

Chinese Ancient Timber Arch Bridges

中国古代木拱桥

Dr. Jie LIU **Associate Professor, Shanghai Jiao Tong University**
劉傑 博士 上海交通大学建筑系副教授

1. INTRODUCTION

1.1 “Qingming Festival on the River”

1.2 The Disappearance of Rainbow Bridge

1.3 Re-building of a Rainbow Bridge in Shanghai

1.4 Re-discovery of the Timber Arch Bridges



1.1 “Qingming Festival on the River”

It is a famous scroll painting from Song dynasty (960-1279AD) .
Drawn by Zhang Zeduan. Kept in Forbidden City Museum, Beijing.



The painting is 25.5cm high and 525cm long.



Bianhe Rainbow Bridge, Kaifeng City, Henan province
Built in 11th Century Length: 28.2m Width: 5.1m Net span: 19.5m



1.2 The Disappearance of Rainbow Bridge

In 1126, Bianjing was occupied by the troops of Jin Kingdom. Lin'an (now Hangzhou) became the new capital of Southern Song dynasty.

Bianjing was fading.

Rainbow Bridges disappeared.

This type of bridge has not existed in any other part of the world for a long time.

1.3 Re-building of a Rainbow Bridge in Shanghai

Time: 1999

Location: Jinze Town, 60 km west of Shanghai

Producer: NOVA of the U.S.

Team members: Tang Huancheng
Bashar Aitabba
Michael Altabba
Tom Peters
Chen Fuxiang
Etc.

The rainbow bridge is 15m long and 3.6m wide.

