Cable-stayed Steel Concrete Composite Structure Study Key Segments

Jixiong LU
Chongqing Jiaotong University, Civil and Architectural Engineering University, Chongqing, 400074, CHINA

Abstract: Steel concrete composite construction segment is one of the key technologies critical hybrid girder cable-stayed bridge, it is designed to directly affect the safety and durability of the bridge, a key segment of steel concrete composite structure has been much research in the world bridge sector is concerned. In this paper, simulation analysis and large scale model test are carried out to simulate the mechanical behavior of steel concrete composite section. To provide a research method of the stress mechanism, the transfer path and the way of the stress and the corresponding reasonable structure of the combined segment.

Keywords: Steel concrete composite section; Cable-stayed bridge; Composite beam

1. Introduction

Cable-stayed bridge since the advent of the world has been for several centuries, and its beautiful shape, across the powerful, well received by the people [1]. As the combination of steel and concrete can improve the mechanical properties and improve the economy, so the recent years, the number of mixed bridge engineering examples[2]. Such as Germany Kurt- Schoemacher bridge, the Japanese port bridge, Tatara bridge [3] ~ [4], French Normandy bridge [5], Wuhan Baishazhou bridge, Queshi Bridge in Shantou, Hong Kong stonecutters bridge have adopted the hybrid cable-stayed bridge [6]. The steel-concrete composite segment key structure is one of the key technologies in the construction of the bridge.

Due to the prestressed concrete beam and steel beam combination on both sides of the site with different materials, the strength and stiffness of girder here generated mutation, so easy to produce stress concentration [7]. Therefore, combined with the structural form can be more fluent in bear and transfer all kinds of internal force and deformation, and it should have good durability and fatigue resistance and appearance also requires steel beam and the concrete beam transition gentle.

2. Development Course of Key Structure of Steel Concrete Composite Section in Cable Stayed Bridge

In the fifties of the 20th century, the bridge construction in developed countries is the most prosperous period, in such a climax of construction, steel and concrete combination beam in its entirety by the economy of force, to play the advantages of both the two kinds of materials is reasonable and easy construction characteristics, has been widely used, steel and concrete combined girder cable-stayed bridge design is in this era of.

Mix in the world of a steel combination beam cable stayed bridge is born 1972 in the former West Germany Kurt -Schumacher Bridge, the bridge connecting the Mannheim and Ludwigshafen, bridge span 287.04m+146.41m, system with single tower cable stayed bridge, steel beam and prestressed concrete box beam of the connecting section is arranged at the position of the tower, steel beam and prestressed concrete box girder with method of shear bonding prestressed crude steel. In the west section of Kurt Schumacher bridge shape, a tower of the material were improved, the span increasing[8].

In 1988, North American Mexico built the main span of 360m Tampico Bridge. The bridge main span the is light and thin steel structure, and side span the heavier of reinforced concrete structures in order to reduce the side span is the negative reaction, and the steel beam and concrete beam connection is arranged along the longitudinal prestressed reinforced so that they form a whole.

1994 years, the French built a total length of 2141.25m, the main span of 856 m Normandy Bridge, the world's first to build the main bridge across the country close to the 1000m cable stayed bridge. This bridge is a steel and concrete combination beam cable stayed bridge, on both sides of the bridge with prestressed concrete box girder, by denser pier supporting until tower, prestressed concrete bridge and tower rigid connection after to the main hole overhang116m. This part of the main span steel box girder, to shorten the length of 624m[9]. Steel and concrete combination beam effective reduce the main span of its load, enhances the intermediate suspension stiffness of the cross, the bridge under live load and dead load, the deformation is reduced, enhanced resistance to fatigue

and limiting horizontal displacements of main span under the action of wind.

Japan state Tataro Bridgefull bridge length 1480m, the main span is 890m, is a three span continuous composite box girder cable-stayed bridge, span layout for 270+890+320m. Beam and PC beam combining parts adopt high fluidity concrete filled steel - concrete, in order to make together. The steel beam and the PC beam are inserted into the steel bar in the reserved hole, and then the concrete is poured, which can effectively enhance the stiffness of the combined parts, and can better resist the earthquake and wind load. Is the inherent characteristics of prestressed concrete shrinkage and creep and relaxation of prestressed force[10]. The above mentioned factors also affect the steel beam stress. The structural form of the combination of the steel beam and the PC beam of the great bridge is effective to reduce the adverse effects of the above factors on the whole bridge.

