2019 Gustav Lindenthal Medal Application

The First Hejiang Yangtze River Bridge - The World's Largest CFST Arch Bridge

The First Hejiang Yangtze River Bridge(Bosideng Bridge) is located in County Hejiang, Luzhou City, China. Hejiang is an un-developed place with urgent demand for transportation. In order to promote its development, Luzhou-Chongqing Expressway was built, which cross the Yangtze River in Hejiang County.

According to navigation requirements, the main span should not be less than 500 m. Engineers compared possible bridge types, they are： concrete cable-stayed bridge, steel truss suspension bridge, steel box arch bridge, and Concrete Filled Steel Tube (CFST) truss arch bridge. Finally, the owner chose CFST arch bridge with the least material consumption, the lowest cost and the shortest construction period.

The First Hejiang Yangtze River Bridge is 841m long, 4 lanes in two directions, 28m wide and design speed at 120Km/h. It was opened to traffic in October 2017 with cost about 40 million US dollars. The span of The First Hejiang Yangtze River Bridge is 530m and the main arch reaches a height of 120m.The arch is a truss rib with rectangular arrangement of CFST structure. The main girder is composed of steel grid beam and steel-concrete composite deck, connecting arch with suspension cable. The main arch steel tube was installed by cable hoisting and cable-stayed suspension method.

The arch rib installation segment is 45m long & 16m high. Its lifting weight is more than 200t, lifting height is 140m and the maximum buckle cantilever is 265m, which has high installation risk and difficult construction control. Engineers have developed a manufacturing, transportation and installation integrated segment unit. No temporary structure was needed and work at site was simplified. The technology realized high precision manufacture and fast installation, which solve the difficulties of steel tube arching.

The design team has developed new concrete filled in steel tube and relevant construction technology. High flowability pumping self-compacting concrete and three-stage pumping technology were proposed to resolve the difficult problems of pumping distance of concrete in main arch tube of the bridge is up to 450m and height difference is 120m, ensuring a single tube to be successfully completed 800m^3 C60 concrete pumping once for all and the density of concrete in steel tube.

Engineers have developed an internal maintenance mechanism to compensate the shrinkage of self-compacting concrete through expansive agent. Innovations of concrete properties and pumping technology solves the difficult problem of large shrinkage and cavitations of CFST arch structures.

After the bridge was completed and opened to traffic, the traffic efficiency of Hejiang was greatly improved and the economic development of Hejiang County was promoted. The first Hejiang Yangtze River Bridge is also a model of economic and environmental friendly bridges. As a competitive bridge type for cable-stayed and suspension bridges, it was built at 60% cost of other bridge types of the same scale.

Hejiang Yangtze River Bridge is a major breakthrough in the span of concrete filled steel tube arch bridge and a landmark bridge of this type. It supports the compilation of China's first design code for highway concrete filled steel tubes, promotes the construction of concrete filled steel tubes spanning 500 meters in China, and guides the construction of the third Pingnan Bridge in Guangxi with 575 meters of main span. Hejiang Yangtze River Bridge is a miracle of bridge engineering in recent years. This project is well worth the IBC Gustav Lindenthal Medal.

Support Material

1.Background

Hejiang, located in the upper reaches of the Yangtze River, is a developing county. In order to promote its development, the Luzhou-Chongqing Expressway was built to cross the Yangtze River at Hejiang.

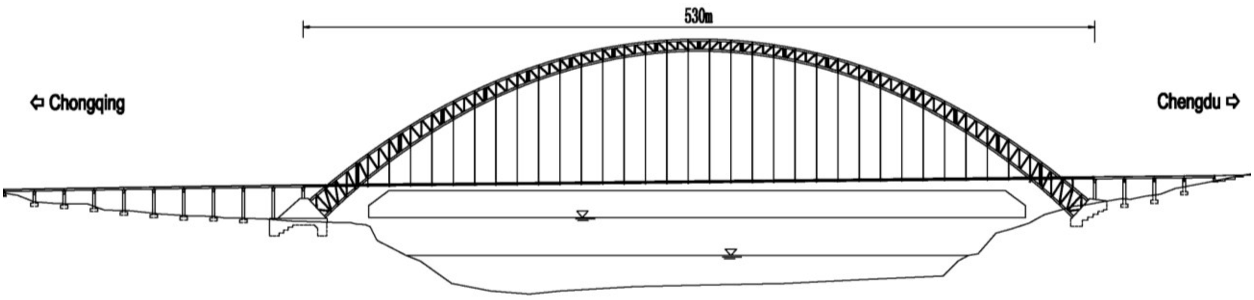
At bridge location, the river is about 500m wide and 50m deep underwater, which has a navigation capacity of 12000t class fleet all year round and 200 ships/day. According to navigation requirements, the main span should not be less than 500m. Engineers compared possible bridge types, they are：520m single span concrete cable-stayed bridge, 520m single span steel truss suspension bridge, 530m single span steel box arch bridge, and 530m single span Concrete Filled Steel Tube (CFST) truss arch bridge. Finally, the owner chose CFST arch bridge with the least material consumption, the lowest cost and the shortest construction period.