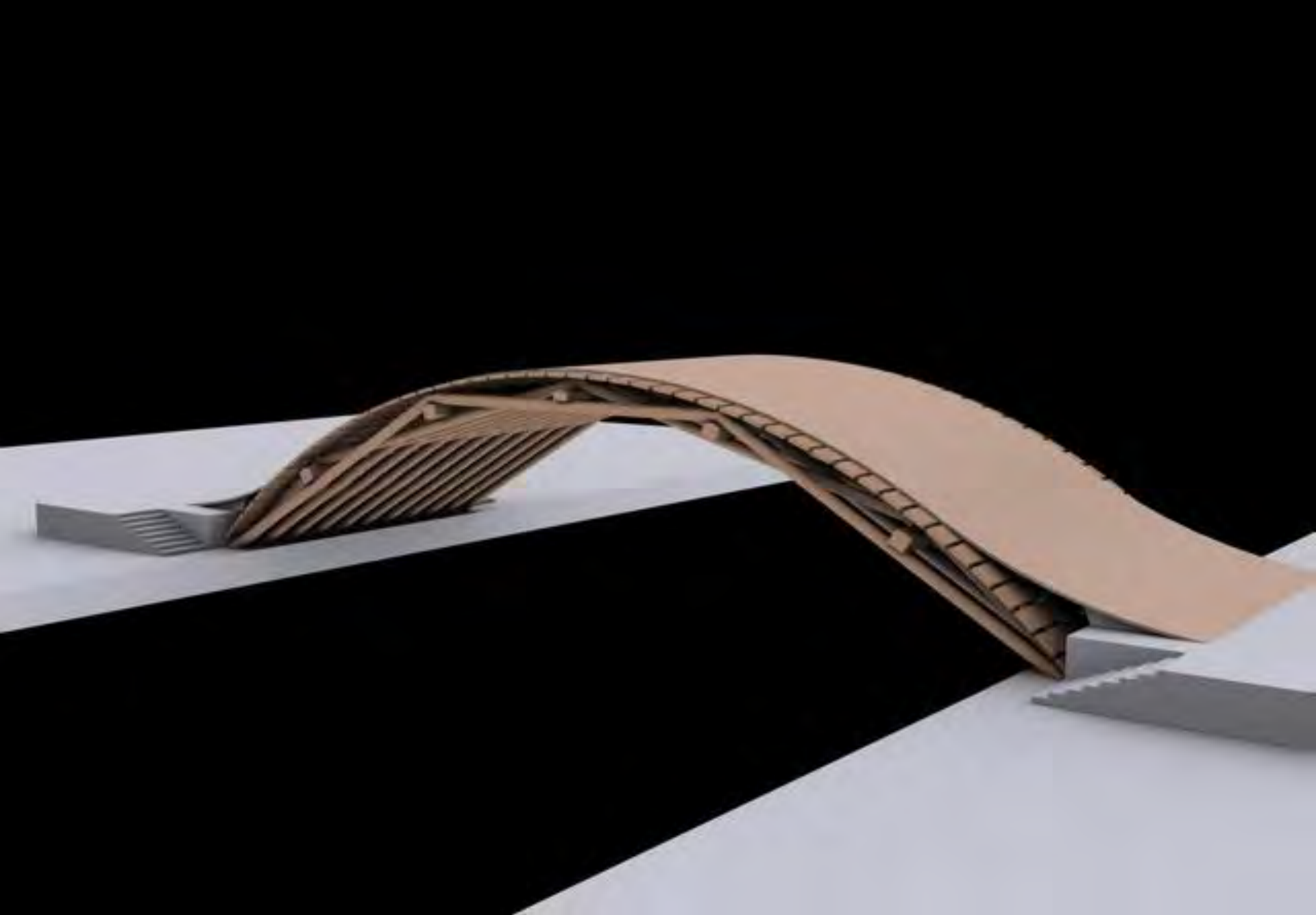




Rainbow Bridge, Jinze Watertown, Shanghai
Built in 1999 Length: 15m Width: 3.6m



Rainbow Bridge, Jinze Watertown, Shanghai



The structure of Rainbow Bridge, Jinze Town



Rainbow Bridge model in Jinze Town for
filmshooting of Bianshui Rainbow Bridge





The lifting equipment used by NOVA during the construction of Rainbow Bridge is manual hoisting.



Details of Rainbow Bridge model in Jinze Town





A Rainbow Bridge Structure constructed by Lehigh teachers and students was finished in May, 2011.





The Rainbow Bridge completion ceremony and opening ceremony in Lehigh on 28th May, 2011.





上海交通大學
SHANGHAI JIAO TONG UNIVERSITY

1.4 Re-discovery of the Timber Arch Bridges

In 1980's, Chinese researchers found ancient timber arch bridges in south Zhejiang and north Fujian Provinces. There were eleven (11) bridges recorded in the book “Technology History of Chinese Ancient Bridges”, edited by Mao Yisheng and was published in 1986.

Map of the Distribution of the Timber Arch Bridges



2. EXAPLES OF TIMBER ARCH COVERED BRIDGES

2.1 The Oldest, Newest, and Longest Bridges

2.2 largest-number of arch Bridge

2.3 Sister Bridges over Dongxi Stream

2.4 Isolated Santiao Bridge

2.5 The other Bridges



2.1 The Oldest, Newest and Longest Bridges

- The existed oldest timber arch covered bridge in 20th Century.
Yeshuyang Bridge in Taishun County, Zhejiang Province. Built in 1454
Demolished in 1965 due to the construction of a new road. 511 years old.

Rulong Bridge in Qingyuan is the oldest one now.

- The existed longest timber arch covered bridge.
Santan Bridge in Taishun County, Zhejiang Province. Net span: 42m, 5m longer than Anji Bridge, which is a stone arch bridge built in the 6th century and with the longest net span of 37.1 m.
Destroyed in 1950 by flood
Yangxitou Bridge and **Luanfeng Bridge** in Shouning County, Fujian Province

The existed newest timber arch covered bridge.

Actually, there are one or several new timber arch covered bridges will be constructed every year in China.



