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The Practice and Development of Prefabricated Bridges

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Abstract. Due to the standardized (modular) production of components, fast construction speed, easy quality control, and favorable environmental protection, the use of prefabricated bridge is attractive, especially to sea-crossing bridges and urban bridges. This paper reviews available information concerning the application and development of prefabricated bridges. Three bridge examples are then introduced, while the structural design and the construction methods of prefabricated bridge piers are described in detail. Furthermore, main constructions of segmented piers are concluded. Finally the future research direction of fabricated bridge is viewed.

1. Introduction

In recent years, unprecedented traffic problems have appeared in the construction of many cities, especially in occupying lanes during construction, frequent accidents; long construction period increased the illogicality between the automobile and the road [1][2].The current urban bridge structural design has the following two requirements: the safety and durability; less disturbance to the surrounding traffic, less obstruction, less noise in the transportation and construction, etc.

Prefabricated bridge can well meet the above two requirements. The prefabricated assembly technology of concrete bridges which can shorten the construction period , minimize the impact on surroundings and traffic ,ensure the quality of the project and reduce costs, results in the height of the bridges community. In recent years, the construction of certain cross-strait bridge projects (See Fig.1 and See Fig. 2) has also promoted the application of segmental erection technology due to the limited space of the offshore construction platform and the complex climatic conditions and other factors.

Figure 1 Hangzhou Bay Bridge Construction

Figure 2 Donghai Bridge Construction

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In summary, prefabricated bridges have the advantages of standardized production of components, reduce the construction period. prefabricated bridges are easy control of quality and with good durability , as well as reduce the impact on the environment.

2. Domestic and foreign engineering review

With the technological advancement of the equipment, the world's first concrete prefabricated segment assembly bridge was built in the 1940s. Since then, European universities and institutions , the Federal Highway Agency had continued to carry out systematic research on prefabricated bridges over the years. Since the 1980s, the United States has called it bridge rapid construction technology. At present, prefabricated segment construction methods have been widely used in bridge construction in Europe, the United States, and Japan.

Compared with Western countries, the research and application of bridge prefabricated assembly technology in China started late. Since the 1970s, China had begun to explore bridge prefabrication and assembly technologies . Existing applications and research have focused on the bridge superstructure. As for prefabricated pier structures, exploration and research have also started in recent years, and they have been applied to the piers of bridges and urban viaducts of some cross-sea bridges. Table 1 lists the bridge projects in our country and abroad.

Table.1 Prefabricated bridge examples

Bridge site	Bridge name	Construction time	Prefabricated position
United States/Florida	Long Key Bridge	1982	full-bridge
United States/Florida	Seven Mile Bridge	1982	full-bridge
United States/North Carolina	Linn Cove Viaduct Bridge	1985	full-bridge
United States/Florida	Sunshine Skyway Bridge	1987	pier
Canada/New Brunswick	Confederation Bridge	1997	full-bridge
United States/Texas	Loyta Road Overpass	1998	pier
United States/Florida	Garcon Point Bridge	1999	full-bridge
United States/New York	Belt Landscape Bridge	2002	full-bridge
United States/Texas	Lake Ray Hubbard Bridge	2003	full-bridge
Beijing China	Jishuitan Bridge	1992	pier
Shanghai China	Donghai Bridge	2005	pier
Zhejiang China	Hangzhou Bay Bridge	2007	pier
Shandong China	Qingdao Bay Bridge	2011	pier

3. Bridge Examples

The Xinao Bridge in the Macau SAR of China commenced in June 1990(See Fig.3). The bridge used prefabricated caps and prefabricated piers for the first time. The prefabricated pile platform is a hanging box, and the post-cast concrete is used to connect the pile foundation and the pile platform as a whole. The prefabricated piers adopt I-shaped cross-section block, 10 holes of high-strength reinforced steel reinforcement are reserved, and the prestressed steel bars penetrating the pier and the top of the pier are tensioned and anchored to connect the pier body with the pile cap.

The Donghai Bridge is the first truly expressway cross-sea bridge in China[3].The prefabricated segments are installed on the piers with four prefabricated short column supports. The prefabricated short columns are 1.2 meters high and are prefabricated in three sections. Six holes with a diameter of 80 mm are reserved during the prefabrication, and the steel bars are installed and then the pier segments. Lifting and prefabricated short columns, welded connection reinforcement steel, concrete mold pouring concrete.