Comparison Table

Bridge type	Main Span (m)	Steel (kg/m^2)	Reinforced bar (Kg/m^2)	Concrete (m^3/m^2)	Total cost (million US dollars)
CFST arch bridge	530	718	75	1.561	4000
Steel box arch bridge	530	1152	63	1.504	7617
Cable-stayed bridge	520	145	578	2.971	5435
Suspension bridge	520	385	532	3.072	5673

2.Design Introduction

The First Hejiang Yangtze River Bridge is 841m long, 4 lanes in two directions, 28m wide and design speed at 120Km/h. It was opened to traffic in October 2017 with cost about 40 million US dollars.



Bridge Layout

Main span of this bridge is 530m and main arch reaches a height of 120m. The arch is a truss rib with rectangular arrangement of CFST structure. The width of rib is 4m, the height of arch truss at foot is 16m, and at top is 8m. The main tube diameter is 1.32m, filled with concrete. The empty web tube is 0.66m in diameter and arranged by "N" shape and connected with main tube by welding directly.

According to transverse loading behavior of main arch, a composite transverse steel tube brace was adopted, which is composed of a vertical plane brace and a triangular upper chord plane brace. Each group of transverse braces is arranged in the same segment of main arch. No temporary components are needed for manufacturing, transportation and installation.

The main girder is composed of steel grid beam and steel-concrete composite deck, connecting arch with suspension cable. Bridge deck system is equipped with a limit device in both longitudinal and transverse directions to control displacement of main girder.

Main arch and girder were manufactured in factory and shipped to site, cable hoisting and cable-stayed buckling method were adopted to complete the installation.

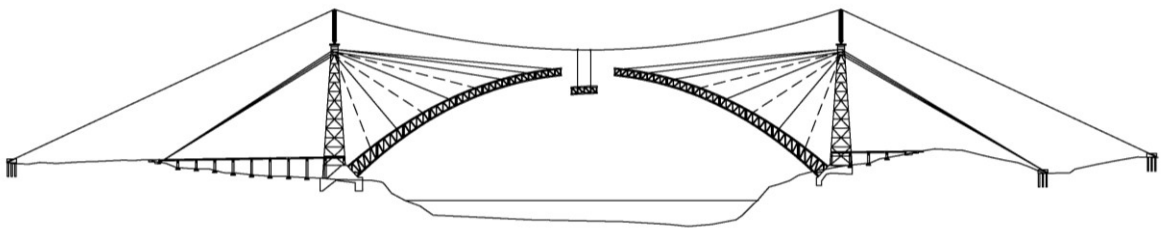
3.Technical Innovation

(1)The innovation of steel tube arching

As the span of the bridge reaches a record 530m, the maximum segment of arch rib is 45m long, 16m high and its weight exceeds 200t. Moreover, the lifting height is 140m and the maximum cantilever is 265m, the installation risk is so high and difficult to control. The installation of arch rib segment is the first major technical difficulty of the bridge.