In 1996, China successfully completed Shanghai Xupu Bridge, the main bridge of the double tower and double cable plane and side span concrete beam with cross steel aliasing synthetic hybrid girder cable-stayed bridge structure. Bridge a total length of 1074 m, the main span of 590 meters. The bridge with the span steel-concrete composite beams and prestressed concrete beam edge processing method in the center section of the tower over. Composite beam combination by steel studs, and prestressed cable, and the steel beam and cast-in-place concrete, cross shore of concrete beam are connected into one unit. The side span reinforced concrete beam and the main cross laminated composite beam that a hybrid structure, increasing the stability of cable stayed bridge and side span can be with the main tower construction at the same time. Is conducive to parallel operations. Another major reason is to reduce the high cost of laminated beam length, the reinforced concrete beam [11], reduce the cost. Guangdong Foshan Pingsheng Bridge, the main bridge length 680.20m. Steel and concrete combination beam of the advantages is to increase the side span beam weight and stiffness, reduce the main span beam internal force and deformation, reduce side span end bearing thenegative reaction force, the main span lengthened, thereby increasing the span capacity of the bridge, effective play of steel and concrete material properties[12].

Steel-concrete joint section is one of the key parts of the bridge, its role is to ensure the steel and concrete box beam between stiffness transition uniform Shunhe force transfer smoothly, does not produce too large stress concentration and folding angle, to ensure bridge durable and vehicle driving smooth and comfortable.

3. Problems in the Key Structure of Steel-concrete Composite Section of Cable Stayed Bridge

Main beam steel-concrete joint section of steel and concrete, two kinds of different materials with, material and structure characteristics of mutation, belongs to a key part of this kind of bridge, but two kinds of material elastic modulus and stiffness, deformation characteristics are not the same, affects the bridge force performance and security, often in the face of the disadvantage of integrity is not strong. The domestic part of the hybrid girder bridge has been the emergence of combination of the cracking damage, such as binding section of longitudinal cracks appeared in, serious in concrete transverse vibration beam chamfer have deeper development. In addition, the combination of section of bridge deck pavement of other parts of the girder more vulnerable to damage.

Fuzzy mixed, although our country has built a lot of long span hybrid girder cable-stayed bridge, were also a lot of steel, mixed together, but with steel - mixed with segment usually consists of a steel shell welding on the steel casing shear studs or shear, filled in the steel shell of core concrete and longitudinal through steel, mixed with prestressed steel beam and steel beam and concrete beam transition section structure particularity and complexity, the stress state and the force transmission mechanism is not very clear, mechanical behavior, each bridge steel - mixed with structural arrangement were different, some there is a big difference. The present situation is the lack of design specifications as the basis, the steel shell, the core concrete and the shear element finite element modeling has the contact, the constitutive equation and so on, the computation difficulty is big. As a result, many problems need to be clarified in the aspects of mechanical behavior, simulation calculation, carrying capacity, durability and reasonable structure.

At present, the transition of cable stayed bridge with steel concrete structure is a key problem in design and construction of bridge. Generally speaking, there are several connection structure schemes for the connection of steel - concrete beam.

The connection between steel beam and concrete beam is mainly connected with the structural form of the lattice and the lattice[13]. The structural form of the grid is based on the position of the bearing plate, the front bearing plate, the rear bearing plate and the front and back pressure plates are 3 ways, and the pressure plate is generally configured with various joints such as welding nails and the like. No joint compartment structure forms the basis of bearing plate, the position after the bearing plate, back bottom plate and the composition of the bearing plate way[14]. Comparison of the structural characteristics of the hybrid beam joint, as shown in Table 1.

Table 1. Comparison of structural characteristics of hybrid beam joint

Content	Scheme 1	Scheme 2	Scheme 3	Scheme 4
Transfer of axial force and bending moment	The connecting piece of the top and bottom plate of the chamber and the bearing of the front and rear bearing plates	The connecting piece on the top floor of the lattice chamber and the bearing of the rear bearing plate	Rear bearing	After the bearing plate and extends into the connecting piece and the shear torque transmission box beam on the floor
Transfer of shear and torque	Connecting parts of front bearing plate	Connecting parts of the web and the web on the grid	The friction between the bearing plate and the concrete and the U - shaped steel bar	Connecting parts of bearing plate
Advantage	①Concrete box beam reinforcement, pouring easy; ② concrete quality assurance; ③ axial force is composed of front and rear; board and compartments of the connecting pieces bear; ④ bearing plate in the vicinity of the stress concentration minimum; ⑤ the easiest	①Have a longitudinal stiffening rib, stiffness change is small; ② the longitudinal stiffeners to the U rib pass fluency; ③ in the concrete beam stress eased; ④ c ments should be uniform force; ⑤ in the vicinity of the stress concentration of the small	①By adjusting the arrangement of the stiffening rib, the stress concentration near the bearing plate can be reduced; ②the forcement and the pouring of the concrete box girder section are easy; ③ of the concrete pouring of the joint part is easy to guarantee;	① Through the adjustment of the stiffeners layout can reduce the stiffness variation larger; ②concrete box beam reinforcement, pouring easy; ③ concrete pouring quality easy to guarantee; ④ program beams is easy to manufacture; ⑤ plate in the vicinity of the stress concentrated compared to the scheme 3 small
Shortcoming	①In the case of the room, there is a need to fill the mortar,; ② change in the vicinity of the rear bearing plate.	①The welding construction of the steel beam is poor; ② to be set up, and the reinforcement and the concrete pouring are difficult.	①In the vicinity of the pressure plate, the stress concentration becomes larger; ② the variation of the stiffness near the bearing plate is larger.	①Stress concentration in the vicinity of the pressure plate becomes larger, but it is smaller than the scheme 3; ②In the vicinity of the bearing plate, there is a large change in the stiffness.

