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Project Management for the Chongqing Yangtze River Bridge

Gestion de projet pour le pont Chongqing sur le fleuve Yangtzé

Projektmanagement der Chongqing Yangtze Brücke

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Zuoling Liu, born 1915, received his degree at National Zhejiang University, Hangzhou, China, in 1937. For more than 40 years he was engaged in bridge design and construction works in China. He was responsible for the design of Liuzhou bridge Guangxi, China, and the Chongqing Yangtze River bridge.

SUMMARY
The procedures and systems in engineering and construction management, in general, for major projects in China is described in this paper. Now, as economic reforms are being carried out in China, there are prospects for a change in the management of bridge projects. The Chongqing Yangtze River bridge which is a well-known prestressed concrete T-framed bridge in China, is taken as a practical example.

RESUME
Le système général de la gestion des grands projets de construction en Chine est décrit dans cet article. La Chine révise actuellement son système économique, ce qui ouvre la perspective d'une réforme de la gestion des ouvrages d'art. Le pont de Chongqing sur le Yangtzé, un pont célèbre en béton précontraint, dont la structure principale est un cadre rigide, est présenté comme exemple.

ZUSAMMENFASSUNG
In diesem Artikel werden Verfahren und System auf dem Gebiet des Engineering und Construction Managements dargestellt, die in China im allgemeinen bei grossen Bauprojekten zur Anwendung gelangen. Zur Zeit wird eine Reform des Wirtschaftssystems in China durchgeführt, die auch Aussichten hat, eine Änderung des Projektmanagements für Brückenbauten zu bewirken. Die Chongqing Yangtze Brücke, eine in China bekannte vorgespannte Betonbrücke mit dem T-Rahmen, wird als Beispiel verwendet.

1. GENERAL ASPECTS

The Chongqing Yangtze River bridge, with a total length of 1120 meters, is an eight span T-framed prestressed concrete bridge, made up of a number of cantilever T-frames plus suspended spans of 35 meters each. The main span is 174 meters, which is at present the greatest span of its type in China. The bridge is located at the central district of the city of Chongqing, Sichuan province, China. It serves to connect the urban district of the two shores and joins the inter-state highways. The bridge was opened to traffic on July 1, 1980.

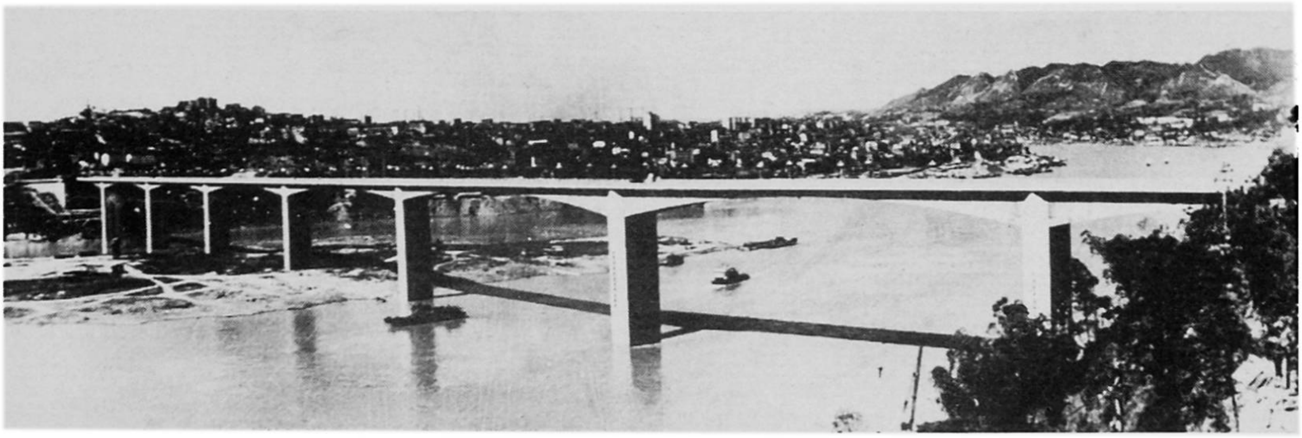


Photo 1 General View of The Chongqing Yangtze River Bridge

Photo 1 is the whole of the bridge completed, the spans are composed of: 86.5m + 4 x 138m + 156m + 174m + 104.5m. The bridge width is 21m (See Fig. 1). The bridge piers are made of reinforced concrete cellular structures, whose height averages 64m from the top of the footing to the top of the bridge deck. The pier shafts are of equal sections to conform slip-form construction. Different kinds of foundations were designed according to the geological conditions at each pier site. Three types of foundations were adopted, namely: the open cut spread footings, reinforced concrete open caissons, the floating steel open caisson with cast-in-place concrete piles.

