

# A Research of the Bridge Structure Form Selection Based on the Mountains City Bridge Aesthetics

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## Abstract

Along with the rapid development of science and technology since the 19th century, the traditional design concept gradually replace the application of new materials, new structure and new skills by bridge engineers study. In people's living standards continue to improve conditions need to be the engineer devised a more perfect, more harmonious bridge to meet the spiritual needs of people. Modern bridge design should not only is a simple mechanical design, structure, construction, but also should be with the perfect combination of philosophy and aesthetics. How to make the bridge satisfy engineering specification, appearance and perfect coordination with the surrounding landscape, is an important topic of the current bridge construction. This paper probes into the basic principles of the mountains bridge aesthetics, with Two- river bridge as the example shows that the bridge aesthetics take the important role in bridge design, and reference for the related projects.

**Keywords:** mountains city, city bridge, bridge aesthetics, bridge design

## 1. The Characteristics of Mountainous City

### 1.1 The Concept of Mountain and Mountains City

Mountain is one of geomorphic types. "Mountain" means in the study of this paper is of high altitude and terrain fluctuant landforms, including not only physical geography on the mountain, but also including bumpy plateau, hilly and valley and basin. Mountains city should not only consider the basic characteristics of the "slope" and influence, and should not be ignored other characteristics, such as the change of the vertical gradient, landform, different environment around the city. Therefore, the definition of mountain city want to consider the natural features of the following two aspects:

1.1.1 the city built in the slope is greater than the hillsides with a slope of above 5 ° of undulating and difference to the city, no matter how its altitude, such as Chongqing, Lanzhou, Panzhihua, Hong Kong, Qingdao, Yanan, Zunyi, etc;

1.1.2 although cities built on flat land, but because of its complex terrain and natural surroundings condition have a significant impact on structure of the layout of the city, the development direction and ecological environment such as Gui zhou, Kunming, Guilin, Hangzhou, Yantai, etc.

### 1.2 The Characteristics of Mountainous City

Because of its topography, physiognomy, Mountain city often formed rich resources and unique landscape, more large difference of national culture blend, accent, tourist attractions in many aspects of characteristics, in addition, the general also has the following features:

#### 1.2.1 The Obvious Contradiction between People –Land Relationship and Fragile Ecological Environment

Mountains city have more people and less land, what's worse, mountainous inconvenient use and the flat which is easy to use is less. In recent years, with the acceleration of urbanization and the advancement of the western development strategy, the consumption of mountain resources and mountain environment stress increasing, in the mountains and mountain city, the contradiction between people –land relationship is more outstanding.

#### 1.2.2 Has the Characteristics of Apparent Vertical

Mountains city in the vertical has obvious administrative levels sense, vertical feature of urban natural geographical environment is the basic conditions of forming vertical mountain city landscape features.

### 1.2.3 The Characteristics of Mountain Building

Mountainous city and plain city buildings has obvious difference. Because of the urban land insufficient and geological conditions are relatively good, so the modern mountains cities' building generally high and dense. And, as a result of numerous buildings along the slope distribution on the elevation at all levels, buildings appear layer cascade folds, formed the mountain city administrative levels on the important features of the characteristics.

### 1.2.4 Built along the River, Easy to form a Landscape City

Special terrain mountain for a deep cut, tend to form a large river, river blocks on both sides of the people's communication, but also brought the convenience of production water, passenger and cargo transportation. Mountains city was often the landscape city. The city depends on the landscape composition, connecting to a number of big cities become a group, keep the group of "a mountain, a water and a city".

## 2. The Characteristics of the Mountains City Bridges

The beauty of mountains city Bridges lie in the structure of bridge engineering, architectural aesthetics, structural engineering, architectural aesthetics in proportion to the unified harmonious, stable equilibrium, coordination, and the perfect combination of exquisite rhythm, etc. Urban Bridges combined closely with the mountain city Bridges, so mountains city have more aesthetic characteristics, mainly reflected in:

### 2.1 *The Overall Coordination between Mountains City and Mountains City Bridges*

Mountains city of China, has been in the arms of natural landscape, the city of artificial environment and natural landscape environment organically fuses in together, especially the mountains city bridges are in harmony with the landscape and the surrounding environment.

