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Chongqing Yangzi River Bridge, China

Pont Chongqing sur le fleuve Yangtze, Chine

Chongqing Brücke über den Yangzi Fluss, China

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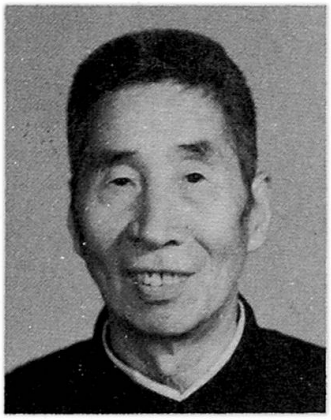
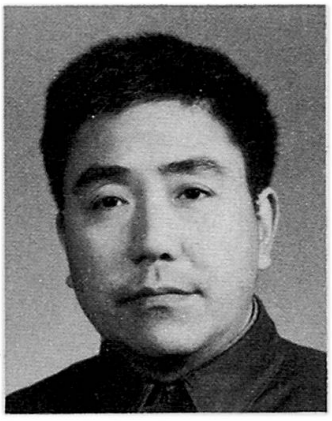




SUMMARY

The authors give a summary of their experiences in constructing the great Chongqing Yangzi River Bridge, combining long-term practice in construction and construction management of bridges with the actual conditions. Technical programs, construction control, and technical management as well as technical and managerial actions are shown, reflecting to deep-water foundations, placing concrete for piers and structural frames.

RÉSUMÉ

Les auteurs présentent un résumé de leurs expériences dans la réalisation du grand pont à Chongqing, sur le fleuve Yangtze. Ils combinent leur grande expérience de chantiers et la gestion de la construction, en tenant compte des conditions locales. Les programmes, le contrôle de la construction et la gestion technique, ainsi que les décisions et les réalisations sont présentées. Des exemples sont donnés pour les fondations en eau profonde et la mise en place du béton pour des piles et d'autres structures.

ZUSAMMENFASSUNG

Die Autoren geben eine Zusammenfassung ihrer Erfahrungen bei der Bauausführung der grossen Yangtze-Brücke in Chongqing und setzen sich auf der Basis ihrer grossen Erfahrung im Brückenbau und in der Ausführungsleitung mit den speziellen Bedingungen an Ort auseinander. Die technische Ablaufplanung, die Ausführungskontrolle und die technische Leitung werden ebenso gezeigt wie die Massnahmen auf den Gebieten der Bauverfahrenstechnik und der Führung. Dabei geht es vor allem um Fundationen in tiefem Wasser und das Betonieren von Pfeilern und Rahmen.

1. INTRODUCTION

Chongqing city is located in the Sichuan province of South-west China. It is the governmental seat of 9 districts and 12 counties. It has an area of 22'340 km2 with a population of 13'800'000, of whom 3'100'000 are urban inhabitants. It's an important industrial city of our country, the economic centre of the upper reaches of the Yangzi River, the hub of water and land communications as well as a port for foreign trade.

Located at the juncture of the Jialing and Yangzi rivers and like a peninsula embraced by them, Chongqing, a mountain city, looks very beautiful, with undulating ground, verdant mountains and clear water. It's a famous city with a history of 3000 years. History tells us that the area was the Bazi State in early years of the Chou Dynasty (12th century B.C.). During the Anti-Japanese War, the capital of our country was moved there. For this reason, quite a lot of foreign friends once lived there. They may still have fine impression.

