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Prestressed Concrete Highway Bridges in China

Ponts-route en béton précontraint, en Chine

Strassenbrücken aus Spannbeton in China

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SUMMARY
This paper briefly describes the progress and trends of prestressed concrete bridges in China. Some typical examples of prestressed concrete bridges in China are presented to show application and development of long-span highway bridges, as well as their design concepts and structural analysis.

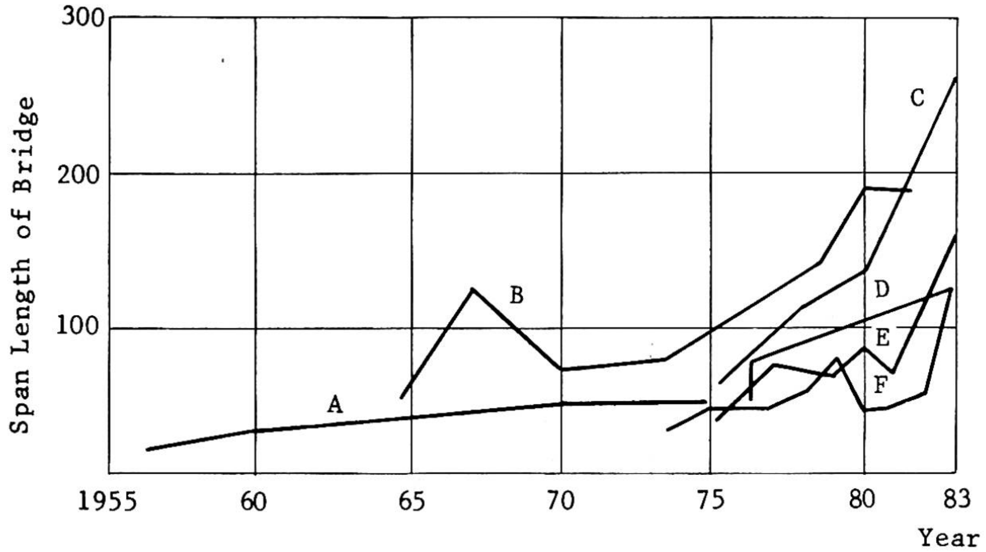
RESUME
Ce rapport présente succintement les progrès et les tendances des ponts en béton précontraint en Chine avec quelques exemples typiques montrant l'application et le développement dans les ponts de grande portée, ainsi que leur conception et leur calcul.

ZUSAMMENFASSUNG
Der Beitrag behandelt hauptsächlich die Fortschritte und Tendenzen im Spannbetonbrückenbau in China. Einige typische Beispiele von Spannbetonbrücken in China werden präsentiert, um die Anwendung und Entwicklung der weitgespannten Spannbeton-Strassenbrücken zu zeigen. Entwurfskonzepte und Tragwerksanalyse von Spannbetonbrücken werden dazu skizziert.

1. INTRODUCTION

As early as the 1950's. Chinese bridge engineers had already begun on research work of the application of P.C. bridge. The first P.C. bridge consisted of simply-supported girders with 20 m span built in 1956.

During the period of the 70's and 80's, the design and construction of P.C. bridge developed with great speed in application of different structural systems and their maximum span lengths, as shown in Fig.1. Up to now, 11 cable-stayed bridges, 18 balanced cantilever bridges (e.g. T-frame), 19 continuous girder



A: Simply Supported Bridges
B: Balanced Cantilever Bridges
C: Cable-stayed Bridges
D: Balanced Cantilever Truss Bridges
E: Truss Arch Bridges
F: Continuous Bridges

Fig.1 Maximum Span Length Records of P.C. Bridge in China

bridge, 5 truss arch bridges and 4 balanced cantilever truss bridges have been built by adopting the new construction technique, such as: 1) balanced cantilever casting, 2) incremental launching, 3) segmental construction and 4) erection by the 4905 KN flooting crane. In 1983 a number of long-span P.C. bridges (L > 50m) were under construction or planning, as shown in Fig.2 and Table 1, from which it may be seen that the development of long-span P.C. bridge in China is quite outstanding.

