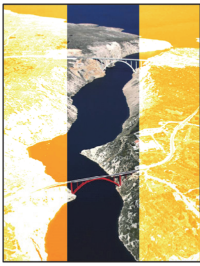

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DESIGN AND CONSTRUCTION

# DESIGN AND CONSTRUCTION OF CHANGTIANYANG BRIDGE

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**Abstract:** *Changtianyang Bridge is located between the Olympic Park and Changtianyang wetlands in the city of Huzhou, Zhejiang Province, China. The bridge is designed as a 21-span arch structure in order to reflect the Watertown's ancient rhyme. All the arch rings are semi-circular shaped. The total length is 336.2m with a full width of 47m. The net span of the mid-span is 16.4m long. The bridge is located at an expressway and it will open to heavy traffic. But This bridge is located at poor geological area. The thickness of the soft soil near the surface is from 15m to 20m. Therefore, the most part of the dead load of this bridge is caused by the arch filler. After a lot discussion, the foam concrete, which has lightweight and high strength, is chosen as the arch filler. Continuously reinforced concrete pavement is creatively adapted as the base course and water barrier. Arch plates are made of cast-in-place concrete. Instead of using the full framing scheme, the lightweight steel truss arch frames which supported on the pile caps are adopted. This is because the foundations of the frame in the water and on the soft soil are expensive and risky. The technique is a very unique construction technology which has reasonable structure, simple construction technology, and low cost.*

## 1 INTRODUCTION

Huzhou is a land of plenty. Many rivers and lakes make a dense water networks. Various kinds of bridges are across on them, most of which are historical arch bridges. The old arch bridges reflect the traditional Chinese aesthetic style. North Outer-ring Road is located in the northern city of Huzhou, designed for the urban expressway in the near future. Changtianyang bridge need to build when the road meet the Changtianyang water surface. The shape of all 21 arch rings is semicircular not only improve the landscape of the Olympic Park but also inherit the bridge culture of Huzhou city. It will reach a harmonious and unique result, as shown in Figure1.

Figure 1: General layout of Changtianyang Bridge

As a bridge on expressway, load standard is highway-I level [1]. The length and width of this bridge exceeded a lot that of a normal bridge. The materials and construction technology are different from traditional arch bridges. New methods need to apply.

Some researchers have studied how to solve the big displacement at the foot of arch. Meishan Bridge in Shaoxing, Zhejiang province, is a continuous arch bridge with eleven spans. Because of thick soft ground, large span and small rise-span ratio, strong external prestressed cables was used to balance the strong horizontal forces [2]. A same method as previous was adopted by Anmin Wang in a deck arch bridge with main span of 65m [3]. Instead of prestressed cables, huge abutments were applied to resist horizontal force by Tinghui Lou [4].

As the rise-span ratio of this bridge is relatively large, external prestressing system is not necessary. Huge abutments, anti-push piers, lightweight filler, et al. are used to reduce the value of unbalanced horizontal forces on the Changtianyang Bridge.

# 2 GENERAL LAYOUT

Changtianyang Bridge located at flat site topography. From 15 to 20 meters in depth direction is Silty clay, which has an allowable bearing capacity of 60kPa. A gravel layer from 35 to 40m below ground surface has a bearing capacity of 600kPa and can be used as piles bearing layer. The vehicle load class is highway-I according to the Chinese codes and the corresponding crowd load is 3.5kN/$m^2$. Although no ships pass through the bridge, some small pleasure-boats maybe pass through it. A ramp will pass underneath the 4th and 5th spans, which have a net height of 4m. The longitudinal gradients of 2.48% are designed symmetrically both sides of the deck. In the middle of (on the top of) the bridge, there is a vertical curve with a radius of 4000 meters. The slope along the cross section of pavement is 1.5%.

The total length is 336.2m and the full width is 57m. The bridge is divided into two halves; the width of each half is 23.5m and the gap between two halves is 10m. The 21-span reinforced concrete spandrel filled arch bridge is symmetrically arranged. The length of span range is between 12.9m and 18.4m.

# 3 STRUCTURAL DESIGN AND CALCULATIONS

## 3.1 Substructure design

This bridge is a 21-span continuous arch bridge. The “continuous-arch effect” is apparent. Imbalance force caused by superstructure is so strong that the abutment and every 4 or 5 piers should be strengthened. Combined abutments which have three rows of piles were designed. Each one of 4 or 5 piers is an anti-push pier. These piers have two rows of piles stronger than normal. All piles are friction piles.