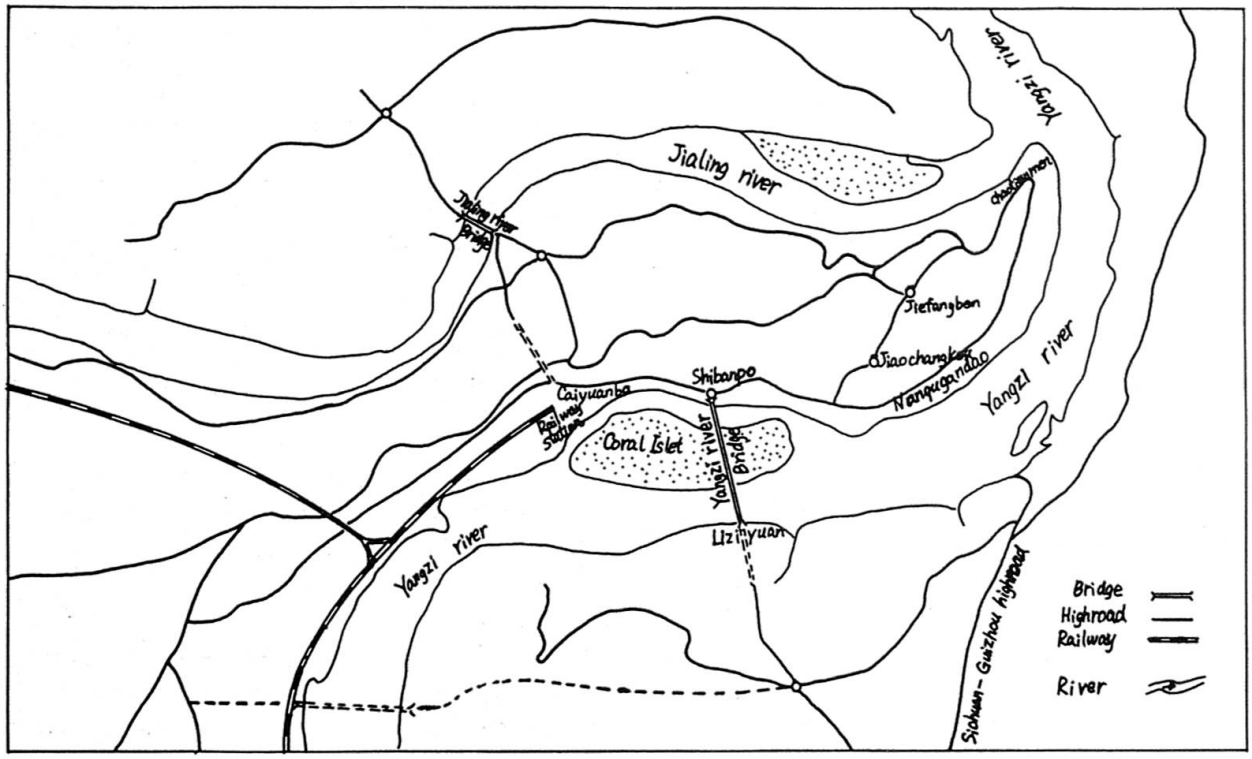
After liberation, with the development of our economy, two highway bridges over the Jialing River and two railway bridges were built some distance up the two rivers in the area of the city. However, people still felt very unconvenient for there was no highway bridge over the Yangzi river leading into the city itself. This caused an adverse influence on industrial and agricultural production as well as the livelihood of the people. In March 1975, the Provincial Government applied to the National Planning Committee for constructing a bridge over the Yangzi in the Central District of Chongqing. The project was approved in October of the same year. This project was started in November 1977, and completed and opened to traffic in July 1980.