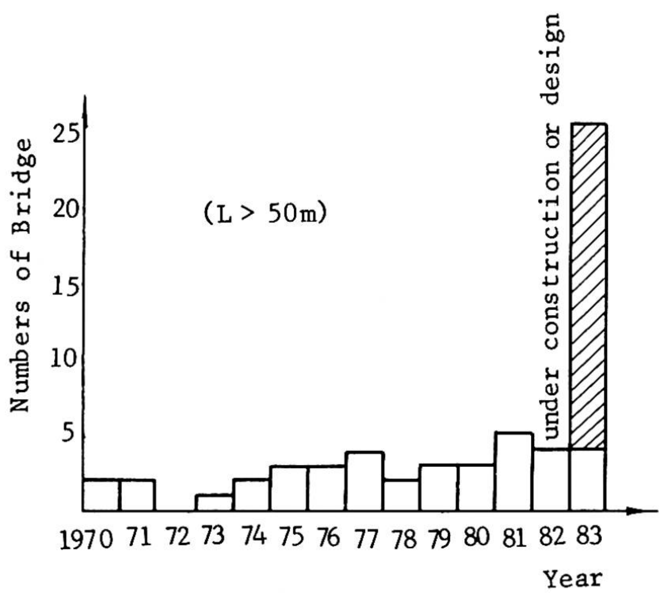


Fig.2 Numbers of P.C. Bridge in China

Table 1 Some Major P.C. Bridge under Design and Construction in China

Name of bridge	Location	Main Span length (m)	Structure System
Yonghe	Tianjin	260	cable-stayed bridge
Changde	Hunan Province	120	continuous bridge
Hongtong	Fujian Province	120	balanced cantilever truss bridge with lower deck
Jianhe	Guizhou Province	150	cantilever truss arch

2. TYPICAL EXAMPLES OF LONG-SPAN P.C. BRIDGE

2.1 Balanced Cantilever P.C. Bridge (or T-frame Bridge)

The Chongqing Changjiang Bridge in Sichuan Province, completed in 1980, composed of eight spans of 81.5m - 4 ×138m - 156m - 174m - 104.5m (Fig.3). Up to now, it is the longest of the T-frame bridge with a total length of 1073m and

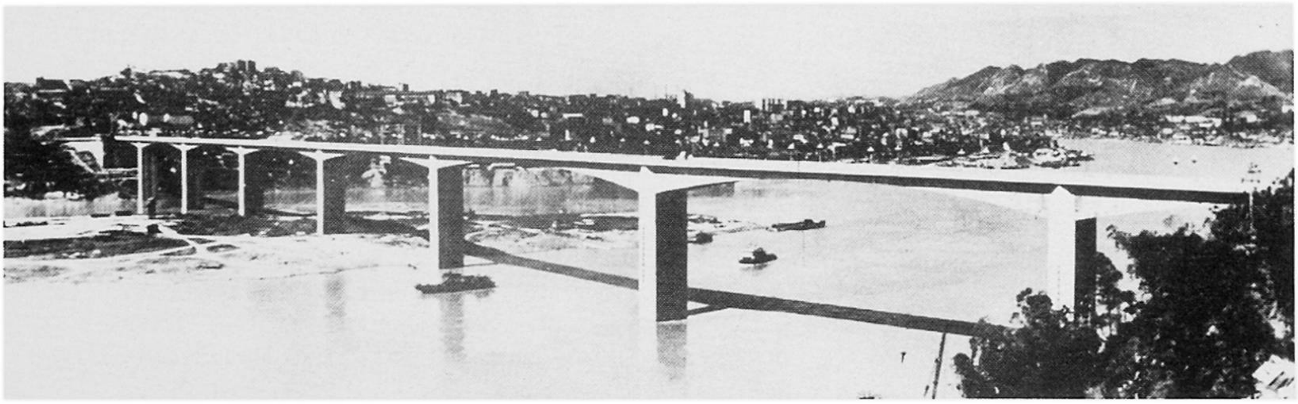


Fig.3 Chongqing Bridge

a total width of 21m, comprising a four-lane roadway of 15m and two sidewalk of 3m each. The bridge superstructure was designed as cast-in-site, post-tensioned P.C. box girder, symmetrically cantilevered from the piers by the segmental cantilevered construction method. A 35m precast suspended span is located in the middle in order to connect the adjacent cantilevers. The cross-section of the cantilevers is made up of two separate single-cell boxes. The length of the cantilevers range from 51.5m to 69.5m with cross-section heights between 11m at the piers to 3.2m at the cantilever ends.

