A large arch bridge using concrete filled steel tubular

A Large Arch Bridge Using Concrete Filled Steel Tubular

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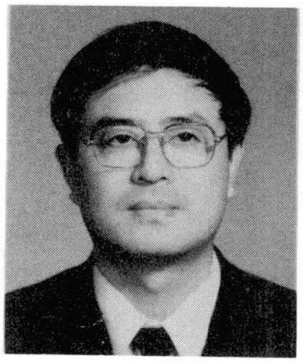

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Summary

A large highway arch bridge with its one span of 160 meters,across the Huangbai River was built on the main road leading to the Yangtze Three Gorges Project in 1996.
The arch rib of this bridge was built on concrete filled steel tubular (CFST) along the river bank, then turning with a balance weight to locate on the bridge site. It is the longest-span bridge of this kind constructed by new method in China today.
This paper not only introduces the static and dynamic analysis of this highway arch bridge, but also discusses the new constructional method of arch ribs turning with a balance weight.
Several structure models have been tested in the laboratory to testify the safety of the bridge. It proved that the construction method and CFST are more suitable and more efficient for the arch bridge.

1. Introduction of the Bridge and Main Technical Standards

The Huangbai River Bridge lies in Hubei province of China and it crosses the Huangbai River, the main sub-stream of the Yangtze River. It belongs to one of the most important water conservancy junction engineering items on the transportation highway of the Yangtze Three Gorges Project in China. Its surface width of water is 150m, the design volume is 500 m^3/s, its depth is 15m and the geological character of the river is arenaceous limestone.
The surface of the bridge is 18.5m wide. The design loading is the automobile team 36-grade standard of China, 4 tracks every row, the weighe of every automobile is 56t, and the checking loading is 200 tons every trailer.
The type of the whole bridge is 4 × 20m PC beam bridge + 160m arch bridge + 20m PC beam bridge and the bridge foundation is on the arenaceous limestone(see fig.1).
The construction of the bridge was set about in 1994 and completed to have traffic in 1996. This bridge plays an important role in the construction of the Yangtze Three Gorges Project(fig.2).

2. The Structure Feature of the Arch Bridge

The CFST was used in the arch bridge. It is the longest-span bridge of the concrete filled steel tubular in China and its arch span is 160m, arch rise is 32m and arch axis coefficient ***m*** is 1.543.
The steel tube diameter ***d*** of arch rib is 1000mm, the wall thickness of the steel tube at arch springer is 12mm and the thickness of other parts is 10mm. The steel tube, whose diameter ***d*** is between 100 and 600mm is used in the connecting constructional elements between the ribs(Fig.3).
The steel tube,whose diameter ***d*** is between 600mm and 800mm is used in the arch column. The wall thickness of steel tube is 12mm and the largest heighe of columns is 27m.
The 16 Mn steel plate was rolled to make the steel tube and 50-grade concrete was filled in the steel tube. Thus the steel-concrete combination structure was formed.
The arch seat foundation was designed into the upper and the lower two parts. The diameter of the middle rotational hinge was 2.2m, the lowe part foundation was reinforced concrete structure and the upper part was prestressed concrete structure.
The bollow pier was designed above the foundation in particular in order to have the balance weight. While constructing, water was filled inside the hollow pier so that the balance system was formed. The plate beam structure of 13m and 14m span was used in the arch beam.

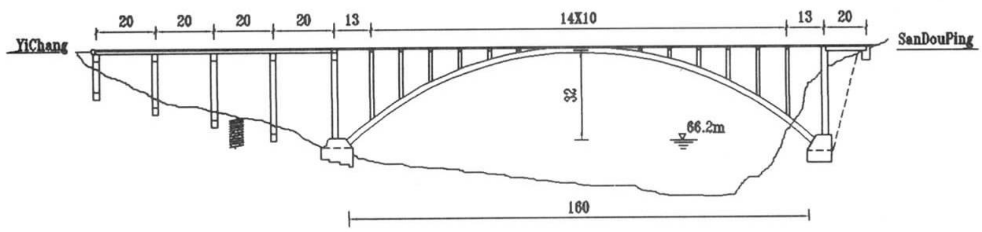


Fig.1 The whole sketch of the Huangbai River Bridge
(Unit:m)