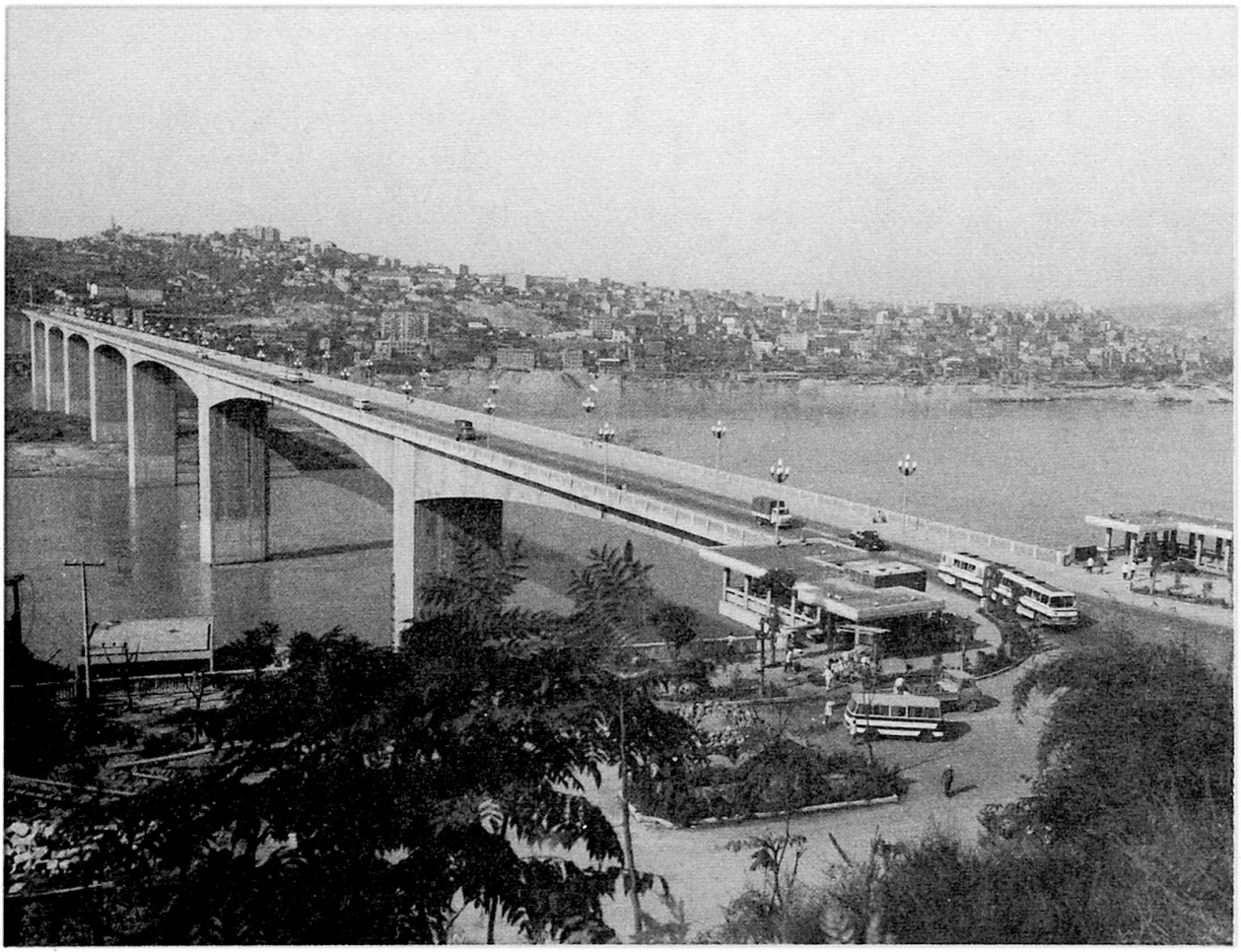
The location of the bridge is in the city itself, 3'289 km from the source of the Yangzi. Geologically, the location of the bridge is of jurassic system Chongqing series. Under the surface of sand and gravels lie interbedded sand stones and shales. The axis of the bridge lies in the west of syncline axis. The inclination of strata is gentle. In the centre of the river there is an islet full of sand and gravels called the Corel Islet which separates the current into two channels. Around the location of the bridge, the highest flood level in a century is 195 m above the sea level (with sea level of Wushong as zero). The discharge of the river is 81'000 m3/sec. The current velocity is 5.2 m/sec. Water level in dry season is 161.47 m. The differential of water level is over 30 m.

The Chongqing Yangzi River Bridge has 7 piers, 2 abutments and 8 spans. It is 1'121 metres long, 21 metres wide (traffic lane is 15 m; 2 sidewalks 3 metres each). The design load for the bridge was H-20 tons and T-100 tons, checked with 210 tons of flatbed truck loads. Sidewalk load is 350 kg/m2. The basic intensity of earthquake is 6 degree, but it is 7 degree in design. The type of bridge structure is of prestressed concrete T-rigid frames with hanger girders. The length of the main span is 174 m which is the longest of the same type of all the bridges in our country. This bridge is the first urban highway bridge over the Yangzi leading to the city itself. In the South it links to the Sichuan-Guichou highway. In the North it joins the main road of the South District.

As far as structure is concerned, the bridge is characterized by a deep foundation, tall piers, high girders with thin web. In construction it needs a tremendous amount of work. Working over rapid current increases the difficulty. Take pier No. 6 for example. Water is as deep as 20 metres during construction. Holes drilled for concrete piles went into rockbed as far as 10 - 12 m. The piers located at Coral Islet with thickness of coating over rockbed varied from 11 to 21 m. Some of the pier foundations' depth in rockbed demanded no less than 5 m. The height of pier columns ranged between 51 and 62 m. The Tee rigid frame girders

LOCATION OF THE BRIDGE SITE





near the pier for main span is 11 m in height. The thickness of its walls is 27 - 40cm. During construction the water level was 165m, with 2.5 m/sec. of flow velocity. For construction of the bridge, 117'000 m3 of earth and stone was excavated and 81'600 m3 of concrete cast.