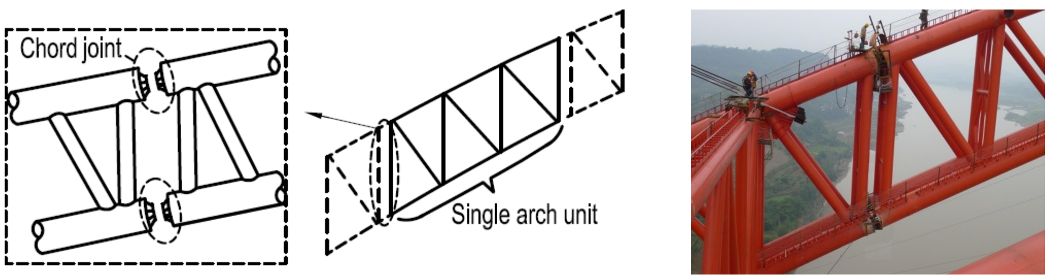
Traditional manufacturing, transportation and installation segments need temporary components to assist during construction. As a result, installation weight is heavier, construction period is longer, accuracy is more difficult to guarantee, and construction risk is higher, which can’t meet rapid arch-forming requirements of 530m CFST truss arch bridge.

Engineers have developed a manufacturing, transportation and installation integrated segment unit, on-site installation work was simplified. The technology realized high precision manufacture and rapid installation, which solve the difficulties of steel tube arching.



Main bridge construction plan

Engineers have developed a manufacturing, transportation and installation integrated segment unit, that is, main arch segment unit and cross brace form an independent structural system. No temporary components are needed. Only in-place matching and welding of main tube joints need to be completed at high altitude. All segments from factory have been manufactured with high precision. Compared with traditional unit, its weight is reduced by 30% and high-altitude joint welding is reduced by 33%. One segment was installed in one day only. The installation speed is increased by 2-3 times and the risk & cost are reduced.



Independent structural unit of main arch

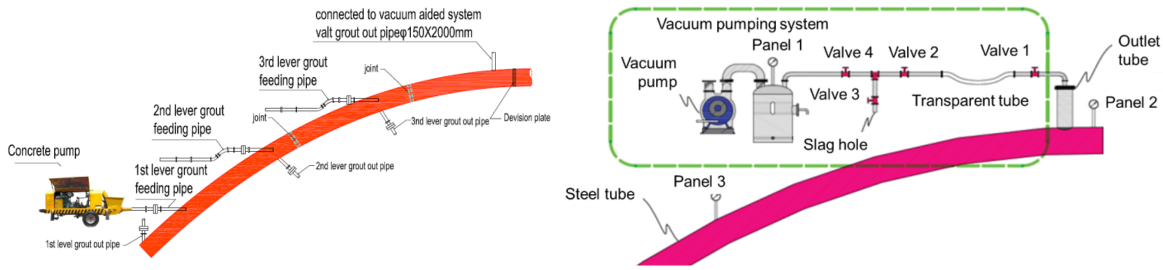
(2)Innovation of Concrete Pumping technology

The pumping distance of concrete in main arch tube of the bridge is 450m and the height difference is up to 120m. It was required for a single tube to be successfully completed 800 m^3 C60 concrete pumping once for all and ensure the compactness, which is another technical problem for arching.

The engineers developed a new concrete pumping technology:

(1)Two high-performance pumps with pressure greater than 20MPa were arranged on both sides, and a spare pump can be used at any time to ensure pressure and continuity of concrete pumping.

(2)Three pumping points of high, middle and low were symmetrical arranged at both sides of half arch, which reduces the difficulty of pumping by 60%. Vacuum equipment is installed on the vault to achieve a negative pressure of 0.8MPa. By reducing the degassing bag of concrete in main arch tube, the air content of concrete is reduced by 30%, effectively avoid cavity formation.

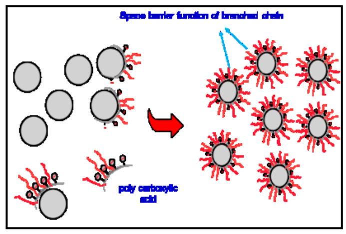


Concrete pumping technology for main arch

4.Innovation of Concrete Material

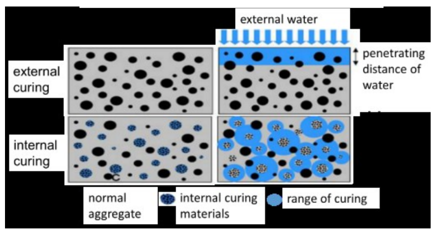
The low fluidity of traditional concrete is easy to cause internal holes in concrete tube, and excessive shrinkage will lead excessive gap between concrete and steel tube, which will reduce the bearing capacity of CFST structure. Talent engineers studied CFST materials, starting with increasing concrete fluidity and reducing shrinkage, developed a large flow rate pumped self-compacting shrinkage compensation concrete.