4. Development Prospect of Key Structure of Steel Mixing Section in Cable Stayed Bridge

Relying on the in built Guizhou Wujiang River Super Large Bridge, the main bridge towers and double cable plane hybrid composite beam cable stayed bridge, the span arrangement for 54m+71m+360m+71m+54m, the full-length 610m. Deck full width 28.0m arranged for 1.75m (the anchorage zone of cable) + 0.5m (barrier) +11.0m (Lane) +0.5m (barrier) +0.5m (median) +0.5m (barrier) +11.0m (Lane) +0.5m (barrier) + 1.75m (the anchorage zone of cable). The deck of the bridge is located in the straight line segment, and the longitudinal surface is located on the uphill section of the slope is 0.6% and the slope is 0.7%.

Girder using hybrid composite beam, side span beam for PI type concrete beam and the central line of the main beam high beam 3.16M, side main rib beam high 2.88m; in cross with steel - aliasing composite beam, composite beam center line girder high 3.16m, steel beam with the edge of the font, font on the beam high 2.9m. Bridge panel thickness 28cm.

As the main tower of H tower, 102m tower above the beam under the tower, tower 70m, each tower consists of 18 3M diameter pile. Hollow thin wall piers with 4.0×4.0m for auxiliary piers.The overall layout of the bridge is shown in the Figure 1.

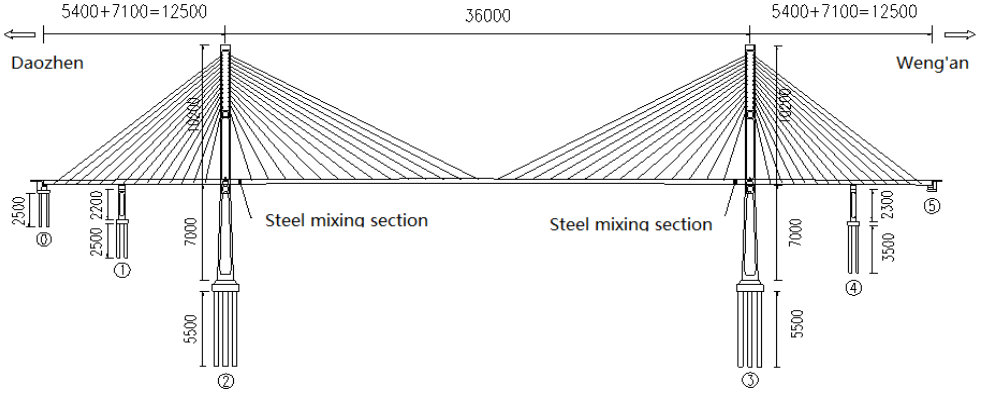


Figure 1. General layout plan.(unit: cm)

Due to the mixed beam in combination with the force transmission mechanism complex, intends to take the method of combination of numerical analysis and model test of the [15].According to the general structure theory shows that, combined with the section under the joint action of bending moment and axial force, the possible failure modes may is one of the following forms:①based on surface of the upper flange of the negative pressure, steel diaphragms and solid concrete beams between peeling and crack;②steel beam flange buckling or box stiffening rib buckling instability;③concrete beams cracking. Therefore, test model design principle is: in strict accordance with the model similarity theory of model design, to ensure the steel girder flange stress is similar; design model under the guarantee main element and prototype must also ensure shear connection piece, a baffle connecting ribs and stiffening rib structural details also fully simulate the structure of the original bridge. According to the above principles and geometry, physical and boundary conditions of similarity theory and of hybrid girder combined with simulation test, model test under the design load control section and control points of component stress distribution, force model and load transfer mechanism of research; mixed by steel and concrete relative slip between the test calculated with connecting piece and a bearing plate force sharing.