The Construction Command Office of the Chongqing Yangzi River Bridge was responsible for the construction of the bridge. The design work was undertaken by the following departments or units: Shanghai Design Institute of public works was assigned to design the bridge itself and the North approach. Chongqing Iron and Steel Design Institute was assigned to design the bridgeheads and the railings of the bridge. Sichuan Art Institute was to design sculptures of the bridgeheads, Chongqing Design Institute to design two tunnels at the South end as well as South approach. The following organizations/companies were assigned the construct tasks including organizing construction teams, setting up command posts etc. to accomplish the project as a whole: The urban Construction Bureau of Chongqing, the Chongqing Command of Provincial Construction Co. (No. 8th Construction Co.), No. 18 Metallurgical Co. 2nd Navigational Construction Bureau of the Ministry of Communications, the Architecture Construction Bureau of Chongqing as well as the South Approach construction Command office, etc.

2. GOOD RESULTS AND PROFITS OF THE BRIDGE

The government demanded that the bridge had to be started in the last quarter of 1977 and completed and opened to traffic by the end of 1980. It was completed and opened to traffic on July 1, 1980, 6 months ahead of schedule. The total investment appropriated for the project by the government was 64'900'000 Renminbi Yuan (converted to $ 31'370'000). The final accounting of the investment was 64'680'000 Renminbi Yuan. The cost per metre of bridge length was 40'361 Renminbi Yuan, or 1'870 Yuan for a square metre of surface. Each of the contract work units gained profits ranging from 6% to 8%.

The bridge was checked and evaluated. 57 out of 64 engineering projects were graded as high quality, 7 as qualified. Through live and stationary loading tests increment of stress for all parts of concrete was less than allowable value in design. The deflection of T-cantilever arm's ends is 1/1000 of span, much less than allowable value. Under live load, amplitude of vibration is under 1 mm. Gravity acceleration is less than 0.02g. These conform to the specifications laid down by our government: the former is within 1 mm; the latter 0.1g. In February 1981, to check and accept the bridge, the government organized a special committee who satisfactorily accepted the bridge after all-round strict checks. It declared that the bridge was of high quality, tallying with all specifications for acceptance as well as other specifications concerned. Chosen as one of high-quality projects, the bridge was awarded a silver medal by the National Economic Construction Committee in 1982. The bridge withstood the catastrophic flood which took place in July 1981. It has been proved by four years' deflection and settlement observation and practical conditions of the bridge after its being opened to traffic, that the bridge is of high level both in design and construction, firm and steady in structure, with a smooth and even surface, thus ensuring a safe and easy flowing of vehicles.

Now, the tonnage of goods transported over the bridge each year amounts to 2'077'000 tons. 17'514'000 passengers crossed the bridge each year. It is reported that 10'932'900 Yuan per year have been saved by factories, mines and enterprises concerned thus all the investment has been repaid due to the shortened distance, lower expenditure for crossing and less transportation fares. Therefore, great profits have been made after building the bridge, and the profits will increase steadily with the increase of the traffic.

Regarding to the public and environment, the bridge is also profitable. Without the bridge, passengers had to waste 1 - 1.5 hours to get on the other side of the river. Instead, when the same number of passengers use the bridge, 1'915'800 work days can be saved per year. Still the bridge facilitates rational rearrangement of the city, affords advantageous conditions for development and exploitation of the vast area on the South bank District and for dispersing the population from the densely populated Central District. At the same time, it helps to improve the environment: There were only 5454 inhabitants in Nanping area of South Bank district before the emerge of the bridge. Now the population there has abruptly increased to 38'000.- A number of factories and stores have sprung up there. Soon this area will gradually develop into a new-type business centre.

