Hang-Rui Dongting Bridge

APPLICATION MATERIALS OF 2019 INTERNATIONAL BRIDGE CONFERENCE AWARD
(GUSTAV LINDENTHAL MEDAL)

Designer: Hunan Provincial Communications Planning, Survey & Design Institute Co., Ltd.
Builder: Hunan Road & Bridge Construction Group Corp.
Owner: Hunan Provincial Expressway Construction & Development Corporation.
Hang-Rui Dongting Bridge is the main construction item for a national expressway. The main bridge spans 1933.6m, and it is a 1480 + 453.6m steel truss girder suspension bridge of two-way six-lane. The bridge deck is 34.5m wide, stiffening girders are 9m tall, and pylon height is 206m. With a total investment of USD 414 million, the project commenced construction in October 2013 and was completed and opened to traffic in February 2018.

Located at the junction of Dongting Lake and the Yangtze River, the area is the only path connecting Hunan with the Yangtze River, the only outlet to regulate and restore the flood of the Yangtze River, and the only channel for fish to migrate between the Rivers and the Lake. The Bridge stands astride Chenglingji Port, through which hundreds of ships pass through every day, and there are numerous wharves and anchorages along the river. The bridge is located adjacent to East Dongting Lake International Wetland Nature Reserve, inhabited by rare endangered animals such as finless porpoise and white stork. Considering not only the requirements of flood discharge, safety of navigation, and avoiding the demolition of wharves and anchorages, but also not impacting the habitats of migratory fish, upon the repeated simulations, a suspension bridge across the main river channel with a main span of 1480m was selected. The original classical pylon design realizes a perfect fusion between the bridge and the local natural and cultural landscape. Aiming at solving difficulties in durability, wind and seismic resistance, and construction of an ultra-long span suspension bridge, the engineers carried out systematic research and made a series of innovations in materials, structure, and equipment.

New super toughness concrete (STC) materials and lightweight composite deck structure. Targeting the problems of orthotropic steel bridges with fatigue cracking and pavement wear in heavy traffic, and the difficulty for conventional materials and structures to meet durability requirements, the engineers mixed two nano-materials into UHPC, densely reinforced with steel fibers, to form a new super toughness concrete (STC), with stress crack resistance over 30MPa. Meanwhile, a new type of steel-STC lightweight composite deck structure was formed by connecting the 45mm thin STC layer with an orthotropic steel deck through studs, and an intelligent STC construction equipment set was developed. Compared with orthotropic steel decks, the stiffness of the composite deck is increased by 40 times, and the fatigue stress of the steel structure is decreased 30%-80%. This technology tackles the problems in steel decks of fatigue cracking and pavement wear, and broken through technical bottlenecks of steel bridge construction and maintenance. It won the First Prize for Invention from Ministry of Education of the PRC.

New axial eddy current damper. The bridge structure is constantly subjected to a number of dynamic loads such as vehicles and wind. Dampers restrains the vibration. Hang-Rui Dongting Bridge spans 1480m, and the damper distance is 2240m, requiring higher damper durability and sensitivity. The engineers developed a 150t large-tonnage axial eddy current damper based on the principle of eddy current and the mechanism of spiral amplification. The starting friction is only 0.5-1% of the designed damping force, and the sensitivity of the damper is 10 times more than that of viscous fluid dampers, which significantly improves anti-seismic and vibration attenuation performance, reduces beam-end displacement, and prolongs the service life of the bearings and expansion joints.

Hang-Rui Dongting Bridge is the second-longest steel truss suspension bridge in the world. Its design has overcomes limitations of navigation, flood discharge, environmental protection, and complex construction, achieving fusion between itself and its surroundings, providing a Chinese solution to perfect and develop orthotropic steel decks. More than 2,800 engineers came from all over the world for technical exchanges during construction. A related paper topped the ASCE reading list for four consecutive months, and its research achievements have been successfully applied in more than ten bridges, including the Fengxi, Zhaohua, and Queshi bridges. It is a model bridge technology. Its completion has great significance for the national expressway network, economic development along the route, and the integration between the East and West of China. In conclusion, Hang-Rui Dongting Bridge fully meets the requirements of 2019 IBC Award.
Supporting materials for Hang-Rui Dongting Bridge

1. Overall Design

Hangzhou-Ruili Expressway is China’s main East-to-West artery. It stands astride Dongting Lake in Yueyang, Hunan Province, adjacent to East Dongting Lake International Wetland Nature Reserve, inhabited by endangered animals such as the finless porpoise and white stork. Its position spans the only outlet from Dongting Lake to Yangtze River, the one and only channel to Dongting Lake to regulate and store the floods of the Yangtze River, as well as the sole channel for migratory fish between the River and Lake. The River is the only passage connecting Hunan with the sea, through which hundreds of ships pass every day, and a great deal of wharves and anchorages are set along the River.

![Fig. 1 Key junction](image1)

![Fig. 2 Wildlife habitat](image2)

Considering not only the requirements of flood discharge, ensuring the safety of navigation, and avoiding demolition of wharves and anchorages, but also not impacting the habitats of migratory fishes, upon repeated simulations, the suspension bridge with the main span of 1480m is selected to span the main river channel. A suspension bridge with 1480m + 453.6m double-pylon and double-span-steel-truss-girders is used, with a rise span ratio of the main cable f/l=1/10. The stiffening girders use a warren truss system, with vertical bars. The main truss is 9 meters high, and the transverse center distance of the main truss is 35.4m. The pylons are 206m tall, and gravity anchorage is used with diaphragm wall foundations. Figure 3 is a diagram of the bridge layout.