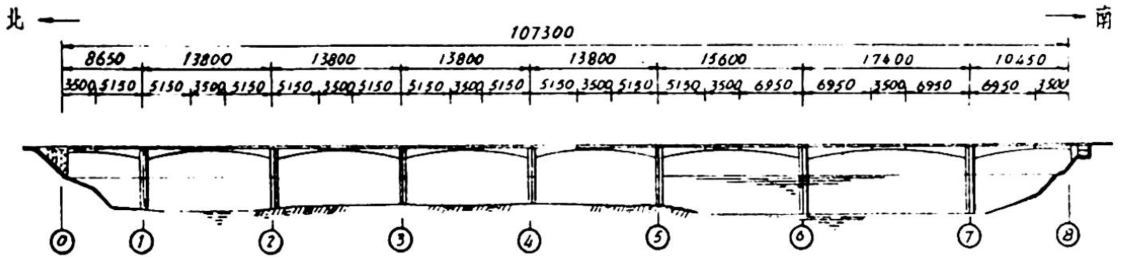


图 1 全桥孔径布置图
Fig. 1 Elevation

Fig. 1 Elevation

Pier No. 6 is a deep water pier, which was a critical part in construction of the whole bridge, and was a controlling factor to the period of construction. Fig. 2 is a sketch of the pier structure, including its foundation. Double-walled steel caisson was used. Outer diameter of caisson is 23.4m; total height of caisson is 17.5 - 19.5m. The knife edge of the caisson was made high and low to fit the contours of the rock surface. The caisson was fabricated in floating position and was sunk by partly pouring concrete between walls and partly by pumping water in.

12 cast-in-place piles of 2.6m diameter each, were arranged within the caisson, and were encased in a solid concrete cap of 6.5m thick.