### 2.2 *The Beauty of Mountain City Bridges in Changes*

Bridge is an important channel of mountain city traffic, because the mountain city spatial structure and changeable and rich changes in the natural environment, make the structure of the bridge must be diversified so as to adapt to the surrounding environment and buildings, the bridge in harmony with the natural environment would make the mountain city of Bridges "a bridge, a scene"s unique beauty.

## 3. The Selection of Mountains City Bridges' Aesthetics

### 3.1 *The Basic Principles of Aesthetics in the Bridge Design*

Bridge aesthetics not only on the external form and modeling, but also meet the visual perception of road users in different traffic conditions. Generally speaking, in the bridge design, the aesthetic theory, principle, characteristic and method of use is mainly manifested in the following areas:

#### 3.1.1 Consistency

Consistency is a bridge of architectural form must be consistent with the purpose and function. Bridge construction in the form is first depends on its purpose and function, only the two aspects to achieve consistency, the beauty of Bridges is a solid foundation and likely to reach the highest state of quality and the unity of beauty.

#### 3.1.2 Harmony

The relationship between Bridges and roads, and the surrounding environment should be in harmony. Bridge is one of the artificial landscape in natural landscape, like pavilions on the surrounding environment is a kind of ornament, supplement and grace. Bridge design should combine road, environmental condition, give enough consideration to agriculture, environmental protection requirements, reasonable planning, overall layout, technical and economic and environmental benefits,.

#### 3.1.3 Uniformity

Uniformity means the bridge of the relationship between the whole and partial wants to coordinate, avoid isolated. Uniformity mainly includes: one is the unity of the structure system, the second is the unity of the geometry size, three is the unity of the main structure and adjacent structures, four is the unity of the color.

#### 3.1.4 Continuity

Continuity is refers to the linear continuous and smooth, this is one of the important standards, roads and Bridges the linear aesthetics mainly including flat, vertical and horizontal aspects of continuity and the coordinated unification between each element. So as to ensure the continuity and flow of visual feeling, give people the beauty of a smooth.

### 3.1.5 Conciseness

Conciseness refers to the structure of the bridge in the line of concise and refined. For bridge structure is reasonable, concise, light, the parts relationship clear, clear, bridge line is concise, lively, strong, mutual coordination and reasonable coordination, to meet the demand of the visual features in modern transportation conditions and seek a kind of simple, natural and harmonious beauty.

### 3.1.6 Individuality

Individuality is a kind of style and characteristic. Different Bridges have different personality, it represents the different design concept, representing the designer style and level of the individual, more represents a different era, nation and region. If the bridge did not have the individuality, played down the value of her life and the meaning of existence.

## 3.2 Mountain City Bridges' Main Structural Forms and Key Problems

### 3.2.1 The Selection of Bridge Span

Girder span are the main factors influencing the structural internal force and displacement. the reasonable span can make the structure has good mechanical behavior and economic benefits. To determine the main-span of a long-span bridge, the first is fully familiar with the preliminary information, especially hydrology, geology, meteorology and shipping at bridge site, to determine the main controlling factors, such as the channel width and depth, water velocity, determine the location and the bridge piers, and then consider the construction convenience and feasibility, including construction method, construction period, etc.

### 3.2.2 The Selection of the Bridge Type

In addition to small and medium-sized Bridges, long span Bridges in mountainous city application is increasingly, and more complicated and typical. The main form of long-span Bridges are: arch bridge, suspension bridge, cable-stayed bridge and combination-bridge. According to the hydrological and geological conditions of bridge site, and the characteristics of the various bridge can choose a reasonable bridge type.

