Study on Steel and Concrete Composite Structure Bridge

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Abstract. With the development of the transportation industry, bridge construction has become particularly important. Bridge materials can be divided into many types, and different materials have different properties. In view of the existing problems of bridge construction materials, this paper mainly studies the structure of steel and concrete composite bridge. By understanding the advantages of steel and concrete composite bridges, the stress characteristics and durability of different types are analyzed. The analysis results show that the steel and concrete composite structure bridge is beneficial to improve the bearing capacity and performance of the bridge structure. In addition, measures such as coating, weathering steel, high performance concrete and prestressing can be taken to improve the durability of steel and concrete composite structure bridges. It is shown that the steel and concrete composite structure can play the respective characteristics of the two materials, so the structure can be widely used in the future bridge construction.

Keywords: Steel and concrete composite bridge; structural durability; durability improvement measures.

1. Introduction

Bridges are indispensable transportation buildings in human life. Bridges in cities can speed up road traffic and reduce traffic jams. The cross-sea bridge can connect many coastal cities, provide more convenient transportation conditions for enterprises in these cities, and promote the development of business cooperation and the prosperity of the national economy. The application field of bridge is more and more wide, and the structure and material requirements of bridge are also higher and higher. Ordinary concrete and ordinary steel structure bridges have some drawbacks. At present, many countries are applying steel and concrete composite structure bridges. The steel and concrete composite structure can give full play to the advantages of the two materials, which is an economic way to improve the service life of the bridge [1]. In France, many road bridges are composite structures, among which 45% of Train a Grande Vitesse Road bridge is composite structure, and the cost of composite bridge is lower than that of concrete bridge [2]. The structure of steel and concrete composite bridge plays a very important role in the bridge construction project in Europe and America. In recent years, China has developed rapidly in the development of long-span bridges, but the development of composite structure bridges lags behind some countries [2].

Therefore, through the study of different types of steel and concrete composite structure bridges, this paper summarizes the advantages of composite structure bridges and measures to improve durability. Then the future development trend of composite structure bridge is analyzed, and some suggestions are provided for the future development of composite structure bridge in China.

2. Advantages of Composite Bridge

2.1. Saving Construction Cost

Steel and concrete composite bridges can appropriately reduce the overall cost of bridge construction, which is probably reflected in two aspects. First, in one workshop, for example, a combination of steel and concrete was used instead of pouring concrete on steel beams, which reduced the amount of steel used by the workshop by about 20 percent [3]. Second, some structures can use ready-made templates combined with steel and concrete, which not only saves the cost of templates

for developers, but also shorts the construction period and effectively avoids developers having to cut corners in order to save costs [4].

2.2. Improving Bearing Capacity and Overall Stability

Compared with ordinary concrete bridges, steel and concrete composite bridges can effectively improve the stiffness of beams [3]. The combination of steel bar and concrete can give full play to the characteristics of the two materials. Concrete is mainly used for pressure, and steel bar is used for tension, which can ensure that the bridge can be used normally after maintenance after slight deformation [4]. Therefore, the composite bridge can effectively improve the stability and bearing capacity of the bridge.

2.3. Increasing Bridge Service Life

Because the construction environment of many bridges is very inconvenient, and the construction difficulty is much higher than that of houses and roads, the construction materials of bridges are also relatively high [4]. The steel and concrete composite structure can not only improve the seismic performance of the bridge, but also improve the local pressure performance of the bridge, which can help the bridge effectively resist the adverse influence of the external environment [3]. Therefore, the combined structure is conducive to the longevity of the bridge and the future development of the bridge.

3. Types and Cases of Different Composite Structure Bridges

3.1. Simply Supported Composite Beam Bridge

3.1.1. Bearing characteristics

Steel and concrete simply supported composite beams have high strength and stiffness, which can not only effectively reduce the structures self-weight, but also improve the durability and load-bearing capacity. Simply supported composite beam bridge has clear force, simple structure and convenient construction, and is the most widely used bridge among small and medium span bridges [5].

3.1.2. Simple supported composite beam of Shenzhen Rail Transit Line 4

The total length of the bridge is 45m. Because the bridge is located in the downtown of Shenzhen, there is a large flow of people and vehicles in the area, and there is a very complicated traffic situation. Considering the advantages of convenient construction and short cycle of simple supported composite beams, the final construction structure of the bridge is positioned as simple supported composite beams. As shown in Fig. 1, the bridge is 2.8m in height and 5.78m in width. The steel beams are in the form of single box and single chamber [6].