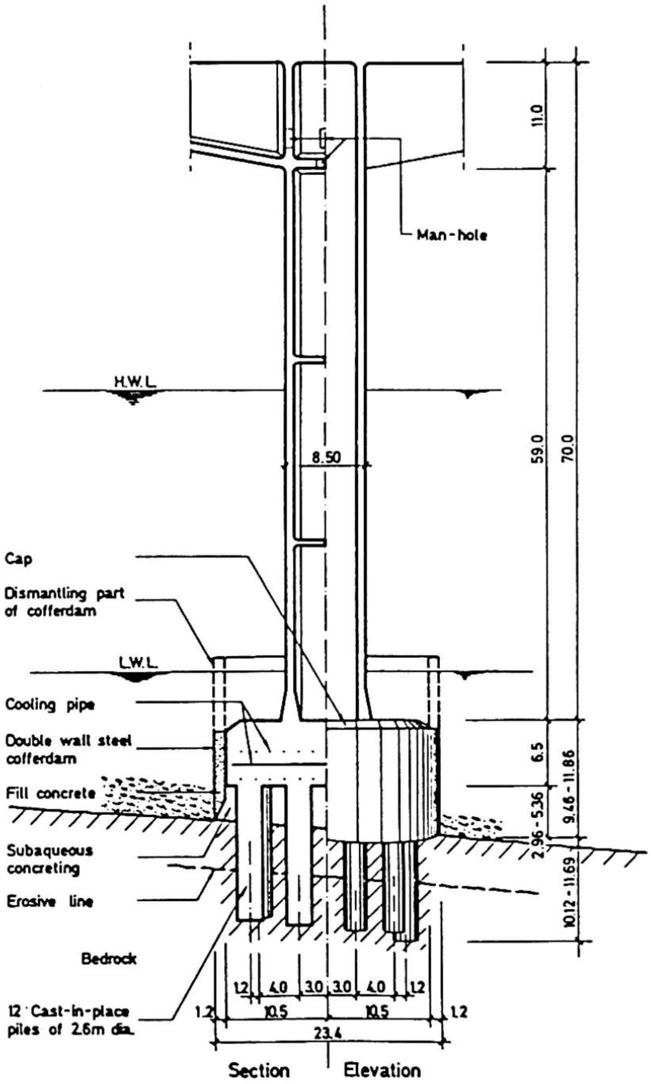


Fig.2 No 6 Pier

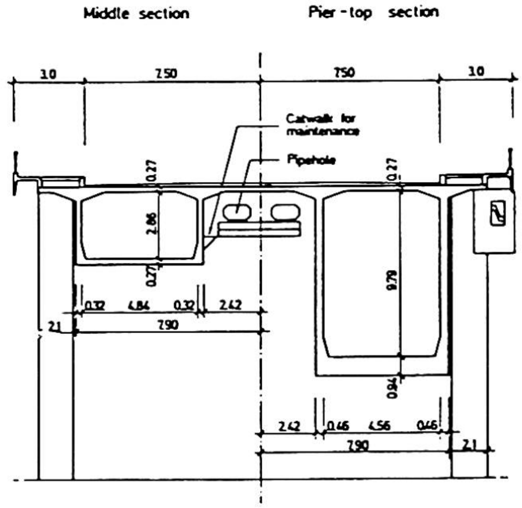


Fig.3 Cross section

In the superstructures, cast-in-place balanced cantilever segmental construction method by means of travelling carriages was used. The cross-section of the cantilever arms is shown in Fig. 3. For the 174m span, the cantilever arm was divided into 20 segments, with the lengths of each segment varying from 2.5 - 4.0m. The weight of each segment was equal around 100t. The box girders were prestressed in three directions. The longitudinal and transverse prestressing tendons were made of 24-5ϕ high tensile steel wires for each strand. 28ϕ high tensile steel bars were used for the vertical prestressing in the webs.

2. DETERMINATION OF THE PLANNING PROPOSAL

Early in 1966, the local government had studied the problem of building a bridge in Chongqing over The Yangtze River. Along the 9.4 kilometers of river shore in the urban district, four bridge sites were sifted out for comparison against ten localities which had already undergone preliminary studies. The bases of comparison are: the city's master plan of municipal construction and present status, geological conditions of the two banks, the navigation conditions of the river section, economic benefit, traffic and transportation requirements, and construction costs, etc. Simultaneously, a preliminary consideration was made for the schemes of bridge types against the recommended bridge sites, and at the same time the amount of investment was estimated.

Actually, the work of this period corresponds to the investment orientated research. If the work done was comparatively thorough, then it will be something like a feasibility study.

According to the result of these studies, the client unit (mostly the competent authority of the local government) immediately compiled the plan of proposal of the bridge project. At the end of 1975 it was approved by the higher level authority. So far, the item of construction was already defined.

Municipal public work projects are mostly non-profit enterprises, their benefits are a kind of social benefit. Proposals for projects were frequently a result of the existing traffic requirements or other urgent needs of the public. In China, up to now, the bridge is free to pass. Recently, a few districts also considered building toll bridges and welcoming private investments. However, this ideas are not implemented yet.

The client unit can usually entrust comparatively large bridge projects to a few designing institutes or universities, and research institutes, asking them to provide some preliminary conceptional schems according to the client's intention. Then these are analyzed, studied, compared by the chosen designing institute together with the client unit.

3. DESIGN

After the approval of the project the design stage is started. The design work does not call for bids, but is assigned to the design unit as a mission by a high level authority or the client unit enters directly into contract with a chosen design unit.

The Chongqing Municipal Construction Bureau confered the design of the Chongqing bridge to the Shanghai Municipal Engineering Design Institute.

Preliminary design consists mainly of the following contents: Estimation of traffic volume after the completion of the bridge; analysis of the bridge's economic benefit; determination of technical criterion of the bridge; hydrological calculations and bridge site design; general planning and the comparative analysis of different alternatives of bridge types; estimation of engineering quantities and amount of materials; special requirements and equipments during construction; construction schedule; total cost of investment etc.

The bridge type alternatives had been extensively investigated in the first stage of the bridge design. Members of the design institute and technical personnels of other units put forward a total of 17 alternatives. Through joint analysis and discussion by the client unit, the constructing unit and the design unit, those which were not suitable to the specific conditions and those which were not mature in design and construction techniques, were eliminated. Finally, six alternatives were condensated by the design group.

a. Double cantilevered frame (πframe) plus suspended span with a main span of 240m.

