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Fiber Reinforced Plastic Bridges in Chongqing

Passerelles renforcées de fibres à Chongqing

Glasfaserverstärkte Brücken in Chongqing

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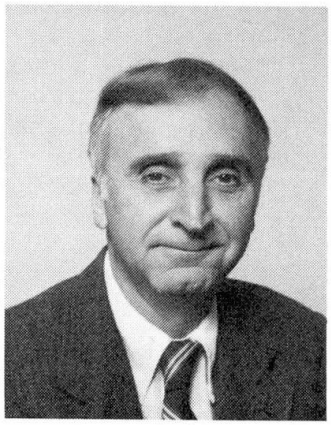

Robert Bruce, born in 1930, earned the PhD. at the University of Illinois, and is the Chairman of the ACI-ASCE Committee on Prestressed Concrete.

SUMMARY

The Pedestrian Cable-Stayed Bridge and the Guanyinqiao Pedestrian Bridge in Chongqing are a unique combination of high strength steel and reinforced concrete with glass reinforced plastic. This paper is a brief report in which the physical characteristics of the bridges are described.

RÉSUMÉ

La passerelle piétonne haubanée et la passerrelle piétonne du Guanyinqiao à Chongqing offrent un exemple unique d'emploi d'acier à haute résistance combiné au béton armé avec apport de matière plastique renforcée par fibres de verre. Cet article vise a décrire les caractéristiques techniques de ces passerelles.

ZUSAMMENFASSUNG

Die Schrägseilfussgängerbrücke und die Guanyinqiao-Fussgängerbrücke in Chongqing sind einzigartige Kombinationen von hochfestem Stahl und glasfaserverstärktem Beton. Dieser Bericht beschreibt die physikalischen Eigenschaften dieser Brücken.

1. INTRODUCTION

Through the efforts of Mr. Chen Kesheng, Senior Engineer, and Madame Cheng Liping, Deputy Chief Engineer of the China Highway and Transportation Society; the author was invited to inspect two of the three fiber reinforced plastic bridges in Chongqing. Both of the bridges were conceived and built by The Research Institute of Composite Material Bridges of the Chongqing Institute of Transportation.

It is noted that this paper pertains to work done by others, and that the author did not participate in the projects reported. The paper is a "trip report" which provides information on an innovative use of FRP (GRP) material in bridges. Much information pertaining to mechanical properties of the materials, technical details of the design, and methods of fabrication and erection, were not available to the author; and thus the paper is limited to the brief descriptions provided. In the case of the first bridge described, some technical information was provided by Mr. Tang Guodong of the Composite Material Bridge Institute in Chongqing.

2. GRP PEDESTRIAN CABLE-STAYED BRIDGE

The first bridge visited was the GRP Pedestrian Cable-Stayed Bridge joining two parts of the campus of the Chongqing Institute of Transportation. The bridge was completed in 1986, and is shown in Fig. 1.