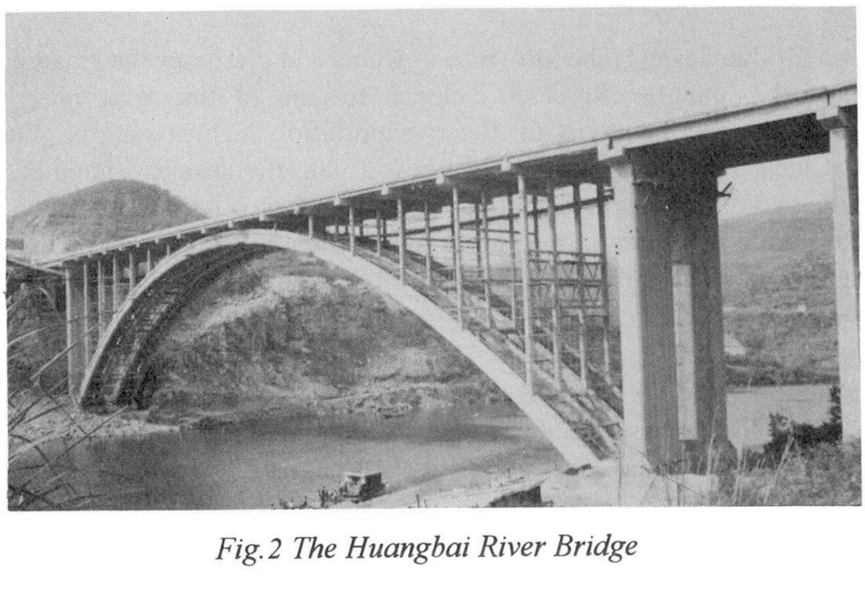
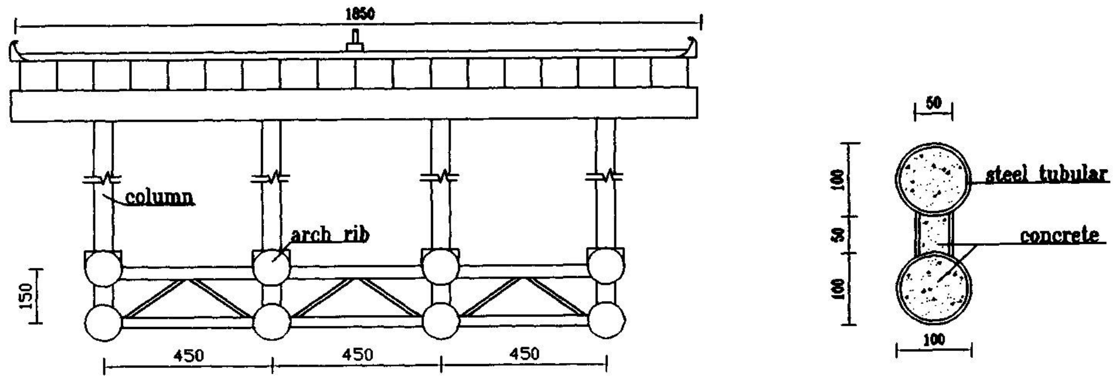


Fig.2 The Huangbai River Bridge



Bridge cross section

Arch rib cross section

Fig.3 Arch bridge structure cross section
(Unit:cm)

3. The Calculating Method of the Arch Bridge and Its Main Results

3.1 Structural Load-bearing Capacity

The Finite Element Method is used to perform spatial mechanics analysis and the structural internal forces are gotten under 24 kinds of loading condition. The structural design load-bearing capacity is judged according to China's "Specification for Design and Construction of Concrete-filled Steel Tubular Structures" (CESE 28:90)while designing.
The formula of design load-bearing capacity for the elements is:

$$N_u = \phi_1 \phi_2 N_0 \qquad (1)$$

where, N_u=design value of bearing capacity for CFST member;
N_0=design value of bearing capacity for short column the axial compression;
ϕ_1=the reduced coefficient considering the influence of slenderness ratio;
ϕ_2=the influence of axial eccentricity.
The load-bearing capacity should meet the following:

$$N \leqslant N_u \qquad (2)$$

Where, N is the design value of axial compression force.