The Mechanics characteristics of arch bridge is, the bridge deck level of vertical load into part of the thrust, the bending distance of the arch greatly decreases, and the main arch under pressure, give full play to the masonry materials compressive performance. the advantages of arch bridge are: (1) have larger span ability, give full play to the performance of the masonry and other compressive materials; (2) structure is simple, mechanical clear concise; (3) various forms and beautiful. Arch bridge's faults: (1) the horizontal thrust of arch bridge have higher requirements for foundation, continuous arch bridge influence each other porous; (2) large span bridge's weight is bigger, and have higher requirements on construction technology and so on; (3) high building height is adverse to the stability

The advantages of the cable-stayed bridge are: small size of the beam body, Bridges spanning capacity is larger; Less restricted by clearance under the bridge and the bridge deck elevation; Wind resistance stability is better than suspension bridge; cable-stayed bridge don't need the concentration of anchorage of suspension Bridges structure and convenient for cantilever construction, etc. The downside is that it is many times statically indeterminate structure, design and calculation are complex; Cable and beam or connected to the tower structure is more complex; The construction of aloft work is more, and strict control of construction technology.

Suspension bridge, is through the cable tower suspension and anchor in cross-strait (or bridge) on both ends of the cable (or steel chain) as upper structure main bearing component of Bridges. The cable geometry is determined by the force balance condition, generally close to the parabola. From many derrick cable down, and the bridge deck crane, between the deck and derrick set stiffening girder, often with cable combination system, to minimize deflection deformation caused by live load. Because of suspension bridges can make full use of the strength of the material, and has the characteristics of materials provinces, light weight, the suspension bridge's across ability is biggest in all kinds of system, the span can reach more than 1000 metres.

In addition to the traditional bridge, the mechanical properties of rational utilization of beam, arch, cable, seek a bigger or more expressive modeling, spanning capacity and better economical efficiency, some combination of bridge structural system has appeared in the mountain city Bridges, such as beam-arch combination, cable-tower-beam combination, even cable - arch - beam combination, etc.

### 3.2.3 The Choice of Bridge Width

At present, as the growth of the traffic, bridge deck width is becoming more and more big. The wider the bridge and under the vehicle load, the greater the possibility of partial load. What's worse, when bridge deck is wider, the gravity load of structure is greater, this increases the consumption structure of material and make the

structure of the economy down. Especially Chongqing is under the complex traffic, how to decorate two male, rail transportation, how to improve the stability of the bridge and how to ensure the safety of the traffic, are the problems of bridge deck width to consider when we make the choice.

#### 3.2.4 The Estimating of Structural Mechanics

The key problem in concept design of structure mechanics is estimating. On the basis of the overall structure and the mechanical relation between points system, using the conceptual approximate estimation method, the structural system is often clear concept, qualitative, right to avoid the unnecessary tedious calculation in the late design phase and has good economic and reliability.

#### 3.2.5 Suspension Bridge and Cable-Stayed Bridge's Tower form and High Level of Design

That Choose bridge tower form to cooperate with the surrounding environment is a important step in the conceptual design. When the design we should notice reasonable, economic and beautiful. Partially cable-stayed bridge pylon structure form in the form of transverse to the bridge can be divided into single, double cylinder, three bar, H, and door, etc. Bridge tower is an eccentric compression member, so the design response to the cable tower's own strength, stiffness and stability, cable layout, girder of the bridge deck width, cross section form, infrastructure and the bridge of geology, terrain factors such as comprehensive consideration.

#### 3.2.6 The Seismic Conceptual Design and Wind Resistance Concept Design

The Bridge seismic concept design and wind resistance concept design throughout the design process, from the choice of bridge to bridge deck beam in the form of choice, we must consider the bridge seismic and wind resistance. Especially for the large span Bridges, seismic and wind resistance is especially important, this is also experience we pay a heavy price in the engineering practice.

