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Feasibility Study of Long Span Bridges in Chongqing, China

Etude de faisabilité de ponts routiers à grande portée à Chongqing, China

Machbarkeit der weitgespannten Brücke Chongqing in China

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SUMMARY
This paper studies some important aspects of the feasibility study of long span bridges, such as objectives, stage, content, scope, procedures and methodology. The alternative method of the bridge site and bridge type is briefly summarized. The paper is chiefly introduced on new construction and erection procedures for the long span bridges in Chongqing.

RÉSUMÉ
L'article aborde des aspects importants concernant les études de faisabilité sur les ponts routiers à grande portée, tels que des objectifs, contenus, domaines, procédures et méthodes des études ainsi que le choix du type de ponts et de leurs emplacements d'implantation. Les nouvelles méthodes appliquées à Chongqing pour la mise en oeuvre et la construction du pont routier à grande portée, sont présentées.

ZUSAMMENFASSUNG
Dieser Fachbericht untersucht einige wichtige Punkte der Weitspannbrücke, beschreibt Ziel, Inhalt, Bereich, Prozess und Methode der Machbarkeit der Weitspannbrücke sowie Auswahlmöglichkeiten des Brückenstandorts und der Brückenkonstruktion. Der Fachbericht gibt einen Ueberblick über die neue Bau- und Aufbauweise der Weitspannbrücke Chongqing.

1. INTRODUCTION

Chongqing is a mountain city with a long history of more than 3000 years. It is at the juncture of the Changjiang and the Jialing rivers, which flow through the city proper. Chongqing consists of nine districts and twelve counties, covering an area of 22340 Km^2 with a population of 14.06 million, of which 3.36 million are urban inhabitants.

Since 1949 three highway bridges and two railway bridges have been built across the two rivers. In addition, more than 560 bridges have been built over the valleys and tributaries of the two rivers. The total length of these bridges is up to 20 Km.

The Niujiaotuo Jialing River Bridge which built in 1966 is a steel truss bridge; main span 88m, traffic capacity 4 lanes, and total length 600.56m.

The Beipei Jialing River Chaoyang Bridge which was built in 1969; its main bridge is double-cable suspension bridge; the main span is 186m, traffic capacity 2 lanes, and total length 233.24m.

The Changjiang River Bridge, with a total length of 1120m, traffic capacity 4 lanes was built in July 1980. It is a T-framed P.C. bridge, made up of a number of cantilever T-frames plus suspended spans of 35m each. The main span is 174m, which is the largest span among the same type of bridge in China.