3.2 Structural Non-linear Influence

The combination of the Increment Method and Newton-Raphson Method is used in the non-linear calculation of structural analysis. The calculation results are very close to that of the linearity and the error is among 2-3%.

3.3 Seismic Checking

The seismic force of bridge structures is calculated according to 7 earthquake intensity degree.
The first three natural vibration periods of the arch bridge structure are as follows:

T_1 (S)	T_2 (S)	T_3 (S)
0.979	0.822	0.607

The arch rib footing is the most dangerous part of the structure when earthquakes occur and its axial force *N* is 64KN, bending moment *M* is 154KN-m , which is much smaller than the internal force induced by automobile loading. It indicates that such kind of structure has good seismic capacity.

4. The Construction Erection Method of the Arch Bridge

In order to avoid the assignments such as instalment and welding of steel structure in the air and to take advantage of the geographical position of the bridge site as well as the features of the lighter weight of hollow steel tube and its higher strength, the flat surface swing method was used in the construction of the arch bridge. The weight of swing body is 3600 tons, which is the heaviest bridge swing body in China. The construction sequence is as follows:

(1)The steel tubes of about 2 meters long were manufactured in the factory, then were welded into 10 meters long members and sent to the bridge site. They were erected on the built supporting framework and the mountain body in opposite direction.
(2)Held fast the prestressed "tie". Filled water in the hollow pier so that the balance system was formed and was able to rotate on the flat surface; rotated 180 degrees and 105 degrees, and the bridge members were thus linked into a whole body (Fig. 4, Fig. 5).