According to the real bridge spatial finite element calculation results, determine the steel concrete composite segment model test interception range[16]. Selection of steel-concrete combined with some local structures were analyzed, according to the Saint Venant's principle, steel-concrete combined with each side length should be not less than the width of the size, in order to ensure that in the two ends of the truncated equivalent load steel-concrete combination section should stress state and the real bridge line.

Because of the full bridge calculation is not able to with the reflect of steel-concrete joint section should force and stress distribution, the international large-scale general-purpose finite element analysis software ANSYS on the girder of steel-concrete joint section of the local structure do fine spatial finite element analysis and calculation [17], steel - concrete joint section of by force characteristics and stress distribution, the observation and the overall and local stress situation, combined with the analysis of the ultimate bearing capacity and stress reserve level.

According to the spatial fine finite element calculation results of the combined section of the main beam steel, the stress of the combined section of the steel under various loads is analyzed, and the load condition of the model test is shown as follows:

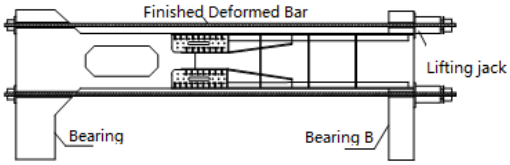
1) maximum axial pressurecondition
2) maximum shear condition
3) maximum bending condition
4) maximum torque condition

According to the design drawing, making the test model of steel - concrete composite section. In order to better reflect the stress state of the concrete bridge steel mixed section, the fabrication of the test model needs to consider the shape dimension of the model structure, manufacture and installation, loading mode and test site. Figure 2 shows the structure of steel - concrete composite section beams.

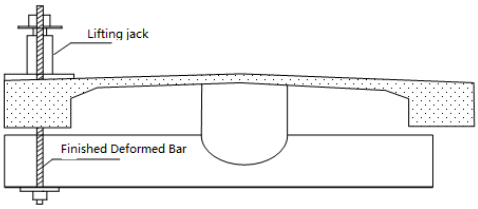
Figure 2. Structure diagram of steel and concrete composite section steel beam.

According to the steel-concrete joint section of the actual mechanical characteristics, simulation of force and displacement boundary conditions [18]. The two ends of the model are provided with one-way rotary support, and the support reaction force and rotation capacity of the self weight are provided. Model of axial force, bending moment and torque are used self balance loading method and by tensioning finishing rolling rebar implementation, combined with the surface of shear values
relative to the axial force, bending moment and torque is very small, not a separate loading. The loading device

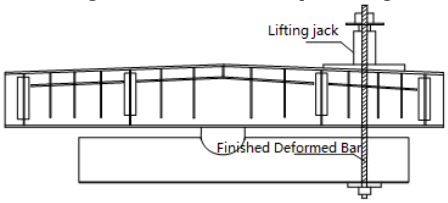
and the loading method are shown in Figure 3. Model both ends are symmetrically arranged between two loading points, loading end connected by finishing rolling rebar. Combined with section of axial force and bending moment applied by the loading end up finishing rolling rebar unbalanced Zhang to achieve and torque applied by in model of beam section at the two ends of the cantilever beam vertically arranged planished steel, lower end anchorage on the beam, by Jack tension finishing rolling rebar is loaded.



(a) Schematic diagram of longitudinal bridge loading device



(b) Schematic diagram of concrete end torque loading device



(c) Schematic diagram of steel box girder end torque loading device

Figure 3. Steel - concrete composite section loading schematic diagram (initially proposed)

For the static test, the test load condition is carried out according to the above mentioned. Test the test load step loading [19] and loading into the early reading loading to 0.1 times the design load, measuring and reading; continue to load to 0.2 times the design load, measuring and reading; so to 0.1 times the design load for classification of loading step by step, measuring and reading, to 1.0 times the design load after unloading, after unloading to zero reading, so round-trip times, finally loading to 2.0 times the design load.

5. Conclusion

Hybrid beams have been widely used in ordinary cable-stayed bridges. In recent years, there have been many applications in low tower cable stayed bridges and continuous girder bridges. After two kinds of main girder of bridge type by force with its own characteristics, can not copy the design method of cable-stayed bridges and need to a large number of model test and numerical analysis of. This paper introduced low tower cable stayed bridge with the before and after bearing plate joint way, and with open hole plate connection piece instead of the stud connectors are pieces of the joint design of new technology, to solve the mixed beam design and the key technical problems provide a new train of thought.

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