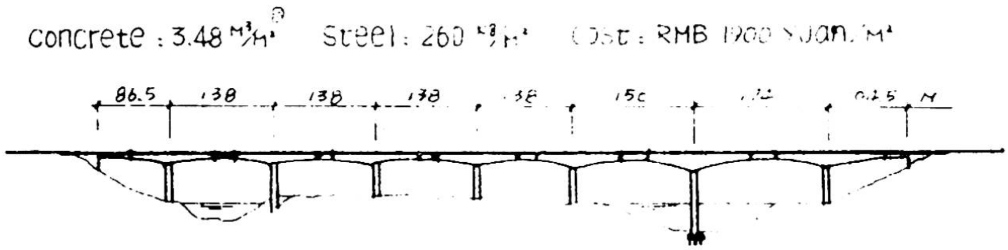

FIG 1 ELEVATION OF CHANGJIANG BRIDGE

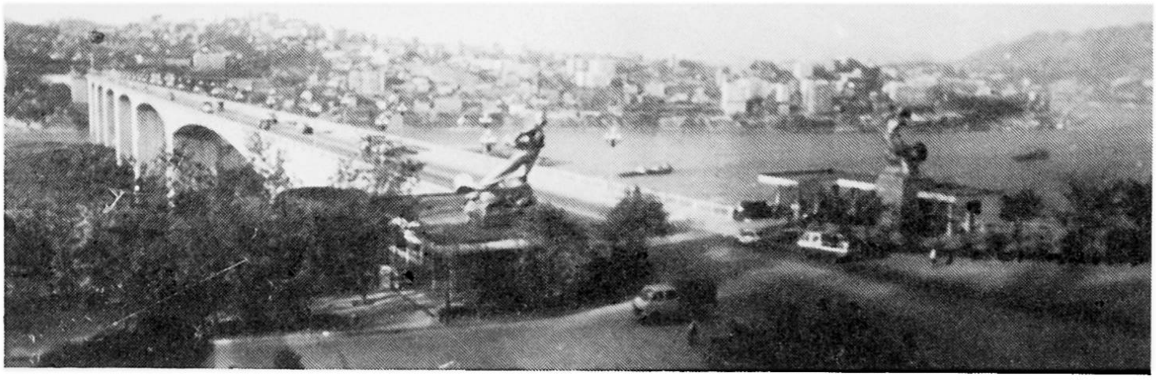

Photo 1. General view of Changjiang River Bridge

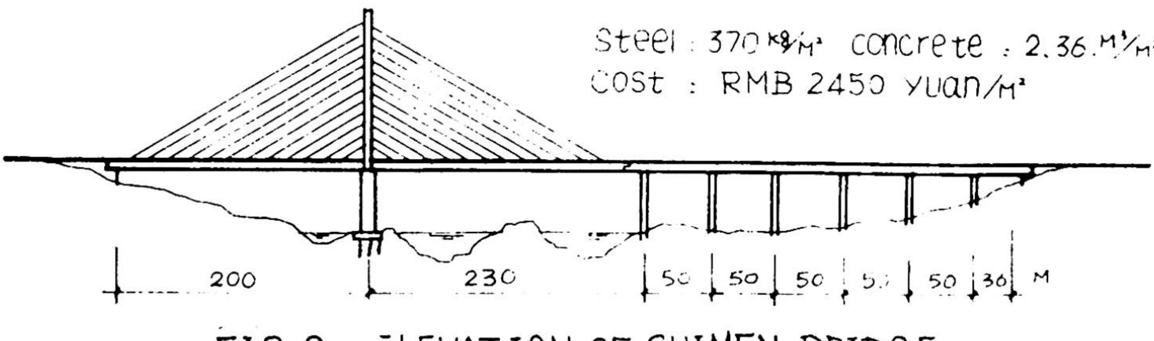

FIG 2 ELEVATION OF SHIMEN BRIDGE

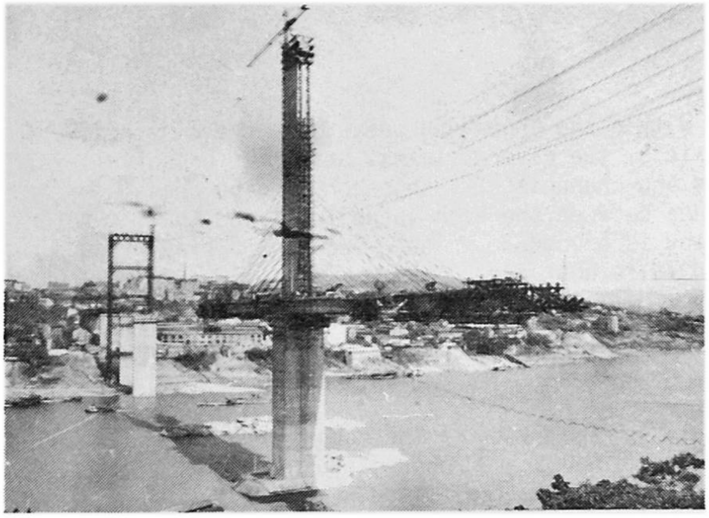

Photo 2. General view of Shimen Bridge

The Jialing River Shimen Bridge is under construction. Its main bridge is P.C. cable-stayed bridge, with single tower, the main span 200+230m, traffic capacity 4 lanes and the length 780m. It was designed by Shanghai Municipal Engineering Institute and constructed by Chongqing Bridge Co.. It will be completed in Dec.1988. The completion of this bridge will indicate that we have the ability to design and construct cable-stayed bridges with spans larger than 450m.

The project of the Second Changjiang River Bridge, which was approved in 1986, to build this bridge by making use of the third round of yen loan. The office of pre-construction preparation of the Second Chongqing Changjiang River Bridge which was organized by Chongqing construction Commission, consists of Urban Construction Bureau Research Institute, design and construction units, universities and colleges, etc.

2. OUTLINE OF THE FEASIBILITY STUDY OF BRIDGES

2.1 The objectives and task of the F/S are to carry out the investigation, analysis and study in terms of economy, technique and finance so as to settle a scientific foundation for the proposed schemes and the decision to be passed on and fully prove the construction of this project is feasible economically, technically and financially.