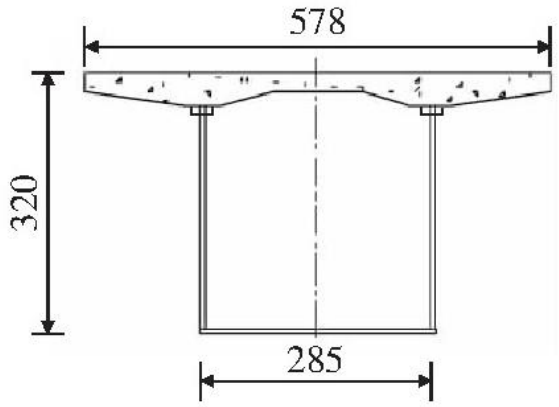

Fig 1. Cross section of 45m single-line simply supported composite beams [6].

3.2. Continuous Composite Beam Bridge

3.2.1. Stress characteristics

The continuous composite beam bridge has large structural stiffness, small deformation, less expansion joints and stable and comfortable driving. However, under the influence of factors such as environment, material itself and beam subjected to large tensile stress, cracks may occur on the bridge deck [7]. In order to solve this problem, a prestress can be applied in the negative moment area of the center fulcrum or the neutral axis can be lowered [6].

3.2.2. Ancient City Bridge of Shanghe-Hangzhou high-speed Railway

The combination of steel and concrete continuous beams is used in the Gucheng Super Bridge of Shanghe-Hangzhou high-speed Railway. The steel beams of the bridge have a closed section of single box and two chambers. Stiffening ribs are provided on the top and bottom plates and web plates of the bridge. The lifting and twice falling beams of the steel beams in the lower part of the bridge are equivalent to imposing a prestress on the upper surface of the bridge, which can well prevent the cracking of the bridge floor. The cross section of the main beams of the bridge is shown in Fig. 2 [6].

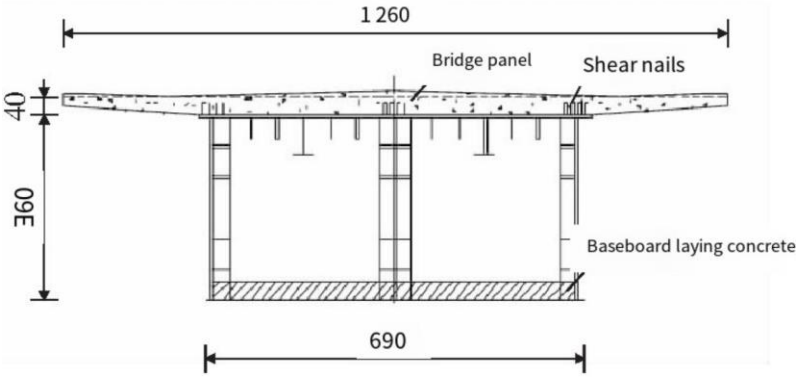

Fig 2. Cross section of the main beam of Chengcheng Large Bridge of Shanghe-Hangzhou High-speed Railway [6].

3.3. Composite Girder Cable-stayed Bridge

3.3.1. Stress characteristics

Compared with ordinary bridges, steel and concrete composite bridges have light dead weight and high stiffness, which can effectively prevent the cracking of bridge steel bars, so they are more suitable for cable-stayed bridges with large spans. The weight of steel and concrete composite beams is greater than that of steel beams, so they can be applied to the main beams of cable-stayed bridges and play a role in balancing the negative reaction of side span auxiliary piers [6].

3.3.2. Shanghai-Sutong Yangtze River Bridge

Shanghai-sutong Yangtze River Bridge is a control project of Shanghai-Nantong railway. The bridge is located about 45km downstream of Jiangyin Yangtze River Highway Bridge and about 40km upstream of Sutong Yangtze River Highway Bridge. The total length of the bridge is 11.072km, and the length of the combined bridge is 6993.062 m, of which the total length of the steel beam of the main bridge is 5831.3 m. In order to save the total investment of the project and make full use of the precious bridge location resources, the bridge adopts the common construction mode of Shanghai-Nantong Railway, Suzhou-Jia intercity Railway and Xitong expressway. The main channel bridge: 142+462 +1 092+462 +142 =2300 (m), is a two-tower five-span cable-stayed bridge. The main channel bridge of the bridge is a new structure of box girder and trusscombination. It adopts welding between two sections and lifting construction of the bridge position as a whole, with lifting mass of 1700t. It is fully welded between two sections and the overall manufacturing and erection of two sections. The bridge adopts Q500q high-strength steel and 2000MPa grade high-strength durable parallel steel wire cable-stayed new materials, and the main tower adopts C60 high-performance