On the bridge site, the bedrocks outcrapped at both sides of the river bank, and the overlying soil layers below the river bed vary from 3-4m to 21.4m. According to geological condition at the location of each piers, three forms of foundation are adopted. The side span piers are founded on spread footings or R.C. caissons, and the main span piers are founded on 12 bored piles of 260m diameter, constructed in steel plate cofferdams. These piers are designed as hollow R.C. rectangular columns with two intermediate wall and constructed by slip forms. The main span piers with a maximum height of 64m is designed to resist a ship collision force of 4905 KN at right angle to the bridge center line and 2943 KN in the direction of the bridge.

2.2 P.C. Cable-stayed Bridge

2.2.1 The Maogong Bridge crossing Mao River in Shanghai suburb was opened to traffic in 1982. The main span is 200m and two side spans are 85m each, totalling 370m (Fig.4). Throughout the bridge site, the substrata are very soft clay. Unequal settlements of piers and abutments may amount to 30m, the bridge superstructure was designed as an externally static determinate structure system. It has two cantilever box girders of constant depth 2.2m rigidly fixed to 44m high portal frame pylons and a 30m suspended span which is provided in the middle of main span which is provided in the middle of main span to connect two cantilevered portions. The cables are arranged in two plans each of which consists of 11 pairs of inclined cables in parallel form. For the main span the segmental cantilevered construction method was adopted. The side spans were constructed on a temporary scaffold. The cantilever box girders are supported on neoprene bearings in the main span, with a movable and adjustable steel pendulum link supports which, in side span for anchor spans, can rotate 5% longitudinally to maintain the superstructure statically determinate under D.L. during the course of settlements of piers and abutments after the girder deflected to a certain value. Under the service condition, the pendulum link bearing will subject to tension or compression with the L.L. in the center span or side span. Total width of the bridge deck is 9m, comprising two-lane roadway and two sidewalks.

Fig.4 Maogong Bridge

The cables composed of two tendona of 73 ø 5mm wires are used on the bankside and two tendons of 147 ø 5mm wires on the river side.

2.2.2 The Ji-Nan Huanghe River Birdge, completed in 1982, shown in Fig.5, is located in the northern suburb of Ji-Nan City, the capital of Sandong Province.

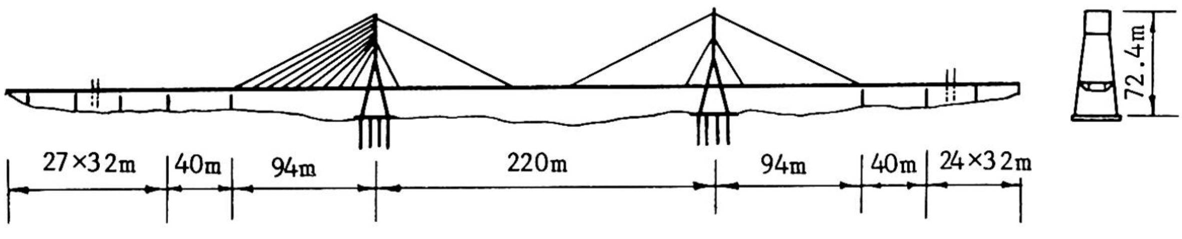


Fig.5 Ji-Nan Huanghe Bridge

The bridge is the current record for P.C. cable-stayed bridge in China, with a main span of 220m, total length of 2,022.8m and total width 19.5m, comprising four-lane roadway. The approach spans consists of 51 @ 30m prestressed composite structure. This P.C. cable-stayed bridge has 5 spans (40m - 94m - 220m - 94m - 40m) continuous box girders suspended at the "A" shape towers with close spaced cables.

The main girder is designed as two separated closed box girders with sharp edged wind nose, and with a centre slab deck and intermediate diaphrams, in accordance with the requirements of aerodynamic stability and static wind forces.

The bridge is constructed by cast-in-situ segmental cantilever construction method.

The two main R.C. towers, standing about 60m above the water, are rigidly fixed on piers supported by 24 casted piles of 1.5m diameter bored to a depth of 84m below bed-level and embedded into weathered rocks. Cables are made up of 4-8 tendons, in turn, composed of 67-121 parallel wire of 5mm diameter made of galvanized high strength steel. The coldcast button headed anchorages are being used.

The whole superstructure is designed as a floating system, no bearings are used in the main span, only sliding bearings are provided at extreme pier and auxiliary pier. The expansion joints are located at each end of the 488m main bridge. The bridge is designed for an earthquake intensity of VII.