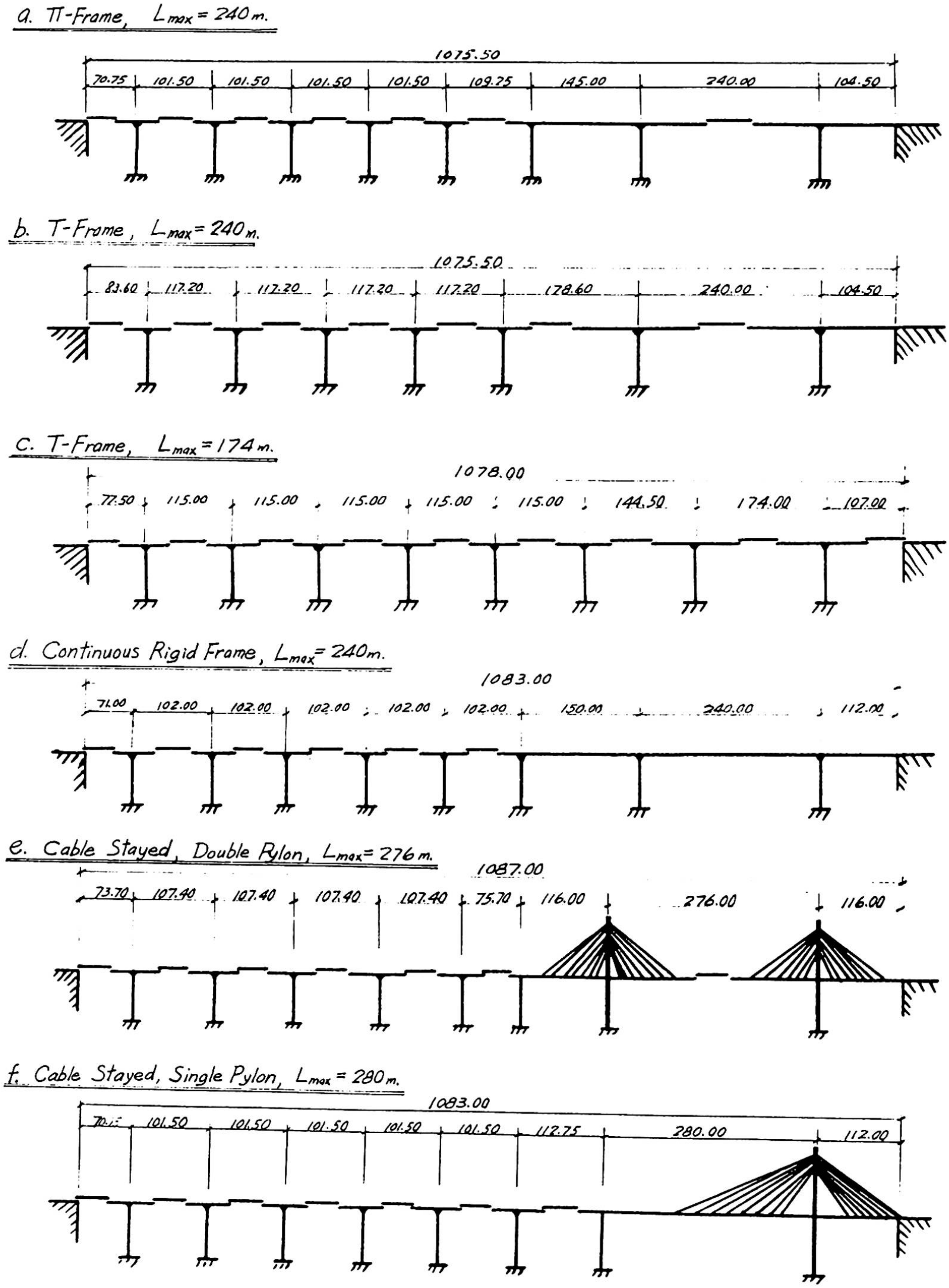
b. T-framed structure plus suspended span with a main span of 240m.

c. T-framed structure plus suspended span with a main span of 174m.

d. Three span continuous rigid frame with a main span of 240m.

e. Double pylon cable stayed bridge with a main span of 276m.

f. Single pylon cable stayed bridge with a main span of 280m.