Rulong Bridge, Qingyuan County, Zhejiang province
Built in 1625 Length: 28.2m Width: 5.1m Net span: 19.5m





East Elevation of Rulong Bridge



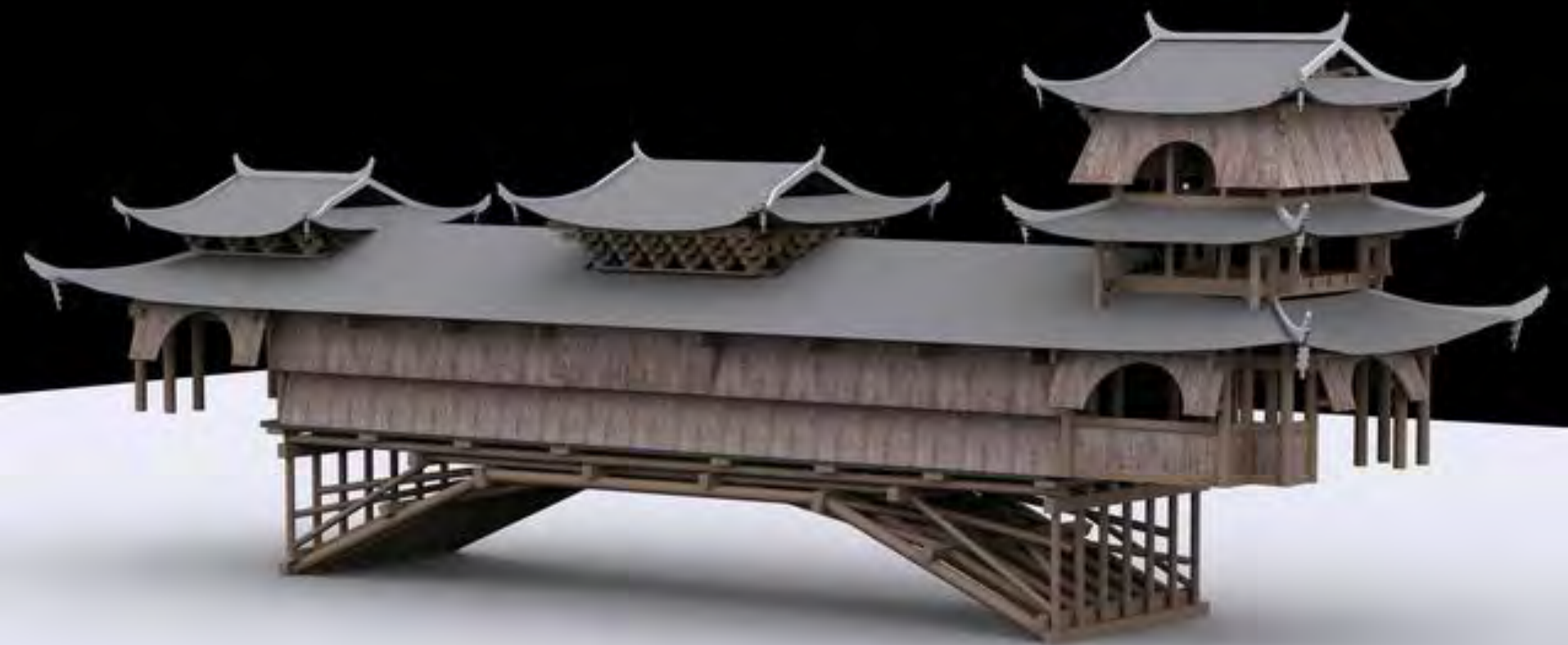


East Elevation of Rulong Bridge



Drum Tower(left) Bell Tower(right)

Rulong Bridge



3D Sculpt of Rulong Bridge

The existing longest timber arch covered bridge

Luanfeng Bridge in Shouning County, Fujian Province.

Built in 1800 Length: 47.6m Width: 4.9m Net span: 37.2m

Yangxitou Bridge in Shouning County, Fujian Province.

Built in 1967 Length: 50.5m Width: 4.96m

Net span: 36.56m



Luanfeng Bridge, Shouning County, Fujian province



Luanfeng Bridge, Shouning County, Fujian province



Yangxitou Bridge, Shouning County, Fujian province
Built in 1967 Length: 50.5m Width: 5.1m Net span: 37.6m





Yangxitou Bridge, Shouning County, Fujian province

2.2 The bridges with the largest number of arches

- **Wanan Bridge** in Pingnan County, Fujian Province.
Rebuilt in 1932 Length: 98.2m Width: 4.7m spans: 6
Max Span:15.3m Mix Span 10.6m
- **Qiancheng Bridge** in Pingnan County, Fujian Province
Rebuilt in 1820 Length: 62.7m Width: 4.9m spans: 3
Span:27m



Wanan Bridge in Pingnan County, Fujian Province



Wanan Bridge in Pingnan County, Fujian Province



Wanan Bridge in Pingnan County, Fujian Province



The interior of Wanan covered Bridge in Pingnan County



The elder and Children in the Wanan covered Bridge.