### **4. The Type Selection Design of the Bridge Aesthetics by the Tve-River Bridge**

#### *4.1 The Simultaneous Introduction of Tve-River Bridge*

Chongqing Tve-riber Bridge engineering is located in the central business district (CBD) core, from the east gate of the Yangtze river bridge, Chongqing-middle-tunnel and thousands of portal jialing river bridge in Chongqing, the main line is 3.453 km. Tve-riber Bridge project is a rail transit line 6 river carrier and important passage through the yu-zhong peninsula. Tve-riber Bridge engineering combined with public transport mode, is the urban north and south through eastern Chongqing key node of urban comprehensive transportation engineering. Combination of Tve-riber Bridge engineering complex influence factors, including a busy waterway ChaoTianMen port and Marine operation, two rivers and high-grade waterway navigation requirements, the yuzhong peninsula, the core region of complex network relations, the jiangbei a cluster of tall buildings and the underground pipe network, Huguang guild hall and HongYa -hole history humanities construction, represents the characteristics of Chongqing Tve-riber Bridge overall urban style and features, etc.kat the same time, the complicated environmental factors and technical requirements of the complex interaction of composite Bridges and rail, and influence each other.Liangjiang bridge overall scheme for comprehensive environmental adaptation, and eventually build up a harmonious and unified whole design process. the locations of Tve-riber

Bridge show in Figure 1.



Figure 1. The locations of Tve-river Bridge

#### 4.2 Tve-River Bridge's Landscape Orientation

"mountain, water, unique urban" landscape is the symbol of mountain city of Chongqing, how many visitors are obsessed with time, become the pride of Chongqing people. The bridge near the Yangtze river and the Jialing river interchange, the natural landscape on both sides and planning of the overall style of bridge landscape coordination is put forward very high requirements for the bridge's design, how to play to the positive effect to improving urban landscape is the key point of the bridge landscape. The bridge in the unique regional characteristics determine the Liangjiang bridge must be a beautiful, harmonious, humility, balance, historical continuance and not lose the modern bridge structure, must be able to play with urban landscape, foil each other and must be able to take on a future international metropolis with its unique mission.

#### 4.3 The Type Selection Principle of Tve-River Bridge

##### 4.3.1 Attaches Great Importance to the Functional Requirements

East gate bridge and thousands of portal bridge project is the first phase of the rail line 6, first of all should meet the demand of the traffic function, considering all kinds of wiring schemes, fully realize the resource sharing, Tve-river Bridge engineering will become a city orbit transportation is given priority to, the road is complementary, consideration of pedestrian traffic integrated transportation solutions.

##### 4.3.2 Structure Safety and Feasibility

Design should take into account the project condition, project risk, the technical level of domestic construction and installation. Plan to demonstrate in detail, to create conditions for the smooth implementation of project; And considering convenience of practicality and maintenance.

##### 4.3.3 The Construction of Operability

Scheme of the design should fully consider the construction of structure, combined with the feature of the bridge, making reasonable construction scheme, as far as possible to reduce the construction cost, reduce the disturbance to the environment.

##### 4.3.4 Landscape Harmonious and Respect the Environment

The general conception in bridge design is the bridge should be in landscape effect reveals itself and blend in the surrounding environment, make full use of mature technology, handle the relationship between the bridge and the surrounding environment. In addition, a bridge in the design and construction process, should strengthen the environmental protection measures to minimize the impact on the environment.

#### 4.4 Two-River Bridge Scheme's Selection

##### 4.4.1 Suspension Bridge Scheme

Two Bridges in the rail transit tunnels along the yuzhong district a few main streets below arrangement. The tunnel is about 600 m long and a station in it. With a pair of main cable and considerable along the light rail tunnel beneath the lasso, connect the two Bridges in the main cable.tunnel and bridge main cable through the tunnel at both ends of conversion block to realize conversion, tunnel cable tension is a little higher than the maximum cable force of main cable design. tunnel cable through independent cavity is placed on the bottom of the light rail tunnel section, It both neither affect rail traffic, but also with the tunnel section construction at the same time, simple operation and cost savings. The characteristics of the solution are:

###### (1) Harmonious whole

Two modelling is similar arranged on both sides of the yuzhong peninsula, as if two streamers flying, hugging together the yuzhong peninsula and the two rivers and four shore integration into a harmonious whole.

