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Dynamic analysis of concrete filled steel tubular arch bridge

Ajmi Junoob[1], Anseena Basheer[2]

[1] Student, Department of Civil Engineering, CISAT, Kerala, India
[2]Assistant Professor, Department of Civil Engineering, CISAT, Kerala, India

Abstract - *Concrete filled steel tubular (CFST) arch bridges have been building in China since 1990 under the background of fast development of economy and the requirements of sound highway networks. Research has focused on the static behaviour, thermal stress and erection technique, however, and there has been very little research of natural vibrations and dynamic responses of these bridges. CFST members have better strength than those of masonry or reinforced concrete and can provide larger stiffness than steel tubes. This paper presents the analytical dynamic analysis of a concrete-filled steel tubular (CFST) half-through arch bridge by ANSYS 16. Based on ANSYS for model analysis of bridges, the basic steps includes: building up the FEM model, applying the load and solving the model, expanding the mode, observing the results and so on. The building procedures of FEM model were described from the definition of member section, element selection, and the determination of relevant attributes. A three-dimensional finite element(FE) model of CFST arch bridge and solid steel tubular arch bridge is developed and an analytical model analysis is carried out to obtain deformation. At last, the deformation of the concrete filled steel tubular arch bridge and solid steel tubular arch bridge were compared.*

Key Words: *Concrete filled steel tube, arch bridge, Finite element modelling*.

1. INTRODUCTION

The arches are mainly subjected to compression. The concrete-filled steel tubular (CFST) arches, taking advantages of both steel and concrete, make the arch spans longer. The first CFST arch bridge in China was completed in 1990. After that, more than two hundred bridges have been built or under construction in China. The span length has reached to 460m or even longer. The nonlinear static behavior of CFST arch bridges was intensively studied by experiments and finite element analysis. However, the dynamic characteristics of this type bridges have been studied rarely in the literatures.

The basic principle of arch bridge is its curved design, which does not push load forces straight down, but instead they are conveyed along the curve of the arch to the supports on each end. These supports (called abutments) carry the load of entire bridge and are responsible for holding the arch in the precise position unmoving position. Conveying of forces across the arch is done via central keystone on the top of the arch. Its weight pushes the surrounding rocks down and out-ward, making entire structure very rigid and strong.

The dynamic properties of bridges can be obtained by either experimental modal analysis or analytical modal analysis. The modal parameters such as natural frequencies, damping ratios and mode shapes can be identified through the field vibration measurements. Finite element (FE) method is now a common way to the analytical modal analysis where the dynamic characteristics of bridges can be calculated.

In modern analysis of bridge dynamics, much effort is devoted to the derivation of accurate models. These accurate models are used in many applications like damage detection, health monitoring, structural control, load-carrying capacity evaluation. The FE model of a bridge is usually constructed on the basis of highly idealized engineering blue prints and designs. When field tests are performed to validate the analytical model, inevitably their results, commonly natural frequencies and mode shapes, do not coincide with the expected results from the theoretical model. The purpose of FE model updating is to modify the mass, stiffness and damping parameters of the numerical model in order to obtain better agreement between numerical results and test data.

In arch bridges, it may be practical to use concrete filled steel tubes (CFT) for the arch ribs in which the compression axial force is predominant. The infilled concrete delays local buckling of the steel tube, and the steel tube reinforces the concrete against tension, bending moment, and shear force. The tube also serves as a formwork for the concrete during construction of the bridge, thus saving a major construction cost. Moreover, the composite structural action between the infilled concrete and the steel tube improves the member's load carrying capacity. As a result of these advantages, CFT construction for bridges has become widespread in recent decades. More than one hundred CFT arch bridges have been constructed since 1990 in China, and a CFT arch bridge with the span length of over 400m is now being constructed.

One of the most effective composite members we use nowadays is concrete-filled steel tubes (CFST), which have been being used more popularly for construction of bridges with long spans across roads, valleys, rivers and many other different types of topography. The concrete filled steel tube (CFST) is a composite material combined by the thin-walled steel tube and the concrete filled into the steel tube. CFSTs can utilise the best mechanical properties of concrete and steel through interaction between the two. The filled-concrete core possesses high compression capacity and also restrains local buckling of the steel tube. The steel tube in turn provides confinement to the concrete core so that its compressive strength can be further increased.

Due to arching effect the loading supported by the CSFT arch is mainly resolved into axial load which can be very effectively sustained by CSFT. The advantages of CSFT arches arise from the composite action of the concrete core and external steel tube. The confining effects of the steel tube significantly enhance the load carrying capacity of the concrete whilst the concrete hinders local buckling of the steel tube. This results in more effective and economical design.

2. BRIDGE DESCRIPTION

The main span is a rigid-framed tied arch bridge with a span of 150m. The clear width of the bridge is 23.5m.The ratio of rise to span is 1/4.5 and the axis is a centenary curve with a parameter m of 1.167.
In general, for a CFST arch bridge, when the span is larger than 120m, the arch rib is composed of truss with CFST chords and others steel members. The four chord members in each rib are steel tubes of 750mm diameter and 12mm thickness, filled with C50 concrete.