3. CONSTRUCTION PROGRAMS

The essential factors for the successful accomplishment of the bridge lie in the fact that technical programs of the project tally with the objective practical conditions and that the techniques used were rather advanced and mature. Now, some main programs for construction of pier foundations, pier bodies, T-rigid frames and hanger girders are to be touched upon:

Since the No. 1 and 7 piers are near the bank, the construction procedure adopted for their foundations was coffering the pier areas to be excavated. After the water was pumped out and the excavation done, the foundations were poured in place. The procedure for the No. 5 pier foundation, which is located in Coral Islet with less seepage water, was mechanical excavation due to its sand and gravels, followed by drilling deep and dense holes 5 metres in rockbed. Dynamic charges could then be used to blast into the required shape at one stroke. For the No. 2, 3 and 4 pier foundations, which are located in Coral Islet, circular open concrete sunk well with or without water drainage was adopted. For the No. 6 pier deep water foundation, first a double-wall steel cofferdam was sunk with the help of grabbing or airlifting. After excavation, holes were made with a 2.6 m cross drilling bit operated by a hoister, or bored with a power-driven 2.6 m rotary driller, with reinforcing cages placed in. Concrete was then poured into the holes. For large-volume bearing platforms, concrete placement was made layer by layer, with snakelike tubes for the cooling system. As the No. 6 pier foundation was the key structure of the whole project, a double-wall steel cofferdam was added to lower water work level and anti-flood measures taken so as to speed up the progress of the project. As a result, this pier was completed only in one dry season instead of two as had been planned.

As fas as pier columns were concerned, they were of hollow type with even section. The sliding forms were lifted using oil jacks. As deformed joints of columns and footing slabs, fixed forms were used to cast in place. The sliding velocity of concrete piers ranged from 2.83 to 4.65 metres per day (24 hours). The average remained 3 metres per day. 15 days, and at most 20 days, were needed to finish a single pier. These programs ensured quick progress and high quality of the concrete placement of the piers.

T-rigid frame cantilevers of the bridge, which is 69,5 m in main span, were moulded by 20 blocks. Other Spans of 51.5 m in length were moulded by 14 blocks. The concrete of No. 0 blocks at the top of the piers were usually cast with sliding forms. But from pier No. 1 to the end of the T-rigid frame cantilever were moulded in place with sliding forms operated by self-made suspended working platform strengthened with inclined cables. The holes for 3-dimension prestressed wires were formed by putting into tubes made of iron sheets before concrete placement. Then, the wires tensioned with self-made tri-function oil jacks. Finally, cement

grout filler was pressed in to fill up the space of the tubes.

Hanger girders for the bridge, 35 m in length, 3.2 m in height, 120 tons each, were of prestressed concrete, which had been precast near North bridgehead, with the self made bridge erectors - prestressed trusses strengthened with inclined cable, then moved into position by using rails, trailers, rollers and hoisters. After this the prestressed concrete joints were carried out.

4. CONSTRUCTION CONTROL

All the preparatory work, planning, administrative and supervisory work was undertaken by the Command Office for the Chongqing Yangzi River Bridge Construction which was composed of units responsible for survey, design, finance and the construction Bank as well as representatives from the concerned municipal leading departments of these units. The Command Office acted as the contract unit as a whole and as the representative of municipal leading administration, who performed the function of management, supervision and strategical decisions. In a word, it took charge of the whole project, including preparatory work, design and construction. It was set up in October 1975. The administrative offices and staff members were gradually strengthened. (See Table 1 Organization of the Chongqing Yangzi river bridge construction)