Schematic Diagram of Alternatives

Fig. 4

Through conferences and preliminary selection (including the possible construction unit), the above mentioned alternatives a, c, e were considered to be comperatively advantageous and further analysis and comparison had to be made.

For the analytic comparison of factors concerning material consumption, functions in use, navigation influence, cost, time limit for the completion of the project, construction risk, aesthetic appearance, and maintenance etc. of the three alternatives, a T-framed structure with a main span of 174m was finally recommended.

During the preliminary design, the design unit and the probable construction unit kept in close contact regarding the construction problems and exchanged views continuously. But these construction schemes initially considered were often subjected to possible changes due to the alteration of construction unit and changes in conditions. This fact made the design work more laborious. In China, the construction units have comparatively more influence than in other countries.

The selection of standard criteria should be made in the preliminary design. The design of this bridge is mainly based on the Chinese highway bridge design specifications, and refers to Chinese railway bridge design specifications.

For a few exceptional problems, it is necessary to get the information from tests. For instance, the pier locations in the deep water navigation channel were determined through experiments. Utilizing a few representative ship fleets and rafts to pass through the bridge site (the pier marks were set up in advance), measured their navigating track and then made comparisons.

The test and the research expenses of the preliminary design stage were decided by the client unit.

The preliminary design was finally appraized by large scale meeting chaired by a superior authority member. The meeting gathered engineers of some 50 units of bridge design and construction, traffic and transportation, engineering geology, scientific research, universities and colleges for discussion and appraisal in Chongqing.

Finally, at the end of 1976, the preliminary design was approved, and the construction of the 174m T-frame scheme was resolved.

4. PROJECT ORGANIZATION FOR THE REALIZATION PHASES

For the Chongqing Yangtze River Bridge, the local government demanded "Quality first, and complete within 3 years". According to this demand, in view of the size of the project, construction conditions, ability of construction units, the client department decided to assign the job to several contractors under a single command unit.

Therefore, the Chongqing Yangtze River Bridge Headquarter was established as the directing organization. Its main tasks were: to organize surveying and geological reconnaisance as well as design and construction, the allocation of principal materials and facilities, transportation of materials, land acquisition, dismantling of residential buildings, catering of daily necessities etc. Its duties also included: general development of construction sites, planning of a unified general scheme of construction, drafts for the construction methods, determination and control of the quality standard for the whole bridge according to the design requirements; reasonable allocation of the construction funds etc.

All the contractors also established their own directing offices, whose tasks were: to organize the construction essentially according to the planning, technical standards, and construction schemes prepared by the headquarters; to be accountable for the construction quality of the engineering elements, the time schedule, and the safety of the workers; to control the budget and to take responsibility for the profits or losses of the respective contractor.