Shanghai Jiamin expressway (G2~S6) project is fully prefabricated, including prefabricated piers, prefabricated coping and small box girder[4] (See Fig.4).The pier column and the platform and cover beams are connected by a grouting sleeve. The average duration of construction is shortened by 50%, and workers are reduced by 60%. The standardized production process and advanced equipment of the prefabricated factory also ensure the controllable quality. This project is also the first domestic elevated road project to implement and use this construction process on a large scale.

Figure 3 Friendship Bridge

Figure 4 Shanghai Jiamin expressway

4. Current research progress

Due to the discontinuity of the segment pier , its structure is very different from that of the traditional bridge iers. The mechanical properties of pier piers are different from those of traditional bridge piers. According to the classification of the types of joints of segmental bridge piers, the main types include: reinforcement anchorage, welding, retaining ring, inserting, post-tensioned, flange type. The main characteristics of various types are shown in Table 2.

Table 2 Connection type of prefabricated bridge

Connection type	Construction feature
Reinforcement anchorage type	Retain the reinforcing steel on the segment, insert into the reserved slot of another segment, Welding, pouring concrete, should be used to connect the cap pier and the pier.
Welding type	The steel plate or steel bar embedded in the segment is welded with the embedded steel bar or steel plate of another segment and mixed. Concreting pouring, it should be used for the horizontal member and the vertical pier connection.
Retaining ring type	Pre-embedded ring-shaped steel bars are installed in the segment. When installed, the bridge piers fall on the center of the pile caps, and the ring steel bars are misconnected. U-shaped steel bars are used for welding between the rings, and concrete is placed on the outer joints.
Inserting type	The prefabricated section is inserted into the pile caps and the bottom is laid with mortar, filled with concrete. This type is commonly used for the connection between the pier body and the foundation.
Post-tensioned type	Prefabricated segments are pre-stressed with a series of reinforcements, epoxy cement is applied at the joints of the segments, and improve the impermeability of the joints.

Flange type	Flanges are installed at both ends of the connected segments. The joints are connected by flanges. The position of flanges is perpendicular to components, and the joints can be filled with concrete.

In earthquake area , segmental piers have not been widely used. Therefore, many researchers have studied the seismic behavior of segmented piers, especially the theoretical and experimental methods and design methods for the seismic behavior of joints. The current experimental work in this area is described below.

In 2000, Lin and Mo conducted a pseudo-static test of two sets of segmental assembling concrete piers[5]. The hysteresis behavior of the components under cyclic loading shows that the segmental assembly piers and the conventional integral piers in the in earthquake area have similar energy dissipation capabilities. The main reason is that the joints are outside the plastic hinge area and reinforced with prestressed steel bars. Joints have little effect on the plastic behavior of the pier

In 2011, Gao Jing conducted a cyclical load test for a group of segments of reinforced concrete[6]. Among them, there are five components. Based on the research parameters, five types of assembled piers were designed. The test results show that the curvature of cast-in-place prestressed concrete piers is mainly concentrated in the plastic hinge area, and the larger the curvature is, the greater the curvature is, and the curvature of the assembled piers is mainly distributed near each joint. In the process of loading, the joints of segmental bridge piers will open and close, and no plastic hinge similar to that of cast-in-place piers will appear. The damage of segment piers is much smaller than that of cast-in-place piers. Through the comparison of the five components, it is concluded that the segmental bridge piers have better self-return capability and the residual displacement is very small.

5. Summary

With the advancement of equipment, as well as the continuous research on prefabricated bridges[7]. The new prefabricated bridges have the advantages of fast construction speed, easy-to-control quality, saving materials, good durability, and being environmentally friendly. The promotion is imperative. From the current research results , prefabricated bridges have good plasticity, seismic performance and meet the strength requirements, and joint seams will not become weak parts[8]. With the continuous deepening of research, people will continue to explore new splicing methods and construction techniques, and through experiments and finite element software to test the overall performance of the bridge under the method and the construction process and the stress at the node.

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