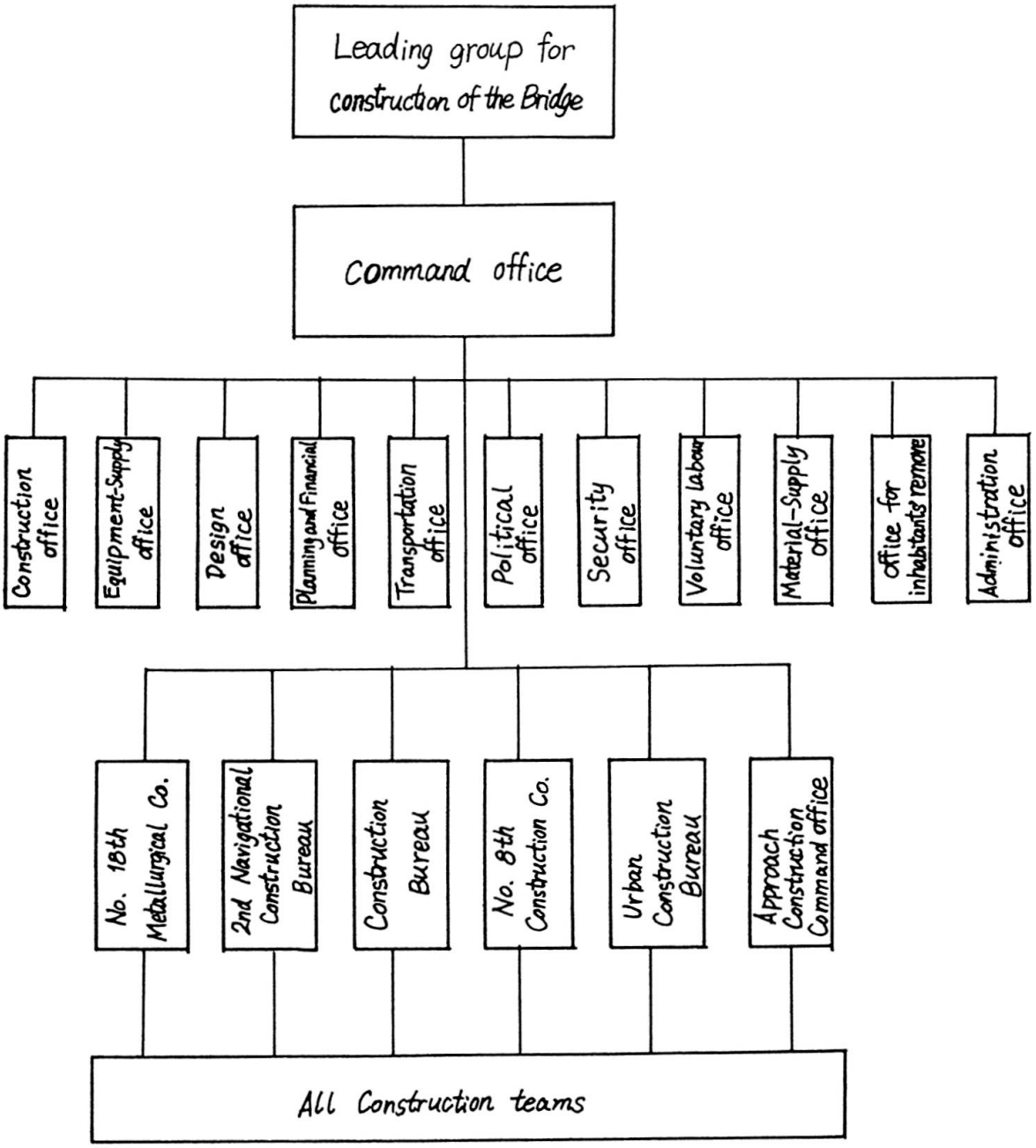
At the first stage, the following activities were stressed and accomplished in time:

1. To make programs for preparatory work and put them into practice.
2. To locate and survey the bridge site by the following units: City planning, Survey and Design, Communication and Transportation, Municipal Construction and Navigation Engineering Administration.
3. To make investigation, collect data, solocit designs.
4. To make design assignments and urge responsible departments to solve the problems concerned.
5. To take over for use the land around the bridge, remove and settle the inhabitants there.
6. To ensure survey and design, sign contracts.
7. To make plans for the construction organization, decide construction units sharing the project, and approve their construction organization plans.
8. To allot or build houses or sheds and solve water and power supply problems, roads as well as to provide sheds for workers, etc.
9. To prepare the main materials needed for the construction, purchase or make huge special mechanical equipment.
10. To make investment control and usage plans, ensure financial supply according to plans in the preparatory stage.
11. To organize the units responsible for making on-the-spot investigation; arrange technical training.
12. To supply construction drawings, solve the problems raised in joint check-up meetings on designs.

During construction, all the items of the project were put under unified leadership. However, each of them was done under particular administration. Common aspects were: survey and design, finance, construction, administrative service

ORGANIZATION OF THE CHONGQING YANG-ZI RIVER BRIDGE CONSTRUCTION

Table 1



and manpower, voluntary labour, safe navigation and supervision. The vertical administrations are units of four levels. They are Command Office, Command posts, teams and groups. According to the procedures taken for the construction, there were 4 stages: foundation building, pier column making, T-rigid-frame forming and floor paving. These tasks were planned and carried out strictly using construction programs to direct and supervise the construction and in accordance with the plans made, fixing tasks, requirements, units and time. These had to be fulfilled on schedule. According to the construction plan, a suitable number of persons were chosen to excercise the overall management so as to ensure good order on the work site. The command office was responsible for making construction plans for a season. Command posts made plans for every month. All the teams and groups arranged their work according to their plans for a week (or a 10-day plan).