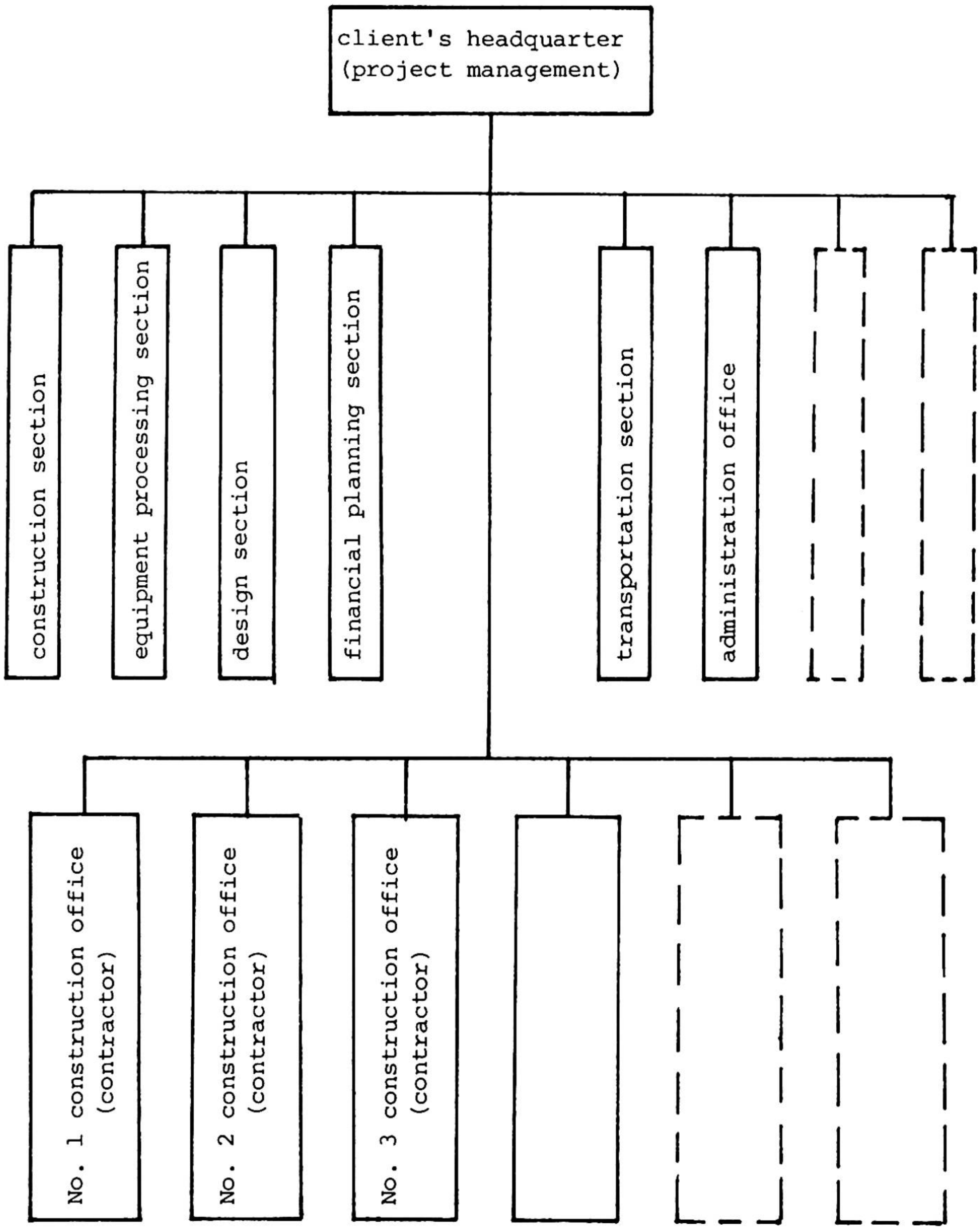


Fig 4: Construction organization chart

As a result of practice, this kind of organization fit to the actual condition at that time. Good results were obtained efficiently due to clear assignments, obvious objectives, democratic decision methods, and coordinated actions of all the organization units.

The main job assigments to contractors were:

First contractor:	Entire Pier No. 1 (including foundation) and T-frame, Prefabrication and erection of suspended spans for the whole bridge, North abutment and approach.
Second contractor:	Foundation of Pier No. 2.
Third contractor:	Pier shaft of pier No. 2 and T-frame, entire pier No. 3 and T-frame,
The forth contractor:	Entire pier No. 4&5 and T-frame,
The fifth contractor:	Entire pier No. 6, 8, 7 and T-frame, South abutment, bridge head tunnel, bridge deck pavement, pedestrian walk etc.
The sixth contractor:	South approach etc.

In People's Republic of China, a construction unit is usually selected by negotiating a contract or by appointment by the higher level authority. Recently, the Ministry of Municipal and Rural Construction resolved that: Hereafter, ordinary engineering projects should use the bidding method to determine the construction unit. As to the design unit, priority should also be given to the most competitive one. Henceforth, this will improve the engineering construction and management.

5. CONSTRUCTION MANAGEMENT

5.1 Time scheduling

In accordance with the anticipated completion time for the whole project, the time schedule of the construction of the bridge itself was divided into 4 stages.

5.1.1 Construction preparatory stage

The scheduled time period for this stage was from March to Oct. 1977. The principal works done in this stage were to pave the way for a predetermined date of commencement of construction work. The following works are included: establishment of a directing office; organization of technical reconnaissance of the project and arrangement of the design of work drawings; drafting of time schedule; study of construction methods & procedure; organizing design for specific construction methods; conducting of necessary research work; supply of resources; planning of construction site; carryout of three installations & one leveling (installation of water mains, of electrice wire cable, of roads and leveling of site ground); establishment of administrative rules; preparing workers to move-in; etc.

The preparatory works are very important. A special schedule for preparatory works was made. The scheduled works were reviewed each week and internal or external disturbances were studied and corresponding measures taken, so as to ensure that the works are completed as planned.