Qiancheng Bridge in Pingnan County, Fujian Province



上海交通大學
SHANGHAI JIAO TONG UNIVERSITY

2.3 Sister Bridges over Dongxi Stream

Names: **Beijian** Bridge and **Xidong** Bridge

Location: Sixi Town in Taishun County, Zhejiang Province



Xidong Bridge(left)

Beijian Bridge(right)



Beijian Bridge, Taishun County, Zhejiang province
Built in 1674 Length: 51.9 m Width: 5.4 m Net span: 29.0 m





Beijian Bridge with Snow in Winter



Xidong Bridge Taishun County, Zhejiang province
Built in 1746 Length: 41.7 m Width: 4.9 m Net span: 25.7 m





Xidong Bridge with Snow in tht Winter

2.4 Isolated Santiao Bridge

It looks pure, natural and graceful.
It is in perfect harmony with the nature.
Its structure is simple, clear and logical

Santiao Bridge, Taishun County, Zhejiang province
Built in 1843, Length: 32.0m, Width: 3.96m
Net span: 21.26 m





Santiao Bridge, Taishun County, Zhejiang province





Santiao Bridge, Taishun County, Zhejiang province

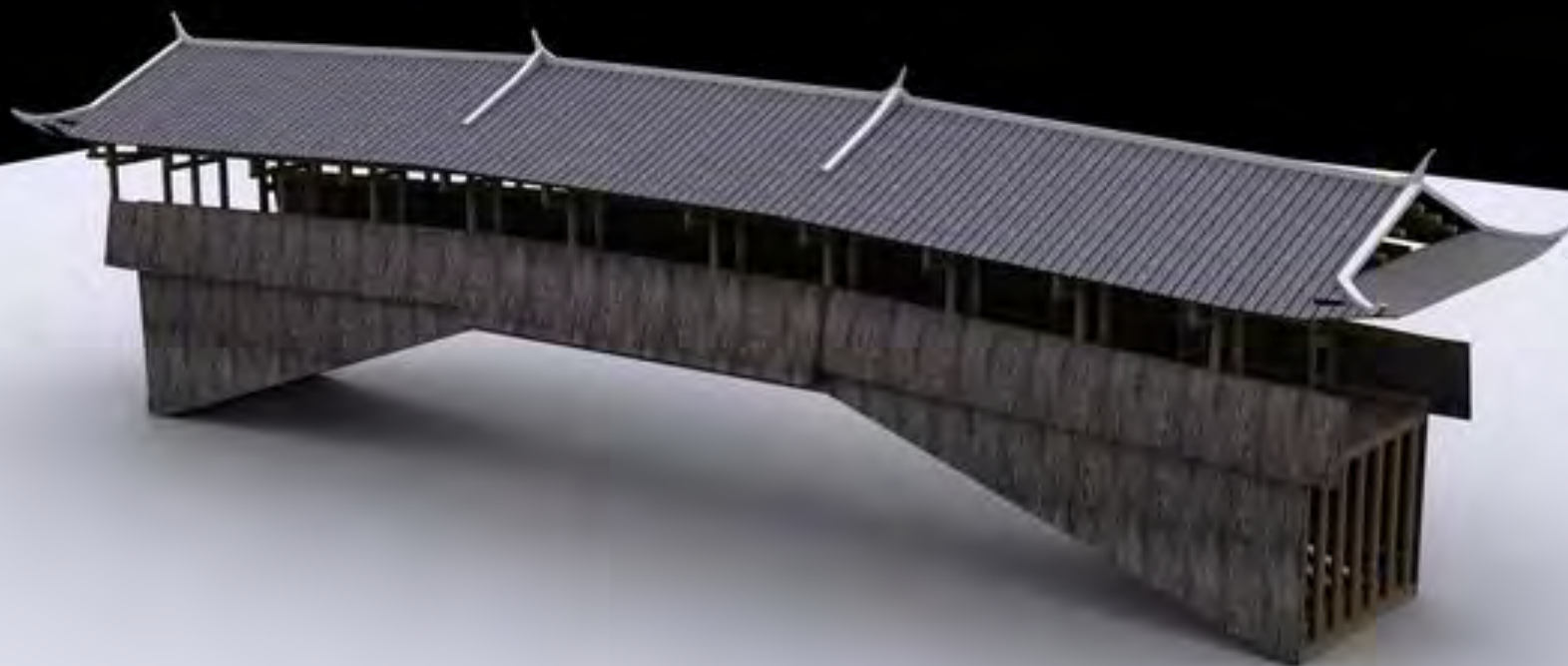


Santiao Bridge Taishun County, Zhejiang province
Built in 1843 Length: 32 m Width: 3.96 m Net span: 21.26 m





The Woven Timber Arch-Beam Structure of Santiao Bridge



3D Sculpt of Santiao Bridge

2.5 The other Bridges



Xianju Bridge Taishun County, Zhejiang Province
Rebuilt in 1673 Length: 41.83m Width: 4.89m Net span: 34.14m





Wenxingqiao Bridge Taishun County, Zhejiang Province
Built in 1857 Length: 46.2m Width: 5m Net span: 29.6m



上海交通大学
SHANGHAI JIAO TONG UNIVERSITY



Wenxingqiao Bridge Taishun County, Zhejiang province



上海交通大學
SHANGHAI JIAO TONG UNIVERSITY



Dachikeng Bridge Jingning County, Zhejiang Province
Rebuilt in 1923 Length: 36.35m Width: 5m Net span: 30m





Yingchuan Bridge Jingning County, Zhejiang province