2.2.3 The Yonghe Bridge in Tianjin will be the longest of the P.C. cable-stayed bridge with main span 260m, and now is under construction. The bridge is also designed as a floating system to withstand the strong earthquake response in the longitudinal direction. It has 5 spans of 25.15m - 99.85m - 260m - 99.85m - 25.15m with the total length of 510m and the width of 11m (Fig.6).

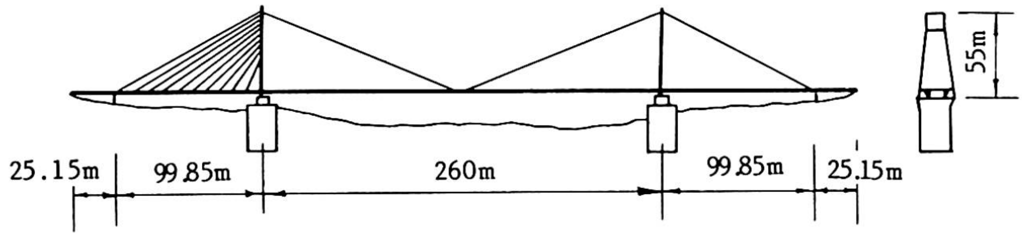


Fig.6 Yonghe Bridge

2.3 P.C. Continuous Bridge

2.3.1 The Shayang Bridge forms a link across the Hanjiang on the highway from Hankou to the Yichang in Hubei Province, which is now under construction (Fig.7). The bridge includes a P.C. continuous box girder with eight spans of 63m - 6×111m - 63m, and 33 spans of 30m for approaches, totalling 1815.5m. The bridge superstructure is a cast-in-situ post-tensioned concrete box girder with a cantilever system for D.D. and with continuity for L.L. by a casting joint section at mid-span to connect the adjacent cantilever. The cross-section is designed as a central box girder with cantilever bridge deck. The width of the bix is 6m and the depth varies between 6m at the piers and 3.0m at mid-span. The total bridge deck width is 12.5m.

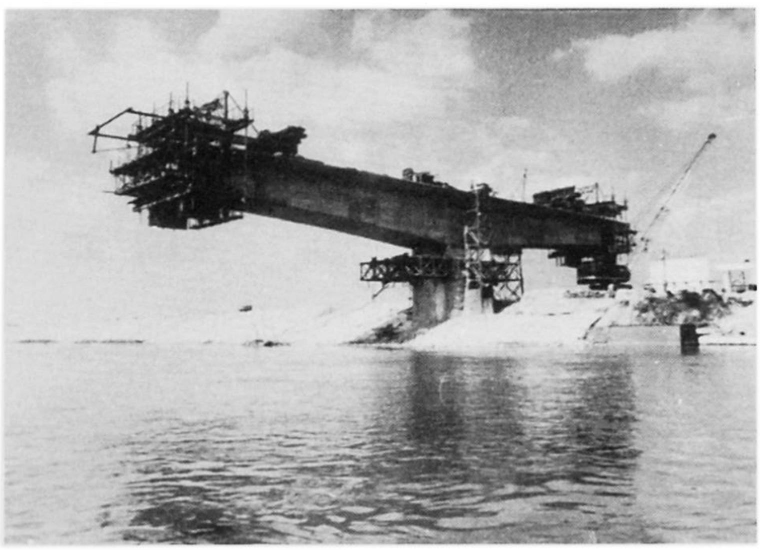


Fig.7 Shayang Bridge

The bridge is constructed by balanced cantilevered method. During the construction, the cantilevered box girder is temporary fixed on pier by vertical prestressed tendons to maintain equilibrium.

The approach piers are each founded on two bored R.C. piles of 180cm diameter, and the piers of main spans are founded on R.C. caissons on sand-gravel rock.

2.3.2 The Rongqi Bridge is located in Guangdong Province and is also under construction. The main span is 90m, approach span 30m and totwl length 1017.06m. The superstructure of the main bridge (spans 73.6m - 3 × 90m - 73.6m) is designed as a precast segmental, post-tensioned continuous box girder, the cross section of which is two separate boxes flanked by centrograted cast-in-situ joint section in 1.8m distance. The box girder divided 9 large precast units along bridge center line whose size depends upon self-weight not more than 4905 KN (Fig.8).