###### (2) Unique structure form

The "sister bridge" of East gate and thousands of fellow door had the main cable connected together, make its real connection on structure as a whole. This structure is unique in the world.

###### (3) The influence of the minimum of two rivers and four shore scenery

"Sister bridge" bridge tower is located in the two rivers and away from the sides of the yuzhong district will not influence the yuzhong peninsula landscape constitute a conflict of skyscrapers and also can highlight contracted, atmospheric style bridge tower itself. At the same time control the bridge tower height in a reasonable scope, with the planned on both sides of the building, jiangbei mouth and nanshan landscape organically fuses in together.

###### (4) The influence of shipping of the Yangtze river and jialing river waterway minimum

Structure of suspension Bridges have large span capacity, the main tower is no longer on the river a bridge pier and fully meet the largest of the Yangtze river and jialing river navigation requirements, have minimum effects on the two rivers and waterways, at the same time reserved navigable conditions. What's more, No demolition wharf, resources and cost can be saved. The scheme of suspension bridge show in Figure 2

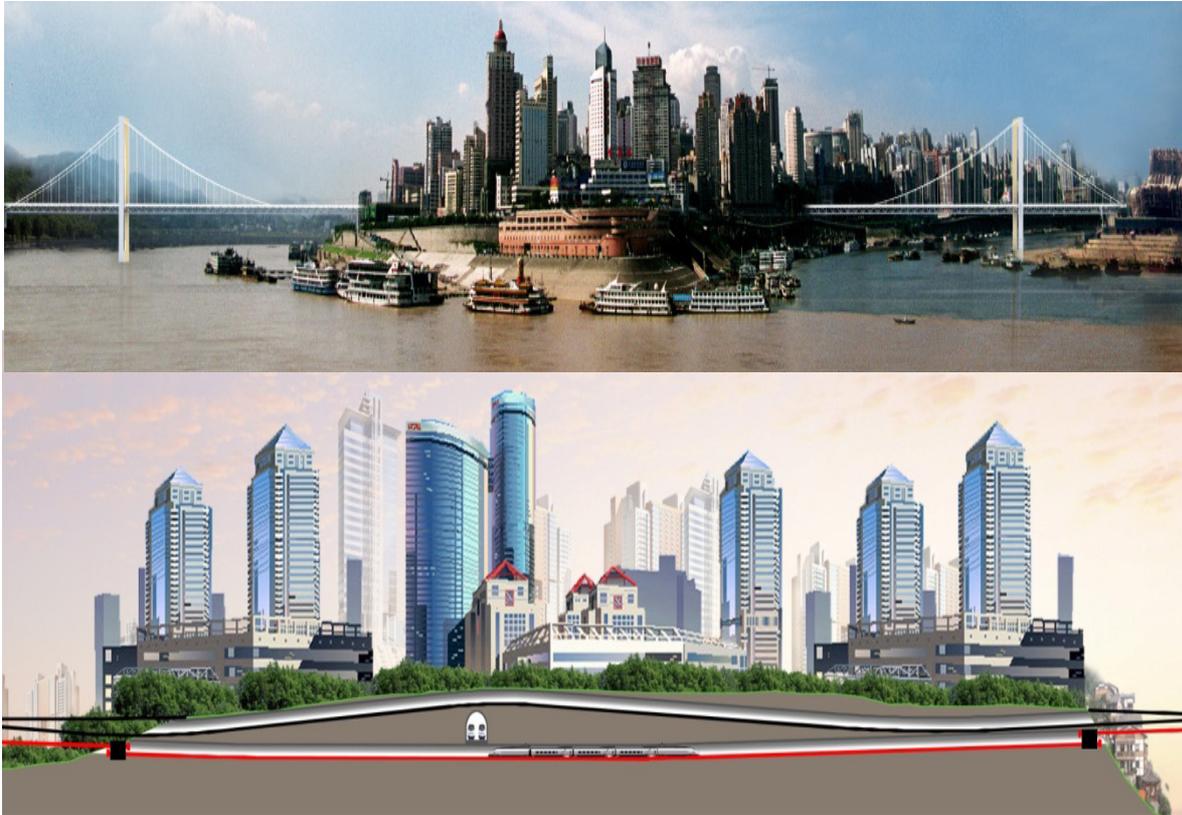


Figure 2. Suspension bridge scheme

#### 4.4.2 Part Cable-Stayed Bridge Scheme

East gate of the Yangtze river bridge and thousands of fellow jialing river bridge bridge scheme design make the two bridge as a whole, should be consistent in the modelling. After whole considering ,the east gate bridge with thousands of fellow gate bridge design become a two single cable plane thin cable system is part of the cable-stayed bridge, the east gate bridge using mainspan cable-stayed bridge is 445 m, thousands of fellow gate bridge using mainspan single pylon cable-stayed bridge is 312 m. The scheme of Part cable-stayed bridge scheme show in Figure 3.



Figure 3. Part cable-stayed bridge scheme

The main characteristic of this scheme are:

- 1) the two bridges, and the present situation of landscape are organic integration East gate bridge and thousands of fellow gate bridge in the two rivers and the sea from nanan district and jiangbei mouth to access the yuzhong peninsula, the two scenery of bridge design brings ups and downs rhythm of visual enjoyment, feel the junction of two rivers and open the majestic momentum, makes the heart born stirring.
- 2) the bridge tower modelling is novel and attractive Scheme of cable tower modelling is novel, gently beautiful curve outline the bottle shape outside the main tower of modelling, the internal line of olive leaf shape and outer contour bring out the best in each other, presents a simple, beautiful and full of modern art styles, and natural scenery liangjiang mouth perfect match. East gate bridge structure of the twin towers, thousands of fellow gate bridge in the form of single tower. twin towers and single tower are coordinated, and each has its own characteristics.