Meichong Bridge, Jingning County, Zhejiang province
Rebuilt in 1912 Length: 35m Width: 4.5m Net span: 26.3m



Lanxi Bridge, Qingyuan County, Zhejiang province
Rebuilt in 1794 Length: 48.12m Width: 5m Net span: 36.8m





Lanxi Bridge, Qingyuan County, Zhejiang province



Guangfu Bridge, Pingnan County, Fujian province
Rebuilt in 1807 Length: 32m Width: 5m Net span: 26m





Guangli Bridge, Pingnan County, Fujian province
Rebuilt in 1774 Length: 30.5m Width: 4.5m Net span: 20.6m





Fushou Bridge, Pingnan County, Fujian province
Rebuilt in 1814 Length: 40.7m Width: 4.7m



Longdang Bridge, Youyang County, Chongqing City
Rebuilt in 1871 Length: 32m Width: 4m





Tongle Bridge, Taishun County, Zhejiang Province
Rebuilt in 2005 Length: 33m Width: 5.2m





Tongle Bridge, Taishun County, Zhejiang Province



上海交通大学
SHANGHAI JIAO TONG UNIVERSITY



www.langqiao.net

Caifeng Bridge, Yunlong County, Yunnan Province Built between 1622-1644 Length: 33.3m Width: 4.7m Net Span: 27m



上海交通大學
SHANGHAI JIAO TONG UNIVERSITY



Caifeng Bridge, Yunlong County, Yunnan Province





Yezhujing Bridge, Tengchong County, Yunnan Province
Rebuilt 1776 Length: 30m Width: 4.7m Net Span: 27m



Yezhujing Bridge: appearance (left) interior (right)



Tongjing Bridge, Yunlong County, Yunnan Province
Rebuilt 1771 Length: 40m Width: 4m



上海交通大学
SHANGHAI JIAO TONG UNIVERSITY



Jinzao Bridge Pingnan County, Fujian Province
Rebuilt in 1948 Length: 41.7m Width: 4.8m Net span: 32.5m





Red Army Bridge Taishun County, Zhejiang Province
Rebuilt in 1954 Length: 39m Width: 5m Net span: 32.9m





Red Army Bridge Taishun County, Zhejiang Province



Shouchun Bridge, Shouning County, Fujian Province
Rebuilt in 1870 Length: 19.6m Width: 4.2m Net span: 12.4m