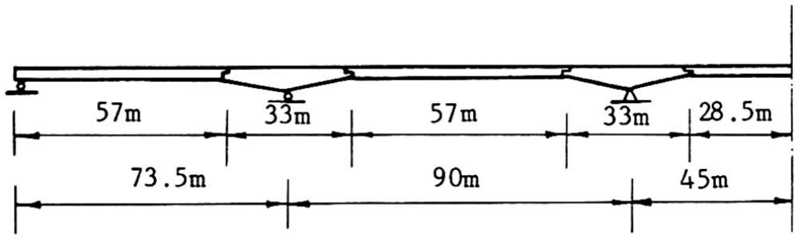


Fig.8 Side View of the Rongqi Bridge

2.4 Balanced Cantilever Truss Bridge with Lower Deck

The Gangkou Bridge with a main span 70m in Zhejiang Province is now under construction, and the Hongtang Bridge with a min span 120m in Fujian Province is in design stage. Both are the balanced cantilever truss bridge with lower deck which is adopted in order to make possibility to reduce the construction height of bridge and to maintain the maximum navigational clearance.

The overall length of the Tongtang Bridge is approximately 1625m separated in 360m main bridge (Fig.9) and 1265m approach spans. The construction height

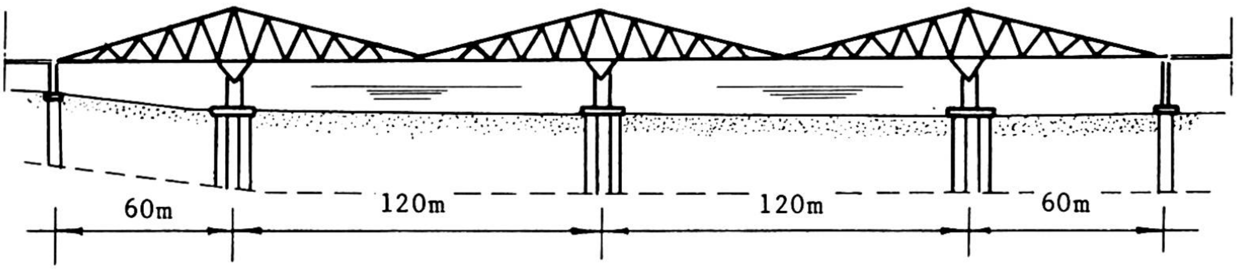


Fig.9 Hongtang Bridge

of the bridge is only 1.32m, so that the span to depth ratio (L/h) is about 91. The nevigational clearance in the main span is 10m in height.

The main bridge has two P.C. truss in 10.14m apart cantilevered over the piers and with a hinge in centre of each span. The behaviors of this bridge structure is the same as balanced cantilever box girder. The heights of the truss are 16m at pier and 1.32m at cantilever end. It should be pointed out that the bridge self-weight is reduced due to the truss instead of the box girder. The bridge deck is placed on the same level with lower chord in order to decrease the construction height of bridge.

The river piers with "Y" shape are founded on 14 bored piles, 150cm diameter, and the land piers are founded on 2 bored piles, 180cm diameter.

3. DESIGN AND STRUCTURE ANALYSIS

The specifications and standards for Chinese highway bridge has been promulgated since 1956, and the specification for P.C. bridge has been enforced since 1978 in China. They are being revised now with the principles of limit state design and advanced technology.

In Chinese prestressed concrete bridges partial prestressing is not allowed at present.

The standardized designs have been widely used, for instance, 1) the simply-supported P.C. girder bridge with span length under 40m, 2) the balanced cantilever P.C. box girder with span length 60m to 80m. It may suit the requirements of most small and medium bridges to be constructed on new highway lines.

In recent decade, a series of computer programs for both static and dynamic analysis of bridge structure by means of finite element method have been made and widely used in highway bridge designs. The function of those programs is quite complete for P.C. bridge, comprising the structure analysis at any construction stage, the redistribution of internal forces due to creep and shrinkage of concrete, the secondary moments caused by self-weight and prestressing, the temperature effects, the settlement of foundation, the earthquake response analysis of bridge structure and so on.

Aerodynamic stability and static wind force checked by extensive wind tunnel testing without the influence of traffic loads have been adopted for design of long-span cable-stayed P.C. bridge.

The Kalman's filtering method proposed by Chinese engineers is first used in cable-stayed bridge construction to control the erection deflection and cable forces with design values.

All of these mentioned above mark the new level in design and structure analysis of P.C. bridge in China

4. Conclusion

Up to now, more than 75% of major and medium bridges on the trunk highway in China are of prestressed concrete. It will be expected from this that we have accumulated quite valuable experience in the design and construction of P.C. bridges. We believe that in the near future, the development of design and construction of long-span P.C. bridge in China will rise to a new level.

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