(1) Invention of hyper dispersant: Adding adsorptive and dispersive groups on the molecular side chains of water reducers to form sufficient adsorptive layer on the surface of particles and increase the strong dispersive effect on stone powder, cement and mineral admixtures; using small molecules released by hydrolysis of slow-release groups, a spatial barrier effect is formed between particles. Through the dual effects of dispersion and steric hindrance, hyper dispersion can reduce its viscosity and improve slurry fluidity.

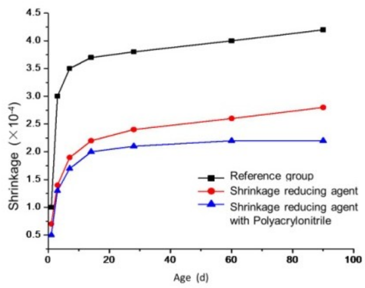


Function of dispersant

(2)Invention of shrinkage reduction technology: Using high branched, multi-active grafting point, high hydrophilic starch as framework, unsaturated hydrocarbons with hydrophilic groups such as - CONH2 as branched chain, provide water storage and release power, play an internal curing role; combined with alkyl poly-oxyethylene ether and other shrinkage reduction components to form an internal curing shrinkage reducer. By controlling the amount of rubber material to inhibit hydration temperature rise, mixing internal curing shrinkage reducing agent (Fig. 8) and expansion agent, triple action synergistically reduces concrete shrinkage. Through the composite admixture with the function of super-dispersion and shrinkage reduction, concrete expansion is greater than 600 mm, slump is greater than 220 mm, slump loss is less than 30 mm in 12 hours, and shrinkage compensation is 5/10,000, which ensures the compactness of concrete in tube.



Water release of inner curing



Effect of shrinkage reducing

After the completion of construction, the maximum void ratio of concrete in main arch is 0.3% and the maximum void height is 2 mm by ultrasonic, drilling and optical fiber testing. A large number of scientific experiments show that when void fraction is less than 0.6%, or void height is less than 5 mm, the restraint effect of steel tube on concrete is reduced by less than 2%, which fully meets the requirements of Co-loading of steel tube and concrete. Through the innovation of concrete pumping technology and concrete material in steel tube, the void problem of long-span CFST arch bridge has been solved.

5.Environmental Harmony

Arch bridge is popular because of its beautiful shape, smooth curve and dynamic feeling. The First Hejiang Yangtze River Bridge crosses the river by single span with magnificent momentum. The main arch is bright red like a rainbow, and the bridge deck girder is silver-gray. The elegance emerging from the combination of bridge structure and painted color is fully in harmony with the surrounding river and hills, which has attracted numerous tourists and become a landmark in the area.

Reasonable span selection of this bridge avoids large-scale excavation. There is no impact on the ecological environment of the Yangtze River during construction. Compared with cable-stayed bridges and suspension bridges of the same scale, consumption of concrete and steel can be saved by 50% and cost can be reduced by 35%. Compared with steel box arch bridges, consumption of concrete is equivalent, but that of steel can be saved by 37% and cost can be reduced by 47%. It makes CFST arch bridge a competitive bridge type for cable-stayed bridges and suspension bridges of the same span.

6.Public Participation

It is the first CFST arch bridge with a span over 500m, and many technical challenges have been encountered. Famous domestic universities, construction enterprises and experts have actively participated in the construction, which not only solved problems, but also promoted the technological progress of CFST bridges.

7.Significance

The First Hejiang Yangtze River Bridge is a major breakthrough in span length of CFST arch bridge and a landmark of this bridge type. After its completion, it merged with the magnificent Yangtze River well. The innovative installation and pumping technology of main arch steel tube have solved the arching problem of 500-meter CFST arch bridge, and the invention of concrete material has solved the void problem of long-span CFST arch bridge. The series of research results supported the compilation of China's first design code for CFST bridges, and promoted the construction of large-span CFST arch bridges, such as Third Pingnan Bridge with 575 m span in Guangxi and Third Hejiang Yangtze River Bridge with 510m span.

The construction of this bridge demonstrates the intelligence, creation and confidence of Chinese engineers. It is a milestone in the history of Bridge Development in China.

The First Hejiang Yangtze River Bridge is a single, latest and most brilliant achievement in bridge design, construction, public participation and economic & environmental protection. This project is well worth the IBC Gustav Lindenthal Medal.