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Pylon Foundation Design of Wuhan Bai Sha Zhou Bridge

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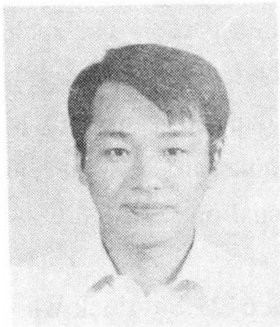

Zhengwu Yang, born 1963, got his civil engineering degree in Shanghai Railways University. Since his graduation in 1984, he has been involved in the design work of major bridges.

SUMMARY

Wuhan Bai Sha zhou Bridge is a cable-stayed bridge with 618.0m main span. Since the bearing bedrock at the bridge site is soft rock which brings a relatively lower bearing capacity, a composed stiffened girder with steel box girder at mid-span and PC box girder at both ends are applied in order to eliminate the dead load of superstructure as well as light weight foundations which are more easily constructed. To meet the strict construction schedule presents another challenge in the project. Based on comparison among foundation alternatives, design of pylon piers are introduced focusing on structural design and constructional methods.

1 FOUNDATION DATA & ENVIRONMENT

The two pylon piers of the Wuhan Bai Sha Zhou Bridge are located in the deep water of the Yangtze River's main flow. The main span between the two pylons and the north side span are within the navigational domain of the current river channel, while the south side span might become a downstream navigational channel in some dry seasons under present river conditions and will become a fully navigational channel after realignment of the waterways. The water depth at the two piers changes along with the alteration of the flood seasons and the dry seasons as well as the variation in scour and deposition .According to statistical data, water depth at the two piers ranges from 12m to 25m and flow velocity from 2.0m/s to 3.0m/s.

As a result of geological survey, the thickness and depth of overlays at the two piers are roughly the same, all bedrock is soft rock. The overlay of the second pier in boring is 10.9~14. 8m deep, at the top of which are loose~denser fine sand, gravel sand and round gravel, at the bottom are hard plastic or medium hard clay, and dense round gravel. The rock surface is even, which is mainly composed of soft sandy mudrock, sandy mudrock, loose argillaceous sand rock, sand stone and gravel rock, which have low strength. The depth of each rock layer is stable with low fluctuation. Influenced by tectonic movement, local joints are well developed in bedrock at pier position. Relatively hard sand stone is deeper than usual one.

The overlay of the third pier in boring is 20.6~21.8m thick whose depth, stratification and textual composition are similar to those of the second pier except slight difference in thickness. Formation of the bedrock at the third pier, which is made up of soft rock, is the same as that of the second pier with little discrepancy in depth, stratification and textual composition. The bedrock is made up of soft rock. The depth of the sand stone is approximately the same as that of the second pier.

The geological conditions of the second and the third pier are almost identical. If the same foundation type is used for the two piers in hydrological calculations, the local scouring level of the two piers is very approximate, and both of the bedrock strength changes from 0.5MPa to 2.5MPa— that is the premise why the same type foundation is applied for the two piers.

2 FOUNDATION TYPES OF THE PYLON PIERS

According to the above-mentioned geological conditions, a caisson foundation and a cast-in-situ bored pile foundation are selected for comparison.

2.1 Floated steel caisson foundation

The floated steel caisson foundation is one of widely used and safe foundation types in China. There are thick dense gravel layers along the dedrock of the bridge piers which can act as bearing layers in caisson foundation, on the basis of which design calculations are conducted. The calculated results show that the caisson foundation is reliable in terms of safety and bearing capacity during its fabrication, flotation and operation. A layer of 6~8m deep hard plastic ~ medium hard clay over supporting layers which the caisson shall go through during its sinking is the only obstacle of the application.

2.2 Cast-in-situ bored pile foundation

The cast-in-situ bored pile foundation is another foundation type with many successful examples in deep water which has been used in China extensively. It is classified in conformity with different alignment and watertight methods. In the design for the bridge, the cast-in-situ bored pile foundation with double-walled steel cofferdam and a suspended box cofferdam respectively are compared for the two pylon piers.

3 COMPREHENSIVE COMPARISON OF FOUNDATION TYPES

3.1 Comparison of structural formation

3.1.1 Floated steel caisson foundation

While using caisson foundation, caisson sinking by air curtain technique is not very effective because the caisson shall go through the thicker hard clay layer. In doing so, the self-weight of the caisson foundation is required to be very heavy and other measures shall be taken at the same time. The size is illustrated in Figure 1.