## 3.2 Arch rings and side walls

Each piece of the upper arch ring has a width of 23.3m. Net spans from the abutment to middle point were 11.3m, 11.9m, 12.6m, 13.3m, 13.9m, 14.7m, 15.3m, 15.9m, 16.1m, 16.3m, 16.4m. Arch rings thickness of the first four spans near the abutment is 0.4m. The thickness of the second four spans is 0.5m. This value is 0.6m for the middle five spans. All arch rings were designed as reinforced concrete members. Some long steel bars are set on the upper and lower edges of arch rings. Additional steel bars are set on the lower edges near mid-spans and upper edges near supports.

Some C15 concrete used near arch supports to strengthen and to protect the arch rings. Sidewalls are poured by C30 concrete. The top width of sidewall is 400mm.

## 3.3 Arch filler

Gravel, lime-soil or other conventional fillers are generally applied to small span arch bridges. Lightweight filler such as lime-fly ash are used when the span become large or soil is soft. To mix fly ash into filler can reduce the weight. It needs to compact by layer and layer. The construction operation is relatively complicated especially for construction work on the wavelike top surface of the arch rings.

For the volume of filler for this bridge is large, two kinds of lightweight filler were focused on: one is solidified fly ash, another one is foam concrete.

The solidified fly ash is based on fly ash from power plants, adding fly ash of special admixtures, water and other materials. All materials mixed by machine uniformly. Solidified fly ash has light weight. Its wet density is generally 1450Kg/m$^3$ and its dry density is 1000 Kg/m$^3$. It has high retarding, water-hardness and toughness characteristics. The construction of solidified fly ash is similar to that of concrete. It has simple process [5]. The main component part of solidified fly ash is fly ash. In recent years due to the increasing demand for environmentally friendly power station introduced desulfurization process in dealing with the waste. This process led to the high sulfur content in fly ash. Using the high sulfur content of fly ash, the roadbed would be destroyed When the rain came into [6]. Many similar incidents have been reported in our country. If solidified fly ash is used as filler in this project, the demand for fly ash will be large. In consideration of the condition of power station near Huzhou Citi, the quality of fly ash is difficult to ensure. So the solidified fly ash is not a good choice.

Foam concrete is a new type of lightweight materials which containing a large number of closed bubbles. Physical method is used to make foam, and then put the foam into the slurry which is mixed with fly ash, cementitious material, water and various admixtures. The next process are mixing, pouring and curing. Foam concrete has characters of lightweight, fire-resistant, heat insulation, sound insulation, thermal insulation and anti-seismic. Foam concrete is a relatively new type of energy-saving building materials in recent years. It has been widely used in walls, insulation boards, roofs, and so on [7]. It has gradually been introduced highways and municipal industry, mainly used for road filling, the pipeline trenchs backfill, and so on [8].

Foam concrete arch filler has the following advantages:

(1) It is very light. Its weight is only 1/4 of normal filler. Even for lightweight filler (eg solidified fly ash), its weight is only a half. It can greatly reduce the value of dead load, thereby reduce the size of arches, foundations and other components;

(2) Construction technology is simple. Many construction equipment and staff can be saved. In actual construction, only two workers operated the mixing machine under the bridge, and two workers poured of foam concrete above bridge. These works will complete all the pouring work for whole bridge.

The conventional filler is not suitable for this bridge because of heavy weight, difficulty of compaction. Solidified fly ash has two advantages as previous, but there is a risk of material quality. Foam concrete has very light weight and can be poured conveniently. Most of all, the quality control is guaranteed. After repeated demonstration, foam concrete of 600kg/m$^3$ is finally adopted as arch filler.

### 3.4 Deck pavement

Deck pavement of other similar arch bridge is generally same as the both sides of the road pavement. A layer of lime-fly-ash stabilized bound macadam is applied as the base, two layers of asphalt concrete surface is applied as surface. This scheme takes into account both the bridge deck pavement with the ordinary differences, but also to facilitate the construction of pavement. These programs were put into practice in many arch bridges successfully.

Changtianyang Bridge is located an expressway in the north of Huzhou. Taking into account the high road class, heavy trucks load, large longitudinal gradient, a suitable deck pavement must be chosen carefully. After many times discussion, the final choice is

continuously reinforced concrete (CRC) and mastic asphalt macadam mixture (SMA) of composite pavement. CRC is a base of SMA pavement. CRC combining with SMA has a very good waterproof performance, preventing rainwater from entering the inner of bridge, to further ensure the safety and reliability of the structure.
After design calculations, thickness of CRC layer is 22cm. The leveling layer located under. SMA surface of 9cm is above the CRC layer.