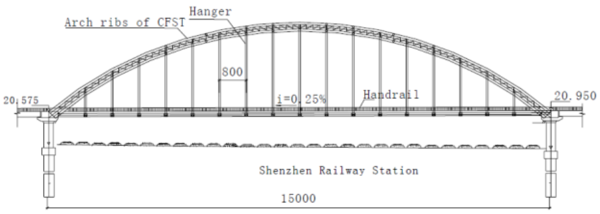

Fig -1: Elevation view of the bridge (unit:cm)

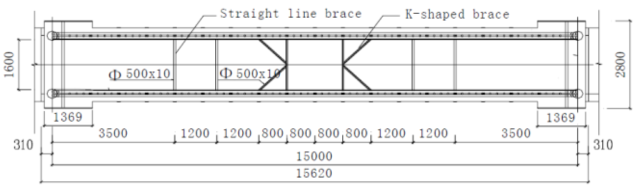

Fig -3: Plan view of the bridge (unit:cm)

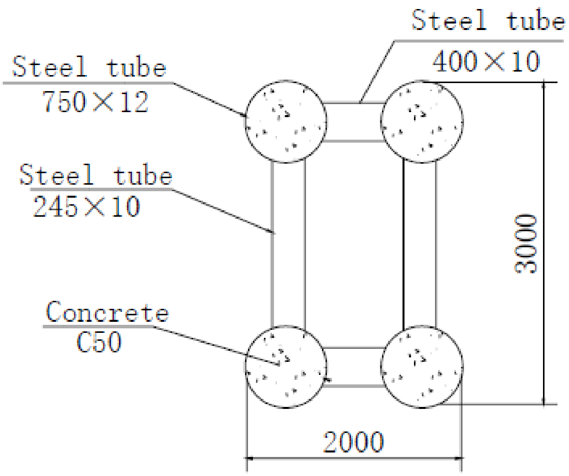

Fig -2: Cross Section of Arch Rib (unit:mm)

3. FINITE ELEMENT MODEL

A three-dimensional (3D) FE model of the Bridge was developed in ANSYS 16. It should be noted that each CFST arch rib consists of the steel tube and the infilled concrete, these two components are modeled separately using single beam elements. Fig. 5 shows the 3D FE model of the bridge.

3.1 Support and loading conditions

The different loads to be considered include the self weight of the deck, arch, cross beams etc. The load is given as static load and dynamic loading. Total load on deck is taken as 200kN. The dynamic loading is provided as moving load. The load is taken as 400kN.The support given is fixed support.