![Fig. 3 Layout diagram of bridge type (cm)](image3)

The bridge is only 2km away from Yueyang Tower, a famous ancient building and one of the Four Great Towers of China, with a history of more than 1,700 years. Inspired by the eaves of the tower, the designer uses classical pylon solution, realizing perfect fusion between the bridge and its environment, and showcasing the history and culture of Yueyang Ancient City. The design has received high praise from the public.
Hang-Rui Dongting Bridge is the second-longest steel truss suspension bridge in the world. Aiming to solve difficulties in durability, wind and seismic resistance, and construction of an ultra-long suspension bridge, the engineers carried out systematic research and made a series of innovations in materials, structure, and equipment.

2. New super-toughness concrete (STC) materials and lightweight composite deck structure

Under the repeated action of heavy-duty vehicles, orthotropic steel decks are subject to fatigue cracking and pavement wear. As a main regional artery, the heavy traffic on Hang-Rui Dongting Bridge is a particular problem. It is difficult for conventional structures and materials to meet such durability requirements.

The engineers mixed two nano-materials into the UHPC and densely reinforced the concrete with steel fibers to form a new super toughness concrete (STC) with stress crack resistance over 30 MPa. Meanwhile, a new steel-STC lightweight composite deck structure was formed by connecting a 45mm thin STC layer of compacted reinforced concrete with the orthotropic steel deck through studs, and an intelligent STC construction equipment set was developed. Compared with the orthotropic steel deck, the stiffness of the composite deck is increased 40 times, and the fatigue stress of the steel structure is decreased 30%-80%. Under the force of the designed fatigue stress amplitude, fatigue tests simulating 20 million impacts were conducted on key bridge nodes, and both the steel structure and the STC remained intact. The relative deflection between the ribs was reduced 6.6 times, and the curvature between ribs was increased 6.8 times, greatly improving the condition of the pavement layer and effectively prolonging the service life of the pavement layer. At the same time, intelligent, automated and large-scale STC construction equipment was also developed, along with key construction joints. Technical specifications for lightweight composite deck design, construction and acceptance were prepared, forming a complete steel-STC composite structure and construction method, solving the problems in steel decks of fatigue cracking and pavement wear, and breaking through technical bottlenecks in steel bridge construction and maintenance.

The bridge has won First Prize for Technical Invention from the Ministry of Education of the PRC, and the paper "Basic Performance of the Composite Deck System Composed of Orthotropic Steel Deck and Ultrathin RPC Layer" topped the ASCE reading list for four consecutive months.
3 New axial eddy current dampers

Bridges are constantly subjected to a number of dynamic loads such as vehicles and winds. The anti-seismic and vibration-damping effects of dampers are critical. Hang-Rui Dongting Bridge spans 1480m, and the damper distance is 2240m, requiring higher damper durability and sensitivity.

In light of these problems, the engineers developed a 150t large-tonnage axial eddy current damper based on the principle of eddy current dissipation and a mechanism of spiral amplification, which has the following characteristics:

1. Full metal structure, no working fluid, and no need for power supply have effectively guaranteed the damper durability;
2. The eddy current is mainly provided by rare earth permanent magnets, whose performance changes little within the temperature range of the bridge, and the damping force characteristic has good temperature stability;
3. The damper uses a low-friction ball screw as the motion support member. The starting friction is very small, about 0.5%-1% of the designed damping force.

The damper realizes the technical breakthrough of large tonnage and long stroke. The sensitivity is over 10 times higher than that of viscous fluid dampers, ensuring effective operation under bridge temperature variation and vehicle braking force, and greatly improves earthquake resistance and vibration reduction, reducing beam end displacement under traffic flow, and prolonging the service life of the bearings and expansion joints.

![Schematic diagram of large-tonnage axial eddy current damper](image)

4 Public participation

Through cooperation with a number of universities, research institutes, and construction units, the Hang-Rui Dongting Bridge project team has carried out the Ministry of Transport Construction Science and Technology Project "Technical Research on Key Technologies for Long-span Steel Truss Stiffening Girders," yielding 21 authorized patents, 3 monographs and specifications, and 63 papers, including 37 indexed by SCI and EI. Upon request by the public, during the design phase, extensive public feedback was sought through the Internet in order to select an appearance design plan. During construction, more than 2,800 engineers from all over the world gathered for technical exchanges; three major academic conferences were held, greatly promoting application of the research findings in similar projects.

5 Conclusion

Hang-Rui Dongting Bridge makes original and outstanding contributions to modern bridge technology. The bridge type overcomes the limitations of navigation, flood discharge, environmental protection, and complex construction, and achieves fusion with the surrounding environment. The new STC material and lightweight composite deck structure solve the problems of fatigue cracking and pavement wear in orthotropic steel decks, and break through technical bottlenecks of steel bridges. The first successful application of the world's largest-tonnage eddy current damper in a bridge of over a kilometer, it overcomes the shortcomings of traditional dampers and widens the applications of eddy technology. The bridge marks the completion of the Hangzhou-Ruili Expressway, opening up a communication artery between the East and the West of China, and promoting the economic development of the line. Its innovations in materials, structure, and equipment have been successfully applied in more than ten bridges, such as the Fengxi, Zhaohua, and Queshi bridges, and the project has become a model of bridge technology.