By plans all the work was checked every week. Plans could be adjusted at meetings called every month, and persons who accomplished their work well were awarded prizes at the end of every stage. Therefore, construction plans were guaranteed to be fulfilled ahead of time. (See Table 2 Chart of the bridge construction progress planned against actual). In financial control, all the construction units made their budgets based on estimate, which were used as the basis for material supply, labour and expenditures. After careful calculation and repeated checks, the investment, through consultation, was allotted to each individual unit by contracts in accordance with estimated costs and tasks assigned. Money was appropriated each month according to the progress of items and tasks fulfilled. Final accounts were not made until all the tasks completed. A special supervision station was set up to ensure navigation safety on the river near of bridge site. Workers were mobilized to take part in the administration so as to allow full play of their sense of duty as masters. Workers were elected to take charge of some work, such as planning, safety and quality check-ups, tools and material supply, while working. This measure drew professional personnel and many workers to take part in the administration work, thus raising administrative and project quality.

5. TECHNICAL MANAGEMENT

During construction, special emphasis was laid on technical management. This work was done with the quality as the core, technical progress as the key link and economic profits as the goal.

1. From the very beginning through to the end of the construction, quality first was the constant and main topic of discussion. High quality was the very basis for speed, economy and profit. The long-standing practice of putting speed in the first place (regardless of quality) was avoided. Construction was the only purpose, less attention was paid to the role of management. The idea quality first was firmly kept in the minds of all the persons. The construction was done in strict conformity with the specifications laid down bythe government for construction, technical requirements and quality standards.

2. The following rules and regulations of technolocical management were carried out: making joint check-up on construction drawings; explaining real intention of designs; modifying of design: check-up at shift relief, check-up quality, testing new materials and new techniques, technical training, technical innovation, prizes for high quality, technical records, etc.

3. Check-up standards were set for quality requirements. The system of job responsibility was established for the chief engineer and the responsible

CHART OF THE BRIDGE CONSTRUCTION PROGRESS PLANNED AGAINST ACTURAL

Table 2

Eng. items	Concrete (M^3) Found.	Pier	Tee	Sum	P / A	1977 11	12	1978 1	2	3	4	5	6	7	8	9	10	11	12	1979 1	2	3	4	5	6	7	8	9	10	11	12	1980 1	2	3	4	5	6	7	8	9	10
N. abut.				7207	P																																		
					A																																			
1st Pier	1621	2731	2308	6660	P																																		
					A																																			
2nd Pier	3206	2752	2308	8266	P																																		
					A																																			
3rd Pier	3994	2658	2308	8960	P																																		
					A																																			
4th Pier	4137	2519	2308	8964	P																																		
					A																																			
5th Pier	2273	2996	2308	7577	P																																		
					A																																			
6th Pier	5283	3992	3866	13141	P																																		
					A																																			
7th Pier	2857	3260	3830	9927	P																																		
					A																																			
S. abut.				4972	P																																		
					A																																			
Hanger girder				3126	P																																		
					A																																			
Deck				2791	P																																		
					A																																			

Note: Planned (P) ---- Actural (A) ————

Flood season for preparation of const. ≡≡≡

technicians of the command office, command posts, teams and groups. The command office controlled quality and progress of the project from foundation making to the construction of the upper structures. It organized complete quality check-ups, made summaries of the work done and appraised work through comparison. All construction teams also established the system of job responsibility according to their tasks assigned. Among the work groups, check-ups were made by themselves as well as with each other, or at shif relief, thus a network of quality check-ups was established.

4. In order to promote technical progress, new techniques, materials were adopted through tests, technical innovations spread. Water-rducing agents were widely adopted so that the workability of concrete was improved, cement saved, concrete strength raised. Power-driven self-made drilling bits bored deep-water rockbed as deep as 1.28 m a day (average) - compared with cross drilling bits powered by a hoist (their depth was 0.47 m per day). The work efficiency increased by 2.6 times. Take No. 5 pier for example, its location was 35 - 40 m away from the main channel during dry season. Holes of 5 m in the rockbed were bored. The foundation excavation area was 15 x 25 m2 through rockbed. The work was done 22 days ahead of schedule. For this, a carefully designed explosion was successfully carried out with a charge of 1135 kg, ignited by 1/1000 sec. electric detonators. T-frame box girders, with great height but thin walls, were moulded with sliding forms (inside of the wall) lifted by oil jacks. Wires were tensioned with long travel 3-funktions oil jack. These new techniques adopted not only guaranteed the bridge quality but also offered great facilities for erecting bridges with spans over 200 m.