The overall construction programme and the choice of construction methods & procedures were all taking their shape in this stage.

5.1.2 Foundation and pier construction stage

The scheduled time period for this stage was the first low water season of Yangtze River in this year, i.e. from Nov. 1977 to May 1978. The requirements for the progress of different items of construction were defined, according to conditions & methods of construction. They were: foundations of piers No. 1 to No. 5 & No. 7 to be completed; pier shaft No. 1, 3, 5, 7 to be completed; at least three piles & sub-aqueous sealing concrete to be finished for pier No. 6, ready to stand against the flood. It should be noted that pier No. 6 was the critical part of construction to the whole job, a controlling factor to the time schedule.

Slide-form was used for pier shaft construction. Many kinds of labor work were involved in the determination of jacking period. So the principles of operations research network planning were used to choose a proper jacking period.

5.1.3 T-frame construction stage

Before June 10th, 1978 all pier shafts except pier No.6 and pier No.7 were entirely completed in advance. From June to October, it is the flood season of Yangtze River, the construction site was often subjected to the flooding threats. During this period, the creation and exchange of the construction team and another part of preparatory works were arranged originally while the construction of the critical pier No. 6 would continue during the flooding period using cableway transportation. According to the latest situation (ahead of time in most works) and from reviewing the work of previous stage, it seemd adequate that the flooding period should be more suitably used. So the construction of box girder sections on the pier went underway intermittently. Using this strategy, a period of about two months was saved.

The continuous construction of T-frame No. 6 during the flooding period progressed smoothly, it was completed ahead of time, before the end of December. Up to now, the T-frame of pier No. 6 which controlled the general schedule of the whole bridge had already been completed six months in advance.

5.1.4 Bridge deck construction stage

The construction works of this stage were: the erection of suspended spans and bridge deck pouring, casting of pavement on the whole bridge decking, installation of the pedestrian walks, railing, lighting etc. and other finishes works. From August 1979, the erection of suspended spans started and up to the middle of Feb. 1980 the entire suspended spans were completed. The erection work had to be interrupted for three months, waiting for the completion of T-frame No. 6.

Hereafter, on the 17th of June, the loading test of the bridge started. Static and dynamic loading tests were made to obtain the stresses, deformations and deflections of the principal parts of the bridge. The bridge was opened to traffic on July the 1st.

5.2 Updating of the construction Systems

Whenever there were disturbances to the planned execution, or when construction works were ahead of time, then the work scheme was adjusted through negotiation. For instance, pier No. 6 was the key portion of the project regarding the time of completion. The original plan was to finish the subaqueous sealing and three cast-in-place piles before the flood, while construction during the flooding period would have been stopped. But after the job started, all kinds of work proceeded successfully. This was due to the delibration of preparatory works, serious construction work and suitable construction procedures. After the subaqueous sealing had been finished, an analysis of the hydrological datas, conditions for construction and time factors led to the conclusion of striving to finish all the piles, provided certain measures could be taken. Then the schedule of the whole bridge could be pushed ahead of the planned times.

Thereby the height of steel cofferdam was resolved to increase, in order to suit to a higher construction water level, and adopting a series of other flood combating measures. Finally the entire foundation piles were completed at the beginning of June.

5.3 Measures of assuring quality and scheduled time

For assuring the engineering quality, the construction headquarters formulated: The stipulations of technical responsibility of Chongqing Yangtze River Bridge; inspection standards of engineering quality of the Chongqing Yangtze River Bridge; regulations of investigating the engineering quality of Chongqing Yangtze River Bridge etc. All contractors were asked for following these policies strictly. The construction headquarter had its quality supervisors, all subcontractors had their own quality inspectors, too. They all investigated every working procedure uninterruptedly during the entire detailed engineering and construction process. The engineers of the headquarters kept themselves well informed about the engineering quality of all sections of construction.

For some new techniques in construction, which were unfamiliar to the subcontractors tests in operation were requested to get experience and to ensure engineering quali

All contractors were responsible for the time schedule of their own work. On each specified period the client's project management called for a meeting to study whether some part was behind schedule or having the possibility of lagging behind. Then measures had to be taken for remedy and the program of the next stage was updated in order to guarantee the overall time schedule. Besides, prompt supply of materials and equipment had to be kept in mind, as well. The supply of materials and equipments of this bridge were all in the hands of the respective departments of the Chongqing municipality and personnel was transfered to work in the headquarters for the convenience of contacting and solving problems.