concrete.The main girder of the bridge is a three-girder structure with a girder width of 35m, and adopts the form of a combined double-deck bridge deck with box beams and trusses. The combined section with concrete bridge panels is adopted for the road bridge deck with a span of 252 m on both sides of the main beam, in order to balance the negative reaction of the auxiliary piers, as shown in Fig. 3 [8].

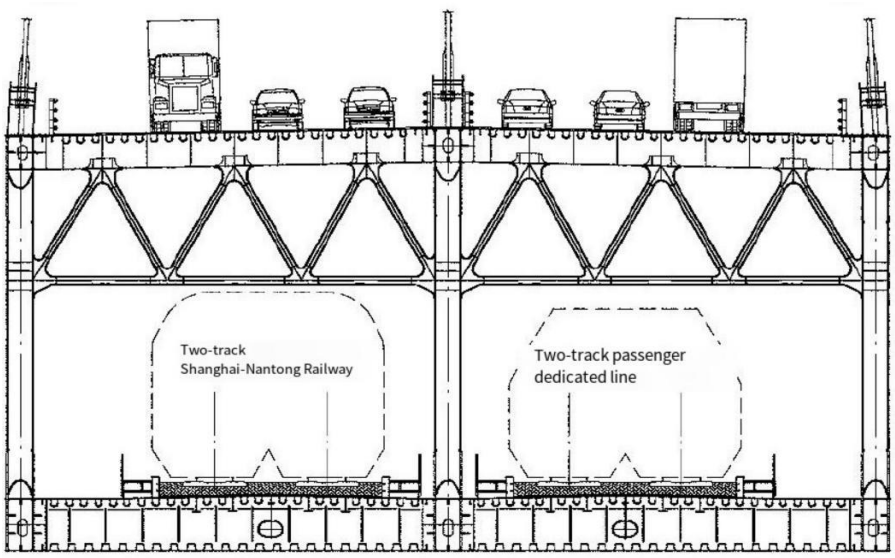

Fig 3. Section view of the main beams [8].

3.3.3. Li Xianjiang Large Bridge

The main span of Li Xianjiang Bridge is 420 m, which is a bi-directional 4-lane expressway super bridge. The layout of the bridge is a two-tower semi-floating system. The composite beams are 3.5 m high, among which the main beams composed of steel are 3 m high. The bridge panels are made of concrete with a thickness of 0.5 m. The cross section of the main beam of the bridge is a bilateral I-section, as shown in Fig. 4 [9].

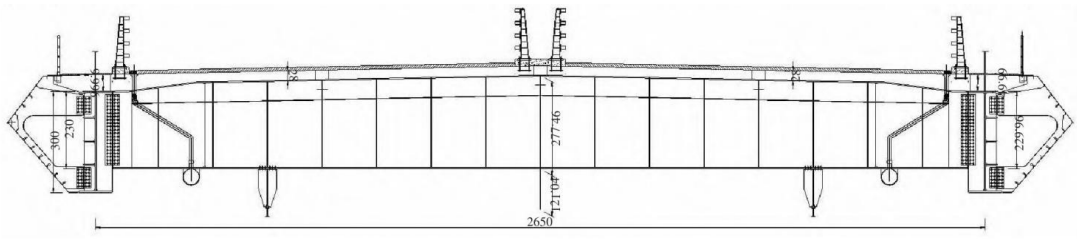

Fig 4. Sectional diagram of composite beams of Li Xianjiang Bridge [9].

4. Durability Improvement Measures of Steel and Concrete Composite Bridge

Many Bridges are located in a very harsh environment, such as the cross-sea bridge. Cross-sea Bridges not only need to face the problems of structural stability and bearing capacity, but also face the problem of bridge corrosion in high salt environment, so some measures need to be taken to improve the durability of bridges. The durability of steel-concrete composite structure is mainly reflected in several aspects. Such as the durability of the steel structure part, the durability of the steel structure and the concrete structure stud connector, the durability of the concrete bridge panel.

