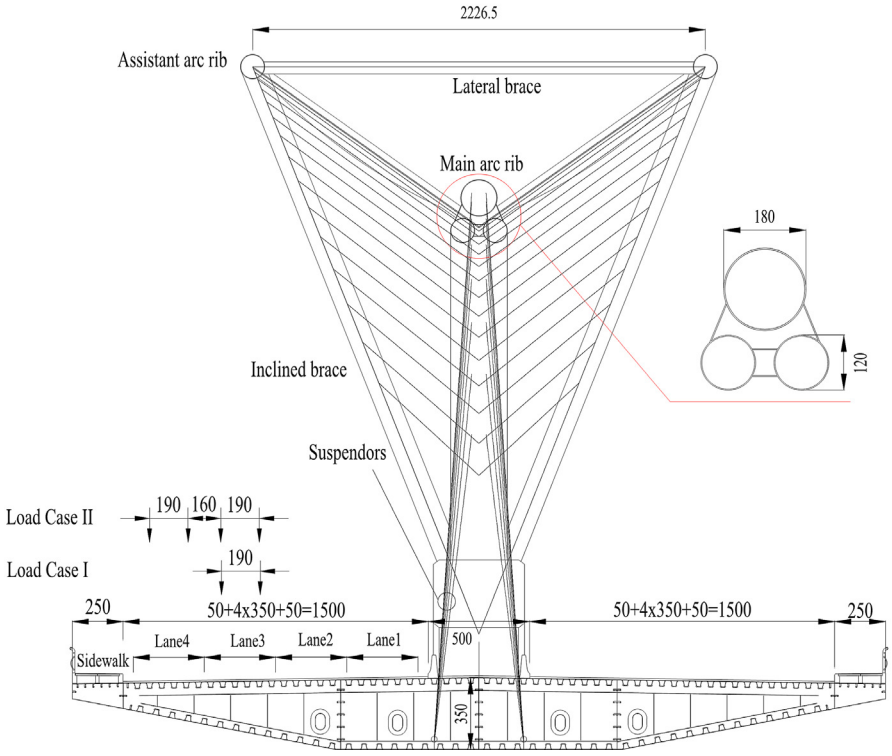


(a) Elevation view of the bridge (units: cm)



(b) Cross section of the bridge at mid-span and vehicle loading position (units: cm)

(c) Overview of the bridge

Fig. 1. Layout of Yitong River Bridge.

However, the suitability of general specifications and conclusions from regular CFST bridges research for the dynamic response and characteristic of this new bridge type is not clear. All of these questions and similar ones warrant further investigation. Until now, studies on the above problem were rare, and related experimental research cannot even be found in the literature. Therefore, further research by combining theoretical analysis and experimental testing on the dynamic performance for this new bridge type is necessary.

In the present study, a large span irregular CFST arch bridge with a hybrid girder in China, named Yitong River Bridge, is taken as a case study, and the dynamic performance of the bridge, especially under moving vehicle loading, is researched based on experimental and numerical methods. The paper is organized by