The work drawing design was furnished by the design department on time, no losses of time in supplying work drawings had occurred in the construction of this bridge. Moreover, a small residential group of designers was assigned to the bridge site to be responsible for solving problems raised by the construction unit and drew some supplementary drawings due to the changes of conditions on the bridge site.

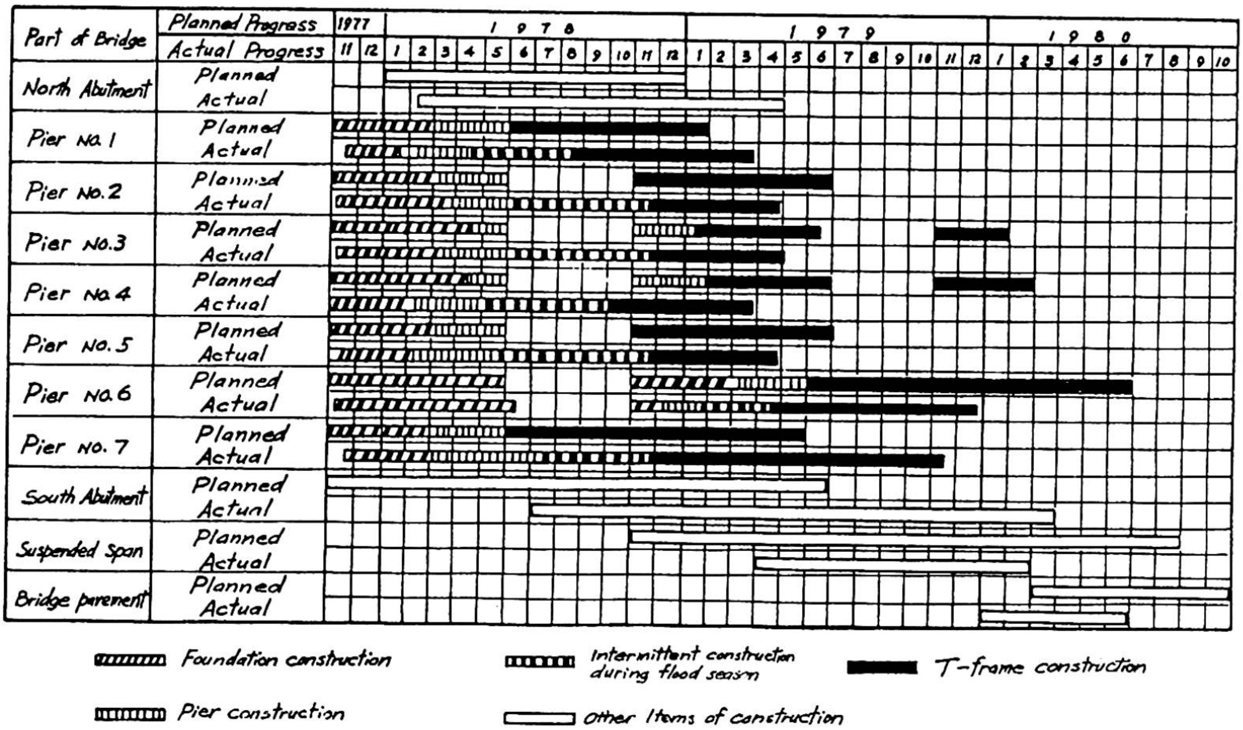
6. CONCLUSION

As to the real assurance of quality and time schedule of engineering construction, attention should be paid to the preparation of construction works and technical reservations. All preparatory works must be made well conscientiously. Furthermore, every phase of construction methods & procedures should be studied seriously to conform with the actual conditions on site. To guarantee the quality and time schedule of a project, this is a kind of vigorous and active measure.

Simultaneously, the innovation of construction program or construction technique should be encouraged, and rationalization proposals should be awarded to enhance quality and to speed up the schedule.

Setting up an on-the-spot design group on site by the design department is a desirable way of enhabling better cooperation between design and construction.

Adopting of test constructions in a limited scale for unfamiliar technologies is also desirable. This small amount of expenses should be allowed within the general investment cost.



Planned Work Schedule Vs. Actual Progress
Chongqing Yangtze River Bridge

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