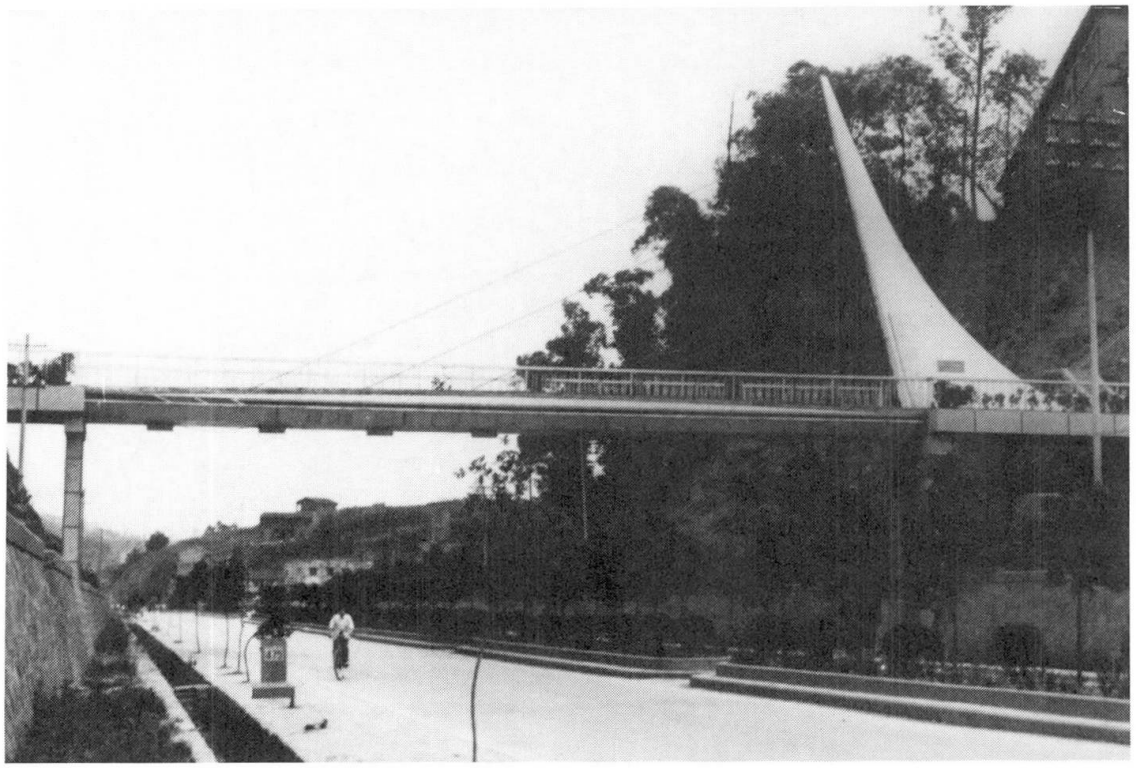

Fig. 1 GRP Pedestrian Cable Stayed Bridge

The layout of the bridge is an unsymmetrical system having a single tower and a single harped array of cable stays. The side spans and the tower are of reinforced concrete, with the tower having a height of 11m and an inclination of 15^{o} from the vertical. Each of the seven cable stays consists of 19 No. 5 steel wires encased in a polyethylene tube.

The entire length of the bridge is 50m which includes a non-continuous main span and two side spans. The main span consists of a single FRP box girder with cover plates. The FRP girder is 27.4m long, and 4.3m wide. The weight of the FRP girder is approximately 8 tons. The cost of the single FRP box girder was 120,000 yuan, or approximately 45% of the total cost of the project. The total cost of the completed structure, including a test program, was 260,000 yuan for a unit cost of 1,000 yuan per square meter. To translate the unit cost into dollars would result in a range between $25 per square foot and $13 per square foot, depending on the exchange rate used.

Complete technical information regarding bridge design, materials, and con struction, was not available at the time of inspection; however, limited information has been provided related to the glass fiber reinforced plastic, and related to design criteria.

The GRP is composed of high strength plastic reinforced with glass fiber. The bond between the fiber and the plastic is enhanced by the use of a resin. The high strength plastic is referred to as a plastic resin. Some of the physical properties of the GRP were provided.

The structural stiffness (EI and GI) is dependent on material parameters and member cross-section. Although the physical stiffness of the material (E, G) is less than that for concrete or steel, the stiffness of individual structural members can be increased by increasing the geometric stiffness in terms of moment of inertia of the cross-section. Values of elastic modulus (E, G) can be increased by the proper choice of fiber orientation.

The FRP box girder used in the GRP Pedestrian Cable-Stayed Bridge consisted of a top and bottom flange, and five vertical webs. The arrangement of fiber reinforcement in the webs could be placed at an angle of 45^{o} in order to provide increased shear resistance to shear stresses, thus improving the strength and stiffness of the laminated sections used in the box girder. This predetermined arrangement of the fiber reinforcement can result in a material having anisotropic properties. These anisotropic properties must be considered in design. In the case of fiber reinforcement placed in a longitudinal direction only, physical properties may be determined.

The elastic modulus of the GRP in tension and compression are given, respectively, in equation (1) and (2).

$$E_o = E_f \cdot V_f + E_m \cdot V_m \qquad (1)$$

$$E_o = E_f \cdot V_f + E_m (1 - V_f) \qquad (2)$$

where

E_o = modulus of GRP

E_m = modulus of plastic resin

E_f = modulus of glass fiber

V_m = percentage content of resin

V_f = percentage content of fiber

The specific gravity of the GFP is between 1.4 - 2.2. For the GRP reinforced in a longitudinal direction only, the tensile strength is 10,000 kg/cm^2.

Design criteria included a design live load of 350 kg/cm^2; with a factor of safety of 10 for direct stress, and a F.S. between 3 and 6 for shear stress. The allowable deflection is L/600. The highest design temperature under service conditions is 70^{o}C.

The FRP box girder was fabricated in the New Material Factory of Wuhan Industry University. The box girder was transported and erected in one piece. The bridge was tested under combinations of dead load and live load. The completed bridge was reviewed by the PRC Ministry of Communications, the agency responsible for transportation. About 40 experts of highway, railway, material and urban construction took part in the review.

The review indicated that the cost of the FRP bridge is less than the cost of the same bridge in steel, and that the FRP bridge is maintenance free. This GRP Pedestrian Cable-Stayed Bridge is the first in the world, and the design may be used for the pedestrian bridges of cities in China

3. GUANYINQIAO PEDESTRAIN BRIDGE IN CHONG QING

The second bridge visited was the Guanyinqiao Pedestrain Bridge of Jiangbei District in Chongqing. The bridge was completed in May of 1988. The bridge is described as a space frame, with FRP deck griders suspended from reinforced concrete rigid frames. The model of the bridge is shown in Fig. 2.