- 3) unique structural system is innovation and leading technology East gate bridge with thousands of fellow gate bridge is single cable plane thin cable suspension system structure, make full use of the main girder of circuit traffic required height, change the conventional cable-stayed bridge girders under only transfer the stress model to the influence of live load, make the main girder and cable joint structure under dead weight, reduce the number of cable, this is a very good solution to the barrier effect of dense cable system, make full use of to structure of main girder stiffness has a good economic performance. Reasonable structure to achieve the function, the harmony of economy and landscape on the same time.

#### 4.4.3 The Results of Scheme Selection

Two plans are excellent scheme which are adapted to the bridge site and the engineering characteristics, the concept design concept of innovation, has reached the advanced level. Suspension bridge scheme, by contrast, despite the modelling is more novel, more wonderful, because of considering the yuzhong peninsula, dense, anchorage arrangement is difficult, total cost is big, small vertical stiffness, beam Angle is bigger, rail transit operating conditions were some reasons, the final, the two-rivers bridge engineering adopted the technology

more reliable part cable-stayed bridge scheme The final option is show in Figure 4.



Figure 4. The final option

## 5. Conclusion

Bridge is passageway cross obstacle. Once the function of bridge construction make people ignore the traditional "beautiful" or "beautiful" in heart is unable to do. But as the bridge technique and technology constantly improve, people in the pursuit of a bridge, on the basis of safe, economic and durable, appearance of the bridge have a higher pursuit - bridge aesthetics. Bridge aesthetics is based on a macro beauty of structure, body beauty. This is the aesthetic structure on modelling, in a certain environment, the landscape Bridges reflect the relationship between people and landscape environment combining site, the degree of Bridges and environmental adaptation, directly affect the overall landscape aesthetic value. In bridge design, we should not only attaches great importance to the function of bridge construction design, but also should have innovation spirit, make the mountain city bridge satisfy function fully show its aesthetic characteristics at the same time, Let Bridges in mountainous areas with era characteristics in the city landscape.

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