2.2 The stages and scope of the feasibility study

Before 1980, the planning task book was used instead of the F/S report. Since the early 1980s, we have started to do the F/S on all large projects. The F/S of Shimen bridge was performed in 1984, the scope of F/S extended from the technical study which used to be the major basis before 1980 for economy and finance. The index of economy of Shimen Bridge is as fllows: N.P.V.=252.4572 million yuan, the ratio of benefit and cost B/C=3.76, E.I.I.R.=21.93%.

Financially speaking, the passing fee used to repay the loan in calculated on the basis of the average of 1.88 yuan per vehicle per time. The period for the investment recovery is seven years. As a result of the F/S report, the Shimen Bridge is a beneficial project. The benefit is remarkable and it is feasible economically, technically and financially. However, for the Shimen Bridge, only the F/S was performed, and the pre-F/S was not performened during the stage of project alternative, while for the Second Changjiang River Bridge, the pre-F/S and final F/S are arranged in two steps in accordance with the international common method and requirement.

2.3 The content of F/S should be include the following:

a). General outline--including the task basis, construction address, project manager, construction scale, project history and background and the outline of F/S.
b). The importance and necessity of the construction of the project.
c). Traffic survey and forecast--including the social and economical survey and study which will indicate the analysis and forecast of the future traffic volume through the bridge.
d). Choice of the bridge site.
e). The design and construction of the project.
f). The investment budget and management expense.
g). The implementation of the plan--studying the schemes of the implementation, arranging the schedule of the construction and material supply.
h). Economic evaluation--the method of cost-benefit analysis is adopted.
i). Financial evaluation--the surplus-loss analysis, fund expenditure analysis, determining the F.I.R.R..
j). Conclusion and suggestion..

3. CHOICE OF THE BRIDGE SITE

3.1 The features of the river:

The Changjiang River and Jialingjiang River within the Chongqing areas have the distinctive natural features of rivers in mountain districts, the rivers zigzag; among the broad valleys, the river has distinguishable river shallows and channels of V-shape or U-shape cross section, and even some side beach. The difference between the high water level and the low water level is 30--35m. The maximum velocity of flow is 5--6m/sec.. The direction of flow is subject to change at the difference levels, and it is unstable.

3.2 The necessary conditions of the bridge site:

The choice of the bridge site should be decided on the basis of the comprehensive consideration of economy, social and scientific development and the demands of masses, taking new ideas and notions instead of old ones, and studying fully the following basic conditions:

a). It should obey the plan of the traffic development. If the bridge sites to be compared are planned ones, and while the road network planning is being made for lacking of scientific basis, it should obey the economic benefit from quantitative analysis.
b). It should obey the interests and demands of masses and serve to improve the prople's life and make things convenient for people. And it must not imperil flood control measures or infringe upon the rights and interests of peasants. It should avoid demolishing valuable buildings.
c). It should meet the demand of navigation clear height and width,and they should be decided according to the hydrological conditions of different river segments and the navigation development. During the flood period, the angle between the direction of flow and the pier's axis should be less than 5 degrees. The river near the bridge should be necessarily straight.
d). The site must have good hydrological and geological conditions for construction without any harmful grological problems, such as faults, caves and slides.
e). It should be supported with good construction conditions, including communications and transportation, material supply, water electricity resources, and construction ground concerned.
f). The sites of special bridges for national defence, big enterprises, scenery and other purposes should meet the demands of their special functions.

3.3 Choice of the bridge sites of the Second Chongqing Changjiang River Bridge:

Egongyan Bridge site and Lijiatuo Bridge site are both planned bridge sites. After comparing according to qualitative analysis, the consensus has not been reached, but after studying by the standard and demands of economic evaluation for projects, we have concluded that the Lijiatuo site is better than the Egongyan site.
The comparision of two sites is as follows (according to the data of the pre-feasibility study):