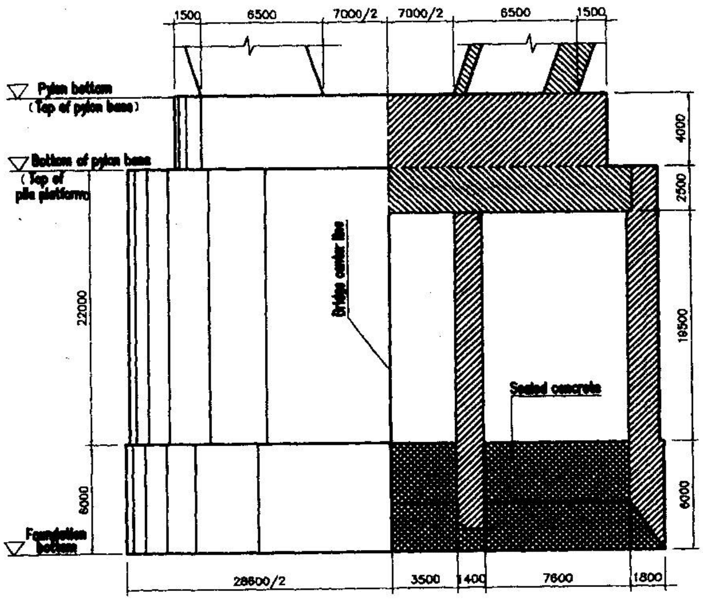

Fig.1: Floated steel caisson foundation

3.1.2 Cast-in-situ bored pile foundation with double- walled cofferdam

The success of cast-in-situ bored pile foundation with double-walled cofferdam depends on the stability of the cofferdam while landing on the riverbed. According to the geological conditions, the double-walled steel cofferdam shall insert into certain depth of the hard clay layer. So the cofferdam is rather high. Except large steel amount consumption, the self weight of the foundation and the watertight sealed concrete will be added to the piles as permanent exceptional loads. Therefore, this foundation type is not cost-effective in the situation of soft rock with relatively lower bearing capacity as for this bridge. The scheme can only be realized by separating the cofferdam and the sealed concrete from the pile groups. It is very hard to ensure the efficiency of the above-mentioned measures. Once they are failed, unexpected loss will occur. Furthermore, the cofferdam shall insert into certain depth of the hard clay layer in order to maintain stability in construction, which is not efficient in terms of constructional period. It is not adopted. The structure is demonstrated in Figure 2.

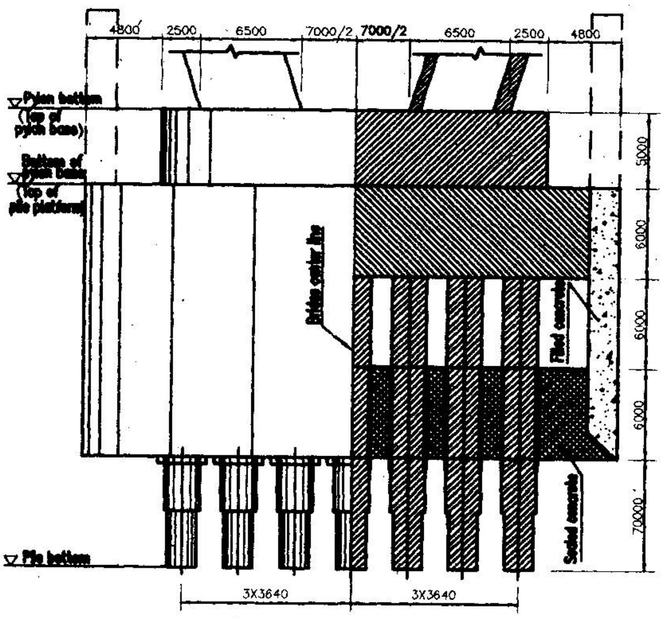

Fig.2 Cast-in-situ bored pile foundation with double-walled cofferdam

3.1.3 Cast-in-situ bored pile foundation with suspended box cofferdam

A cast-in-situ bored pile foundation with suspended box cofferdam also acts as water resistant facility. It is feasible as long as its height can meet the structural requirements. Its watertight sealed concrete is relatively thinner and therefore the exceptional loads added to the pile foundation is much lighter, which is rather beneficial for the soft bedrock. It is shown in Figure 3.