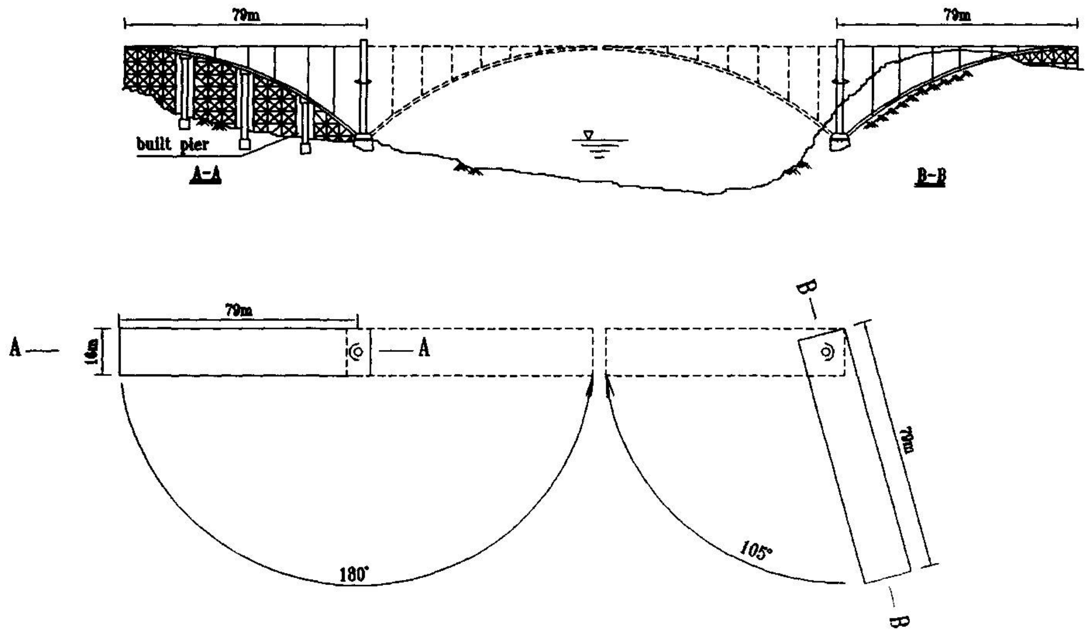


Fig.4 To rotate the arch rib

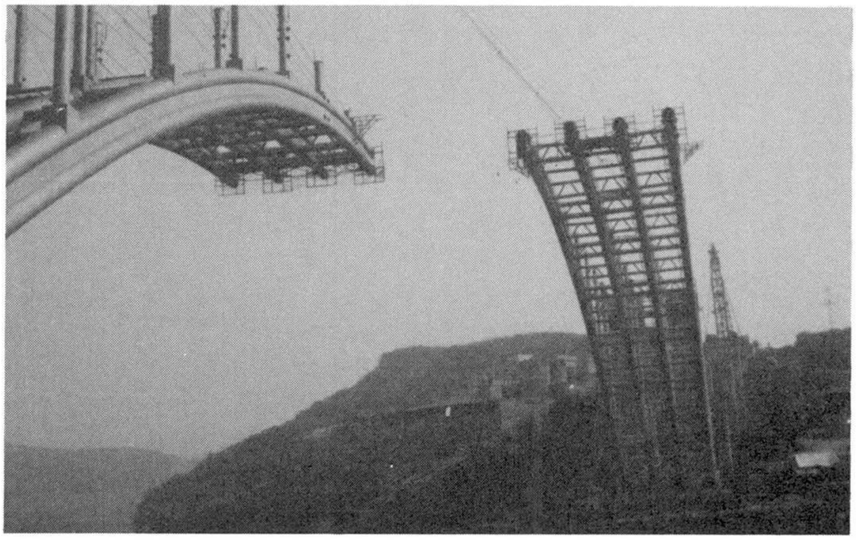


Fig.5 The arch rib turning

(3)Pour concrete so that the arch springer is fixed. Fill concrete to the steel tubular structure. After the strength of concrete was gained, the slab beam on the arch was erected and the floor system was laid and installed.

5. Structral Experiment in the laboratory

5.1 Comparative Model Test of Bearing Capacity of The Arch Rib Cross-section

The aim of the test is to study the mechanical influence of the mid-hollow concrete between the arch rib on the whole structure. The breaking tests of A-type and B-type member were carried out (Fig.6). The similar ratio between the model and the actual members is 1:5. The results of the test indicated that under the same loading, the deformation of B-type members is the same as that of the A-type, but the shear force of the steel plate is double. A-type was used to insure the safety in practical construction.

5.2 Stability Model Test of The Compressive Member of CFST Arch Columns

The ratio of length and the diameter of the CFST arch column λ is L/d=34. In order to keep the stability of the column under the axial loading, the breaking test of the model under the axil centre compression was performed. The results indicated that under the biggest design loading the safety coefficient of the column K was 1.9, which is in correspondence with the calculating results of the actual bridge in design.

5.3 The Fatigue Test for The Surface Protection Course of The Steel Tube

The spray aluminiurm protection layer was used on the surface of the steel tube and the model fatigue test was performed. The results indicate that the performance of the protection course on the surface of the steel tube will be in good condition within 20 years.

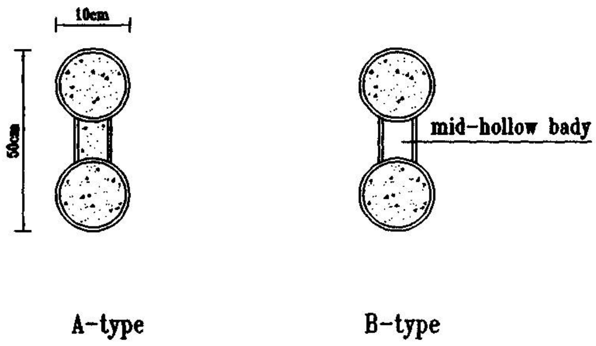


Fig.6 The section of arch rib model

6. Conclusions

It has turned out that there are some excellent advantages of using CFST in the bridge engineering. From the year of 1990, this kind of structure has been used, or is being constructed or is being designed in 37 bridges. The completion of the Huangbai River Bridge makes the study of the CFST develop a lot in the fields of the bridge engineering.

Reference

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2.Shangtong Zhong. "Concrete Filled Steel Tubular"(in Chinese), Scientific and Technological Publishing House of Hei Long Jiang, 1994.