4.1. Durability Problem of Steel Structure Part

The biggest disadvantage of composite structure Bridges is the durability of steel structure [10]. In view of the durability of the steel structure, some measures can be taken to improve its durability, such as the coating of the steel structure and the use of weathering resistant steel. The coating method is convenient in construction and simple in process, so it is widely used. However, this method is

susceptible to environmental impact and generally has a service life of 10 years, so it needs regular inspection and maintenance [11]. Weathering steel is to automatically form a dense protective film by adding some alloying elements to the steel structure. The longer the time passes, the stronger the protective layer of weathering steel will become, which can effectively reduce the corrosion rate of steel structure [11].

4.2. Durability Problem of the Stud Connector

The durability of stud connectors at the joints of steel structure and concrete structure will be greatly reduced in freeze-thaw and corrosion environments. In the composite structure of steel and concrete, the compressive properties of concrete are mainly used. The mechanical properties of concrete in a freeze-thaw environment will be greatly reduced, while the shear properties of stud are mainly affected by the corrosive environment [12]. With the increase of freezing and thawing times, the corrosion depth also becomes larger, and the shear resistance of stud connectors and the mechanical properties of concrete will continue to decline until they are destroyed. Therefore, in order to improve the durability of the joints, some measures must be taken to deal with the harsh environment. For example, concrete with good crack resistance is used, concrete is coated, and the diameter of the stud at the joint is lengthened, generally increasing by 2-3 mm [12].

4.3. Durability Problem of Concrete Bridge Panel

The durability of concrete bridge panels is mainly reflected in the crack resistance of concrete. Some measures can be taken to improve the crack resistance of concrete bridge panels, such as pouring the bridge panels in stages, applying prestress on the bridge panels, lifting the end of the beams before the second phase pavement construction [13]. The specific process of adopting these measures mainly includes the following points: In the first step, the factory needs to prefabricate steel main beam segments; in the second step, temporary piers are set up and steel main beams are built by cranes; in the third step, the bridge panels of the first stage are poured; in the fourth step, the bridge panels of the second stage are poured, and prestress is applied at the bridge panels; in the fifth step, the wet joints between the bridge panels of the two stages are poured, and then the steel beams are lifted through the jacking, and finally the steel structure is coated [13]. By following the above steps to complete the construction, the crack resistance of the concrete bridge panel can be improved, thus improving its durability. In order to fully cope with the corrosion of composite bridges, a comprehensive environmental investigation must be carried out before construction, which not only requires construction in strict accordance with specifications, but also requires workers to accumulate experience and learn to apply anti-corrosion measures [14].

5. Conclusion

This paper mainly studies the structural characteristics and durability of steel and concrete composite bridges, and draws the following conclusions:

(1) Steel-concrete composite bridge structure can give full play to the advantages of steel and concrete. Concrete is mainly used for pressure, while steel structure is used for tensile strength. The combination of the two is conducive to improving the bearing capacity and stability of the bridge structure. The construction period of the combined bridge structure is short, the construction is convenient and the steel amount is less, which can save the cost for the construction side. The composite bridge structure can also improve the local pressure performance and seismic performance of the bridge, which is conducive to improving the life of the bridge.

(2) Through the analysis of some different composite bridge cases, it can be concluded that the simple supported composite beam bridge is simple in design, convenient in construction and can improve the bearing capacity of the bridge, and is mostly used in urban center bridges. The continuous composite bridge has large stiffness and small deformation, but the bridge floor is easy to crack. Therefore, when using a continuous composite bridge, prestress should be applied on its bridge deck,

which can effectively prevent the cracking of the bridge panel. Compared with other bridges, composite girder cable-stayed bridges have light weight and are not easy to crack, and the span is large. Many cross-sea bridges are the composite girder cable-stayed bridges.

(3) For the durability of steel-concrete composite structure bridges, the durability of steel structure parts, stud connectors and concrete bridge panels are discussed respectively. In view of the durability of these three parts, measures such as coating, weathering steel, high-performance concrete, lengthening the diameter of stud and applying prestress can be adopted respectively to deal with the durability problem.

(4) At present, many new materials have been developed and applied in bridge structures, and they have strong properties. However, in the future bridge construction, it is still inseparable from steel structure and concrete structure. The combination of steel structure and concrete structure can give full play to the advantages of steel and concrete, and is conducive to the improvement of all aspects of bridge structure performance. In order to improve the service life of the bridge, it can bring better comprehensive effects to people. Therefore, the future application range of steel and concrete composite structure will be more and more extensive.

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