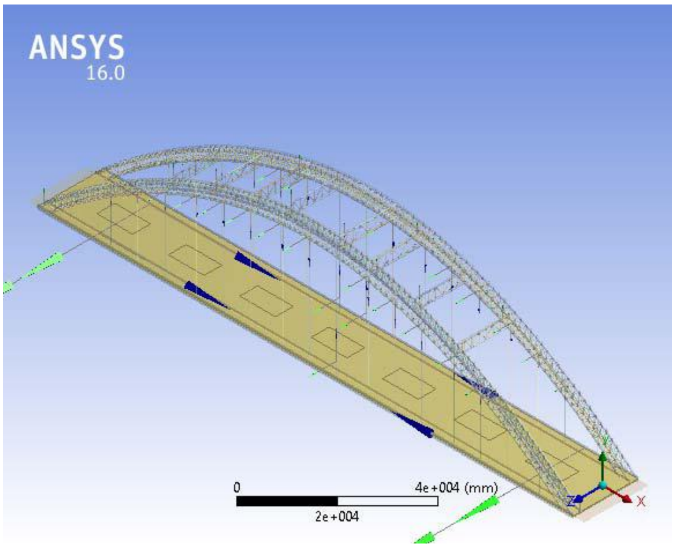

Fig -4: 3D FE model of Bridge

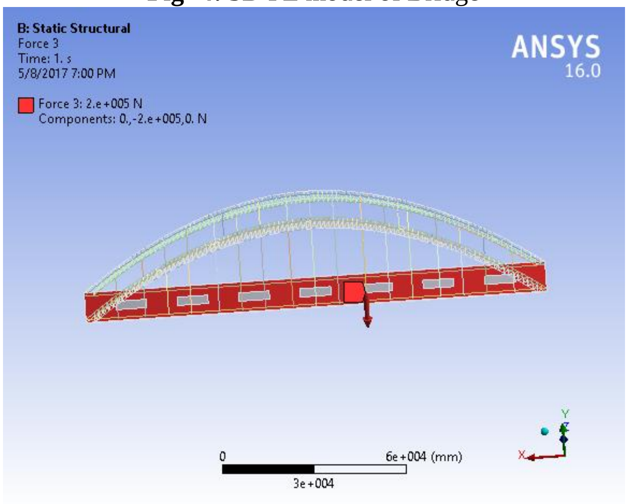

Fig -5: Static Loading

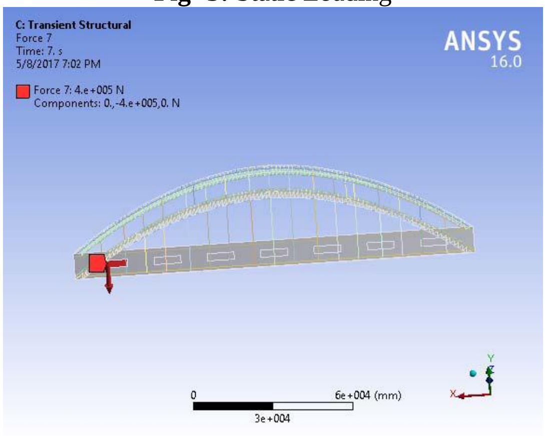

Fig -6: Transient loading

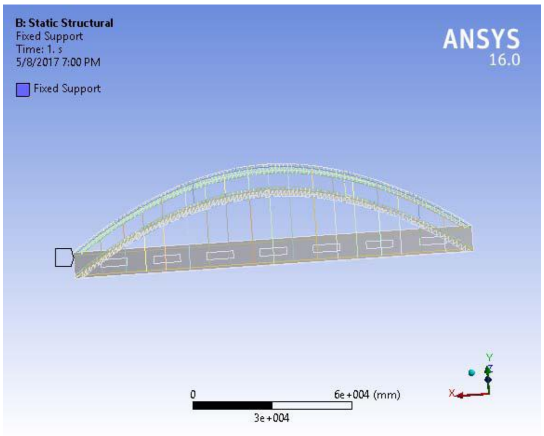

Fig -7: Fixed support

4. RESULTS AND DISCUSSIONS

4.1 Total deformation

4.1.1 Static Analysis

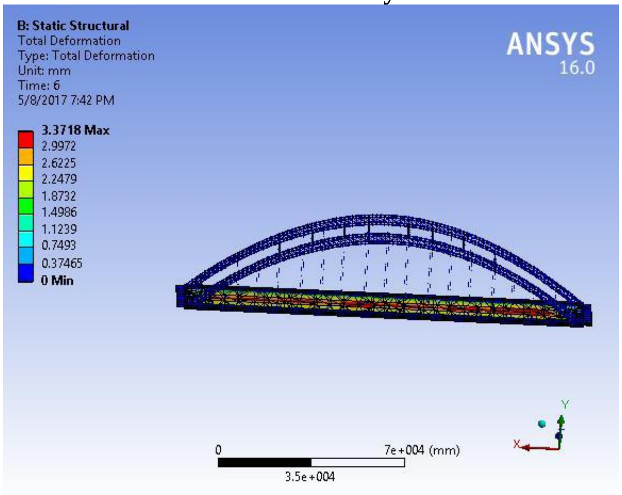

Fig -8: Total deformation-static

4.1.2 Transient analysis

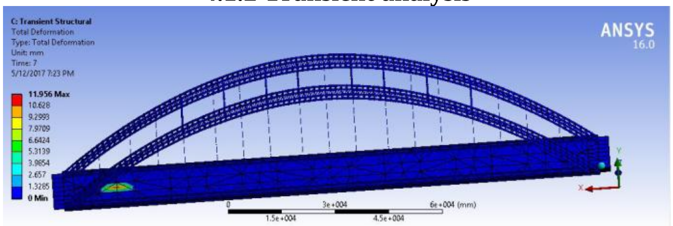

Fig -9: Total deformation- dynamic

4.2 Solid steel tubular arch bridge deformation

The arches are taken as a solid structure made up of steel only.

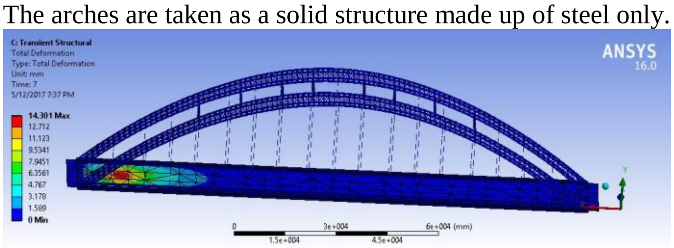

Fig -10: Total deformation

4.3 Comparison

Table -1: Total Deformation

Type of arch bridge	Deformation(mm)
CFST Arch bridge	11.956
Solid steel tubular arch bridge	14.301

From table 1 it is found that the concrete filled steel tubular arch bridge has less deformation than solid steel tubular arch bridge.

6. CONCLUSIONS

In China, CFST structures have been a strong research subject since more than thirty years. The application of CFST into arch bridge has big contribution to increase the development of arch bridges. Many CFST arch bridges have been built and it is predicted that more long span bridges will be built in the future with more advancements.
This paper studies the dynamic response of a CFST arch bridge to moving loads. The 3D finite element model of the CFST arch bridge is developed in ANSYS. The influence of moving load are analysed. The comparison between the performance of solid steel arch bridge and CFST
bridge under moving load is also done. Following conclusions were obtained:

- Test results of CFST model arch and solid steel tubular arch show that the total deformation of CFST arch subjected to a dynamic loading is smaller than that of an solid arch subjected to a dynamic loading.
- CFST arch bridges have greater load carrying capacity.
- Large span bridges can be made of CFST members.

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