### 3.5 Structural calculations

Continuous-arch effect is very obvious because the number of spans is up to 21 and the upper soil layer is very poor. As accurately reflecting arch effect, a full-bridge model is adopted in calculation. To reflect the influence of foundation stiffness, the group pile foundations and pile caps are taken into account. Calculation software is MIDAS/Civil.
Calculation results show that the reaction force at the top of the pile reaches a maximum value at abutments, followed by the anti-push piers. So the foundations of abutments and anti-push piers need strengthened. For landscape needs, all arch rings are semicircular. For spandrel filled arch, the semicircular arch axis is not ideal. Fortunately, the span is not too much, additional reinforced steel bars can solve this problem.

## 4 INNOVATIVE CONSTRUCTION TRESTLE

### 4.1 Construction trestle design

Full framing scheme is usually applied to traditional small spandrel filled arch bridges with small or middle span. Cast trestle has security risk when the span is large or it located in a poor geology. Although the span of this bridge is not large, it is located at a weak ground in which the soft soil has very poor indicator. If traditional full framing applied to this bridge, the most important things is the foundation treatment.
Construction engineers put forward a lightweight welded steel arch trestle instead of the traditional full framing. All components of this trestle are made of ordinary reinforced steel bars. The truss can be divided into many pieces. A piece is a basic part. Each piece has an arc shape and is made of upper chord, lower chord and web members. Some transverse steel bars connected all the pieces (Figure 2). All the arch pieces are supported on pile caps. The horizontal force causing by concrete during constructing will be balanced by steel I-beams connecting two caps longitudinally.
This trestle is so light that it needs few workers and equipment to build. This type of trestle was practiced successfully in two small arch bridges in Huzhou City. If this lightweight trestle is applied in this bridge successfully, it will bring more substantial economic benefits.

Figure 2: Lightweight trestle

Figure 3: Arch rings were finished

### 4.2 Effect and evaluation of trestle

This type of trestle applied to this project, comparing with the traditional full framing, is an innovative, unique, smart trestle. It needs few materials. Above all, it deals with the weak ground well. Actually, it avoids the soft soil completely! The cost of this trestle is just a half or less of traditional method. The components of this trestle can be obtained conveniently because the components are almost common steel bars. For the trestle is very light, workers operation is easy. Large-scale machinery is unnecessary. The bottom die of arch rings is supported on the upper chords of trestle. The chord members which are made of steel bars have appropriate stiffness, so that the shapes of the arches are smooth and sleek (Figure 3). According to the on-site monitoring, the key point deflection was smaller than the theoretical deflection. It indicated that there is a large surplus of structural stiffness.

The idea of this trestle is bold and ingenious. It is fully embodies the Chinese folk wisdom on bridge construction. A most important reason of success is the construction project manager of this bridge has a special workgroup and special management. Almost all the workers are work for a boss for long time, so they are skillful, faithfully and reliable. This is quite different from other builders in China. Nevertheless, to promote this trestle, theoretical research, process details, management mode, et al. need to explore further more.

## 5 CONCLUSIONS

(1) To build a continuous deck arch bridge would open to heavy traffic on soft ground, some effective means should be applied. Firstly, smaller span and larger rise-span ratio were adopted. Secondly, strong abutments and anti-push piers were designed. Lastly, foam concrete was used as arch filler and continuously reinforced concrete is applied as base of SMA pavement.

(2) As all arch rings are semicircular, arch axis is not reasonable. There is large positive moment in vault and foot of arch. It can be solved by set additional reinforced bars. Protective concrete is set up near arch springing.

(3) Compared with conventional fillers, as a kind of arch filler, foam concrete has light weight so that it can be used on weak ground. It facilitates construction greatly, and need less construction equipment and few workers.

(4) Continuously reinforced concrete is applied as base of SMA pavement. It is also a transition layer between the foam concrete filler and deck pavement. CRC combined with SMA is a good waterproof layer to prevent filler from water penetration.
(5) Unique lightweight welded trusses made of steel bars were applied to cast of arch rings. It avoids the foundations of trestle on soft soil completely. Because the chord members which are made of steel bars have appropriate stiffness, the shapes of the arches are smooth. This is an innovative, ingenious, low-cost and high effective trestle.

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