a). Estimated traffic: in 1992, (open to traffic) Lijiatuo site 4995v/d more than Egongyan site 3992v/d.
b). Economic benifits: Lijiatuo site: N.P.V.=293.6697 million yuan, E.I.R.R.=10.3% B/C=1.80
Egongyan site: N.P.V.<0 E.I.R.R.<3% (Interest rate of the loan) B/C<1
c). Local economy and development: Lijiatuo site: 15 Km^2 of land will be developed.
Egongtan site: is not so favorable.
d). Investment and demolition of houses: Lijiatuo site: 40 million yuans more than the Egongyan site, but the demolition of houses is 44000M^2 less than the Egongyan site.
e). Improvement of traffic conditions in the downtown: Lijiatuo site is better than the Egongyan site.
f). Meeting the need of trans. so as to promote industrial development of the south west district. Lijiatuo site is effectively, but the Egongyan site is not so effective.
g). Financial income and repayment of the loan: Lijiatuo site produces more and is quicker than the Egongyan site, its income is more than the expenditure, but the Egongyan site's income is less than the expenditure.

4. FEASIBILITY STUDY OF THE DESIGN SCHEMES OF BRIDGE TYPES

4.1 The Chongqing Changjiang River Bridge:

In the comparision and choice of the six design schemes of three bridge types, we put the stress on (1) the cable-stayed bridge, double pylon, Lmax=276m, (2) the continuous rigid frame bridge Lmax=240m, (3) the T-frame bridge Lmax=174m. Scheme (1) and scheme (2) can fully satisfy the demands of the navigation and avoid the construction of deep water foundation, but the construction of bridge is difficult for lack of experience and needs more investment. According to the condition, then scheme (3) has been adopted because it can satisfy the demands of navigation on the whole, needs less investment, and the design and construction techniques are ready.

4.2 The Jialing River Shimen Bridge:

On the basis of 14 schemes of 5 bridge types, the Shanghai Municipal Engineering Institute offers 10 schemes, 4 of which have been taken for comparision and choice: (1) the P.C. cable-stayed bridge, double-pylon Lmax=265m, (2) the single tower cable-stayed bridge with the main span 200+230, (3) the flexible pier and continuous rigid frame concrete bridge Lmax=220m, (4) the flexible pier and continuous rigid frame concrete bridge with span of 4x105m. All things considered, scheme (2) is better. It can satisfy the demands of navigation. Within the port and wharf region of the south bank, there is no need to build any piers,which can ensure the coexistence of the wharf and the bridge in favour of the organization of construction. Its construction period is shortest, and it can push ahead with the development and advancement of the cable-stayed bridge. Its design and construction can reached the first rate level in the world, and its increase of investment is less than 5%. That is why scheme (2) has been adopted.

4.3 The Second Chongqing Changjiang River Bridge (Lijiatuo Bridge Site)

4.3.1 The main design data:

Traffic capacity--4 lanes, each lane--850v/h; the width of the bridge: 2x7.5m+1.5m(divisor)+ 2x3m(side-walks); the navigation clearance: H≫18m B≫400m and the model test allows the clear width to be ≫240m. Design load: H-20t T-100 flatbed truck 300t (check load). Sidewalks load 350Kg/M^2. Wind force: the maximum wind velocity - 27m/sec. Earthquake force: the basic seimic degree for design is 6 degrees, but will be 7 degrees for antiseismic (H=0.07g).

4.3.2 The Design Schemes For Bridge Types:

The Office of the Second Chongqing Changjiang River Bridge and Sumitomo Construction Co. and I.H.H.I.Co. of Japan offer 14 deaign schemes of 6 bridge types. Among them S.C.Co. offers three schemes of the suspension bridge Lmax=870m, the concrete cable-stayed bridge Lmax=480m and the T-frame bridge Lmax=240m, and I.H.H.I. offers a scheme of the steel girder cable-stayed bridge Lmax=450m.

We must to evaluate the schemes of bridge types, according to the principle of function, safety, economy and beauty.

After the comparison and analysis, we think the scheme of Lmax=870m, suspension bridge demands high techniques and needs too much investment. Its construction period will last 4 years, so it is not considerable. The schemes of the arched truss bridge and the ribbed arch bridge are not considerable, because the piers are over 40m high and bulky, and they need complicated construction and a long period, though they require lower cost and less steel. In addition, the bulky piers will cause the river bed the great changes of scour and fill.

For each scheme of the bridge type, the following problems should be studied: the span allocation, the type and stability of foundation, the wind stability, the form of vibration, the shape of the cross section of the girder and pier, etc.