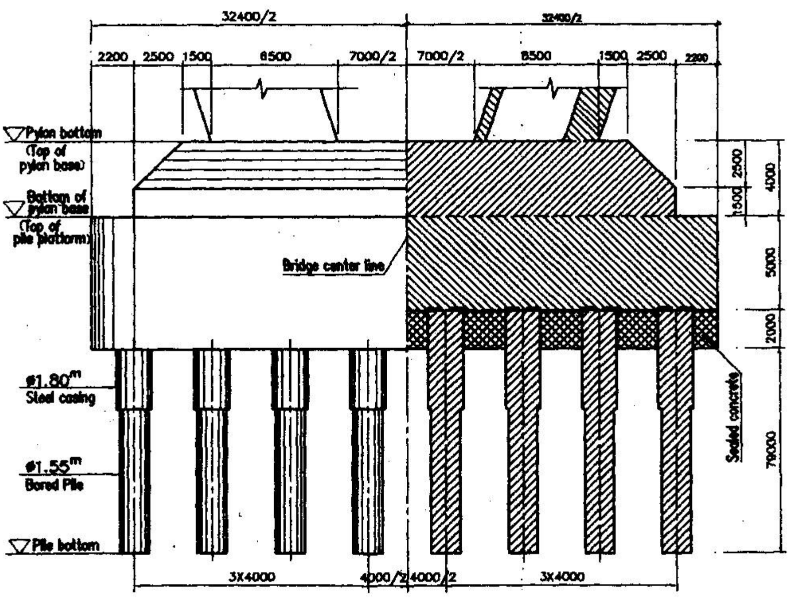

Fig.3: Cast-in-situ bored pile foundation with suspended box cofferdam

3.2 Comparison of constructional methods

3.2.1 Construction of floated steel caisson foundation

Floated steel caisson in deep water consists of well-developed constructional techniques as fabrication, flotation, connection sinking, ejection sinking and other auxiliary measures, among which the most significant is how to go through the thicker hard clay layers. According to previous experience, it might be possible to go through the hard clay layers with high pressure jetting, local explosion and other assisted methods. But it is hard to maintain the time requirements of the project. Since it shall be prepared after flood season and commenced in dry season. Otherwise, the construction period will be even longer and it is difficult to assure the safety of the project during flood season.

3.2.2 Construction of cast-in situ bored piles with double-walled cofferdam

Construction of cast-in situ bored piles with double-walled cofferdam also requires fabrication, floatation, connection and ejection sinking . But, the cofferdam is only needed to insert certain depth of the hard clay layers. It still must be prepared after flood season and commenced in dry season, whose constructional time is restrained. Moreover, since the bearing capacity of the bedding ground is not strong enough, more exceptional loads and more piles are required, which will also lengthen the constructional time. This method is not economical, too.

3.2.3 Construction of cast-in situ bored piles with suspended box cofferdam

Regarding the actual hydrological and geological conditions at the two piers, the cast-in situ bored piles with suspended box cofferdam is very appropriate. Since average annual water level ranges from 14.0m to 18.0m,. And according to the structural calculations, the elevation of the bottom of the pile platform is 6.0m if the sealed concrete can be cast in dry seasons, the water head difference is therefore 8.0m~12.0m. Hence, the solution is feasible. Geologically speaking, the steel casing need only to be inserted into certain depth of the hard clay layer. With relatively higher anti-scouring capability of this layer, the local scour can be eliminated if an elevated platform is used with a suspended box cofferdam. The local scour elevation under the is about -10.0m according to the calculations, so the assumption of an elevated platform is acceptable.

The cast-in situ bored piles with suspended box cofferdam can be constructed in three ways in compliance with different construction schedule requirements. In the following three methods, the construction platform shall only be higher than the maximum flood elevation in order to proceed construction during flood seasons, which is obviously beneficial to the time schedule.

The first method is that the steel casing used for the protection of the pile boring also behaves as support of the construction platform, which shall be commenced at early dry seasons to finish four to six piles before the arrival of the spring flood to assure stability and safety. In this method, fixing piles are avoided to save unnecessary cost.

In the second method, the steel casing also behaves as support of the construction platform, but construction shall begin during dry season. After the first 4~6 casings have been finished, a small temporary construction platform is assembled immediately. As soon as the corresponding 4~6 piles are completed, the temporary platform is dismantled. The construction of the rest steel casings is advanced, followed by assembly of construction platform and construction of bored piles. The whole process shall be well arranged to guarantee each step is finished at time. In spite of its risk, it is still very economical.

The third method can be applied at any time theoretically. But it must be undertaken carefully in flood season to eliminate risk. Fixing piles are driven firstly to support the construction platform which shall meet the flood protection requirements. Then the construction platform is assembled and the steel casings are inserted to construct cast-in-situ bored piles. The method is safe and reliable and less restrained by flood. It is more expensive due to the introduction of fixing piles.

As a result of the above mentioned comparison, a cast-in-situ bored pile foundation with suspended box cofferdam is selected. As to suitable method in construction, it must be chosen in accordance with the construction schedule and building machinery and etc.

4 SELECTED FOUNDATION TYPE

Finally, the cast-in-situ bored pile foundation with suspended box cofferdam is used for this project. Each has 40 bored piles of Ø1.55m which are arranged in matrix shape of five rows and eight columns. The pile platform is 32.4×20.4m in area and 5.0m in thickness. Bored piles are 79.0m long below the 2.0m thick sealed concrete. The plan size and water elevation of the water resistant cofferdam (Figure 3) is designed by constructional companies.

5 CONSTRUCTION

The construction of the foundations of this bridge began in March, 1997, in which fixing piles are inserted to support the construction platform. By the early September, 1997, both of the forty cast-in-situ bored piles have been finished, which is followed by cofferdam installation, dredging, concrete casting and other sequence according to the construction schedule.

At present, the two pylons are under construction.