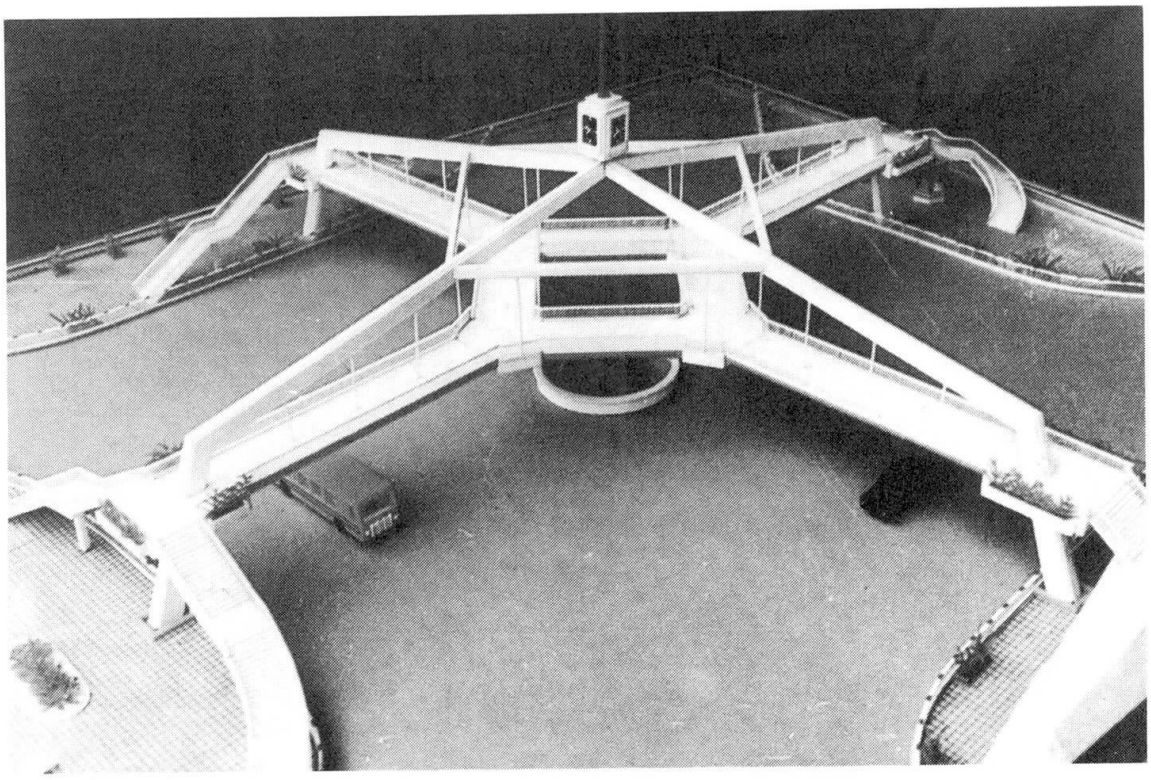

Fig. 2 Model of Guanyinqiao Pedestrian Bridge

The bridge crosses an intersection of two main streets in downtown Chongqing. The structural layout is in the shape of an ancient Chinese coin. The span of the rigid frame is 70m, with the overall total length of the bridge equal to 157 m. The four long FRP girders are 19 m long. The four FRP girders forming the central geometry are 9m long. All eight FRP girders are 4.3m wide, and 0.9m deep. All girders are hung from the space frames by

high strength wire. Total weight of the FRP girders was 43 tons, with the 19m girders each weighing 7.29 tons and 9m girders each weighing 3.46 tons. The cost of the FRP girders in place represented 42% of the total cost of the completed project. The total cost of the project was 1,700,000 yuan. This amount converts to $485,000 to $243,000 depending on the exchange rate used.

The complete bridge in service is shown in Fig. 3.

Fig. 3 Guanyinqiao Bridge in Service

The FRP girders were fabricated in Chongqing Glass Fiber Product Factory then transported and erected in single pieces. Those responsible for the design and construction of the FRP bridges in Chongqing have indicated certain characteristics of FRP bridges as follows:

1. Cost of FRP bridges is less than steel bridges of same type.
2. There is no rusting problem, and maintenance is minimized.
3. Tests indicate that the FRP structure is maintenance free for 40 years, except in especially bad environment. Tests indicate that is it unnecessary to worry about the problem of life span for FRP bridges.
4. FRP has good properties for resisting fatigue and low energy impact.
5. FRP is easy to form and to color.

Attempts are being made to obtain additional technical information on the GRP bridges in China, including the vehicular bridge in Beijing. When such information is received, it will be incorporated into an expanded version of this report.

REFERENCES

1. Guodong, Tang, Analytical and Experimental Work of GRP Cable-Stayed Pedestrian Bridge. Composite Material Bridge Institute, Chongqing, China.