4.4 The alternative design schemes of bridge type and the main technical and economical index are shown as follows: (Remark: The cost of the projects is relatively for each other)

Alternative 1: Lmax=450m, cable-stayed bridge (main span steel girder) span allocation: 2x50+160+450+160+10x50=1370m steel: 480Kg/M^2 concrete: 2.86M^3/M^2 cost: 1.20c yuan/M^2

Alternative 2: Lmax=450m cable-stayed bridge (main span composite girder) span allocation: 216+450+216+9x50=1332m steel: 457Kg/M^2 concrete: 2.62M^3/M^2 cost: 1.10c yuan/M^2
Alternative 3: Lmax=430m cable-stayed bridge span allocation: 2x50+170+430+170+10x50=1370m steels: 410Kg/M^2 concrete: 3.07M^3/M^2 cost: c yuan/M^2
Alternative 4: Lmax=240m cable-stayed bridge with single tower span allocation: 4x50+2x240+13x50=1330m steels: 360Kg/M^2 concrete: 2.88M^3/M^2 cost: 0.98c yuan/M^2
Alternative 5: Lmax=240m P.C.T-frame bridge span allocation: 40+170+2x240+180+4x120+90=1440m steels: 490Kg/M^2 concrete: 2.87M^3/M^2 cost: 1.42c yuan/M^2
Alternative 6: Lmax=2x240m continuous frame bridge span allocation: 3x40+120+2x240+171.5+3x133+81.5=1372m steels: 360Kg/M^2 concrete: 2.78M^3/M^2 cost: 1.14c yuan/M^2

5. THE NEW CONSTRUCTION AND ERECTION TECHNOLOGY FOR LONG SPAN BRIDGES

5.1 In the deep water foundation construction of the Changjiang River Bridge, we adopt a double-wall steel coffer dam with the inner diameter of 24m, and a self-made gear driver is used which is twice as efficient as the general driver. The 12 bored piles with the diameter of 2.6m, 10-12m deep in rockbed, are completed in one dry season. For the foundation of pier No.5, 5m deep in rockbed, the new technology of an electric blast in deep and dense holes into the required shape at one stroke is successful. For the high concrete piers, over 50m high. The hydraulic sliding form method is adopted. The average sliding speed is 2.87m/day, and the maximum speed for No.3 pier reaches 4.65m/day.

5.2 For the Chongqing Changjiang River Bridge, the new technique first used in construction of the cantilever by the fixed outer form and the sliding inner form causes high construction speed and good quality, and gives us new technology in construction of the bridge with the long span of over 200m.

5.3 The tower columns of the Jialing River Shimen Bridge are 113m high, and their cross section is 4.5x9.5m. They are influenced by wind and sunshine, and the stability and stiffness is worse for the dense reinforcements and rolled-steel section in the piers. There are a lot of pre-hidden stayed pipes and bar joints. After careful study, the new technology of sliding form is adopted, and the construction pace and quality is ensured. The transportation of concrete and materials through a 120m tower crane and a six cable crane with the span of 519m ensure continuous construction during the high flood period. The concrete box beam with a single box three cells is 4m high. In its construction, we adopt the method of balanced cantilever by cast-in-situ. The box beam is of 27 segments, and the standard segment is 15m long and built by the flow progress of middle box, side box and cantilever plate.The 15m stiffened steel frame is made by welding with the rolled-steel section hidden in the middle box, thus forming a stayed-cable structure as the supporting structure of side box and lengthening pouring segments. This reforms the old technology of big hanger method, and quickens the construction speed. The Shimen Bridge has 216 cables, the longest of which is 234m. Each cable is made of 265 galvanized steel wires ofϕ5. The cables are made and treated for protection in the factory. We have adopted the hypalon rubber as protection material combined with sectional sulphurization thermopressing forming technique instead of P.E. pipe casting press in grout mixture protection techniques. In this way, the cables are of high quality and low expenditure and easy to erect. The technical index of the protection material of the cable are as follows: tensile strength >11Mpa, the minimum rate of elongation is 300%, hardness IRDH is 70-85, the resisting ability of sulphuric acid, ozone and ageing satisfies the demands. The protection covering of the cables is 5mm thick and their working life last over 20 years. The continuous box girder of the approach with 5 span of 50m and a span of 36m, the girder is 4m high and it is of a single box with three cells. It is built by incremental launching on high flexible piers. The new technology ensures high quality and high construction speed.

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