5. Facts proved technical management played a very important role in ensuring the project quality. A great number of items surpassed the demanded standards. For example, according to the desing, the allowable error of the foundation central line was ±30 mm, but in fact, it was under 6 mm. That of piers was ±20 mm, in reality it was 2-5 mm. The design marks were 15, 20, 25, 40 N/mm2 but actual marks were over 17, 28.4, 26, 50 N/mm2 respectively. The percentage of broken prestressed wires was, as required, below 1%, in fact it was as low as 0.023-0.52%. The percentage of relaxed wires was not more than 2% of the total number, but it was kept down to 1.56% of the total.

6. MEASURES OF TECHNIQUE AND ORGANIZATION

The project of the Chongqing Yangzi River Bridge was completed with high speed, high quality and high benefit. The country's objectives and requirements of the building of the bridge were soon fulfilled. All these are unseparable from the correct measures of technique and organization adopted by the engineering command office of the Chongqing Yangzi Bridge. Now some important measures are cited as follows:

1. The task of building the bridge was difficult, the time for the project was pressing, the technique was complicated, and there were contradictions between the task and the professional bridge building force. Based on this, every relevant construction unit set up six command posts and all joined in the battle. The command office practised concentrated leadership and unified command and management in the respects of the survey, design and construction. These measures were helpful to each unit's superiority into full play. United and cooperating with each other, they surmounted all difficulties and fulfilled the construction task in an all-round way.

2. According to the analysis of hydrological data on record, hydrologic forecasts and the actual construction progress of the deep water foundation of pier No. 6, we timely raised construction water level, prolonged the time for the building of the foundations by adding a double-wall steel cofferdam of 4 m to the original one, so that the foundation was finished within one low-water season instead of two. Not only was the pace of construction quickened, but also the cost was greatly lowered.

3. In order to control investment and bring every positive factor of all construction units and workers into full play, we adopted the measure of contract for a job according to budgetary estimate after repeated accounding and joint delivery. At the same time, in the teams and groups, we caluclated by the piece according to quota or contracted wages and according to separate items or main working procedures. We practised the socialist distribution principle of paying according to one's work and the more one does, the more one gains. In this way, the funds for the building of the bridge were effectively controlled, and both the enterprise and workers had surplus. An initial good basis was laid for an allround implementation of the system of economic responsibility.

4. Make full use of the superiority of Chongqing's powerful equipment manufacturing industry which has a sound basis. Some machines and equipment needed for the construction of the bridge which could not be supplied on time, by depending on purchase, were manufactured in Chongqing. These included universal bolted angle members for construction, hoisting jacks with three functions, hoisters, vibrators, brackets, strengthened with inclined cable, various kinds of cranes, pumps and drilling machines, all in all 38 kinds and 4124 pieces of equipment, weighing 3770 tons. Timely supply of machines and facilities was ensured.

5. Steel and cement needed for the bridge was of variable type and large quantity. All the steel and cement plants in Chongqing were mobilized and all the staff and workers strived to overfulfil their production quoty. The products in excess of the quota were to supply the bridge. Leaders of the Goods and Materials Department and the Transportation Department were appointed members of the command office. And special working branches were set up. All these quaranteed the supply of materials for the project.

6. In view of complicated construction technology, high demand on quality, in order to spread and adopt new techniques, relevant scientific research units, universities, and colleges were organized to engage in scientific research experiments. They made experiments in shrinkage creep of high-tensile-strength concrete, rubber expansion joints, pottype elastomeric bearing, sliding platform and sliding form technique brackets and suspended basket, strengthened with inclined cable No. 0 and No. 1 Block construction techniques (full size test), photoelastic stress analysis of the junction joint of the cantilever portion and its monolithic pier, creep of wire, coefficient of friction between wires and iron sheet tubes, anchorage and uplift stress test for the group of reinforcements near the top of pier, D = 2.6 m drilling machines, etc. More than 600'000 Yuan were alloted for the experiments, provided scientific data for making designs, new equipment and new technique for the construction. What's more, by making experiments, a lot of new technology was developed. They played an important role in raising the quality, shortening the project duration and lowering the cost of the project.

7. ADDITIONAL LITERATURE

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