Huangshuichang Bridge Qingyuan County, Zhejiang Province
Rebuilt in 1872 Length: 54.3m Width: 4.9m Net span: 17.45m





Baling Bridge, Weiyuan County, Gansu Province
Rebuilt in 1934 Length: 40m Width: 4.8m Net span: 29.5m





Baihe Bridge, Jingning County, Zhejiang Province
Rebuilt in 1888 Length: 32.3m Width: 4.8m Net span: 23.9m





Longtan Bridge, Jingning County, Zhejiang Province
Rebuilt in 1929 Length: 21.2m Width: 3.8m Net span: 15.2m





Houkeng Bridge, Qingyuan County, Zhejiang province
Rebuilt in 1884 Length: 36.2m Width: 5.45m Net span: 28.5m





Xuezhai Bridge, Taishun County, Zhejiang Province
Rebuilt in 1857 Length: 51 m Width: 5.2 m Net span: 29 m





Zhangkeng Bridge, Shouning County, Fujian Province
Built in 1828 Length: 40m Width: 5m Net span: 33.4 m





Banluting Bridge, Qingyuan County, Zhejiang Province
Built in 1917 Length: 28.8m Width: 4.9m Net span: 21.2m



Chengshui Bridge, Taishun County, Zhejiang Province
Built in 1942 Length: 15m Width: 4.6m Net span: 11.2m



3. WONDERFUL STRUCTURES OF BRIDGES

3.1 Woven Timber Arch Bridge— Special
Structure of Bian-He Rainbow Bridge

3.2 Woven Timber Arch-Beam Bridge— Special
Structure of Timber Arch Lounge Bridges



3.1 Woven Timber Arch Bridge

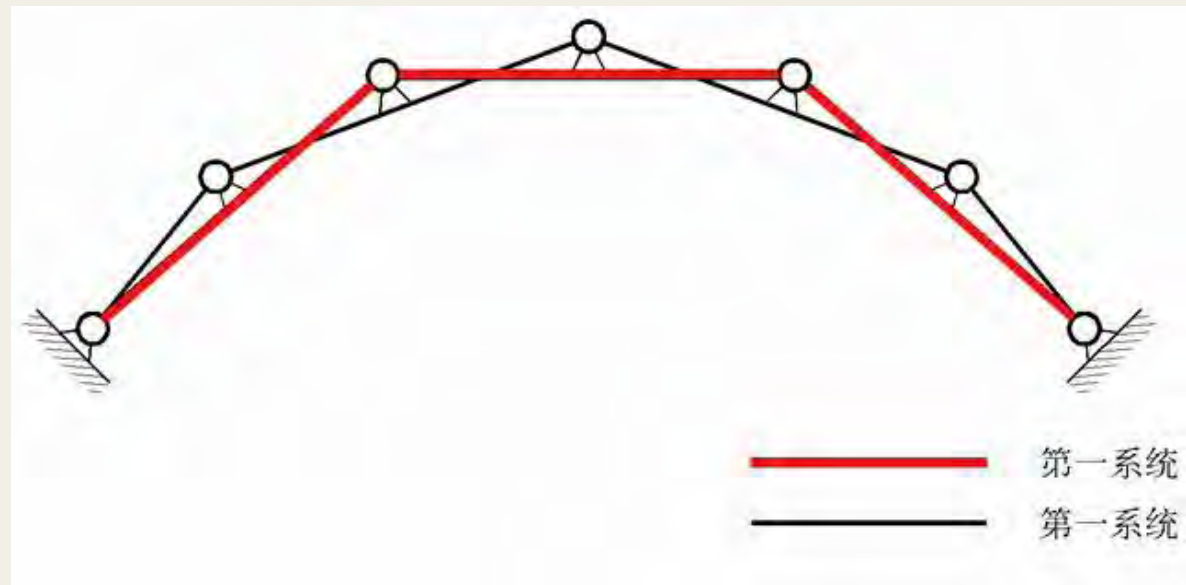
– Special Structure of Bian-He Rainbow Bridge

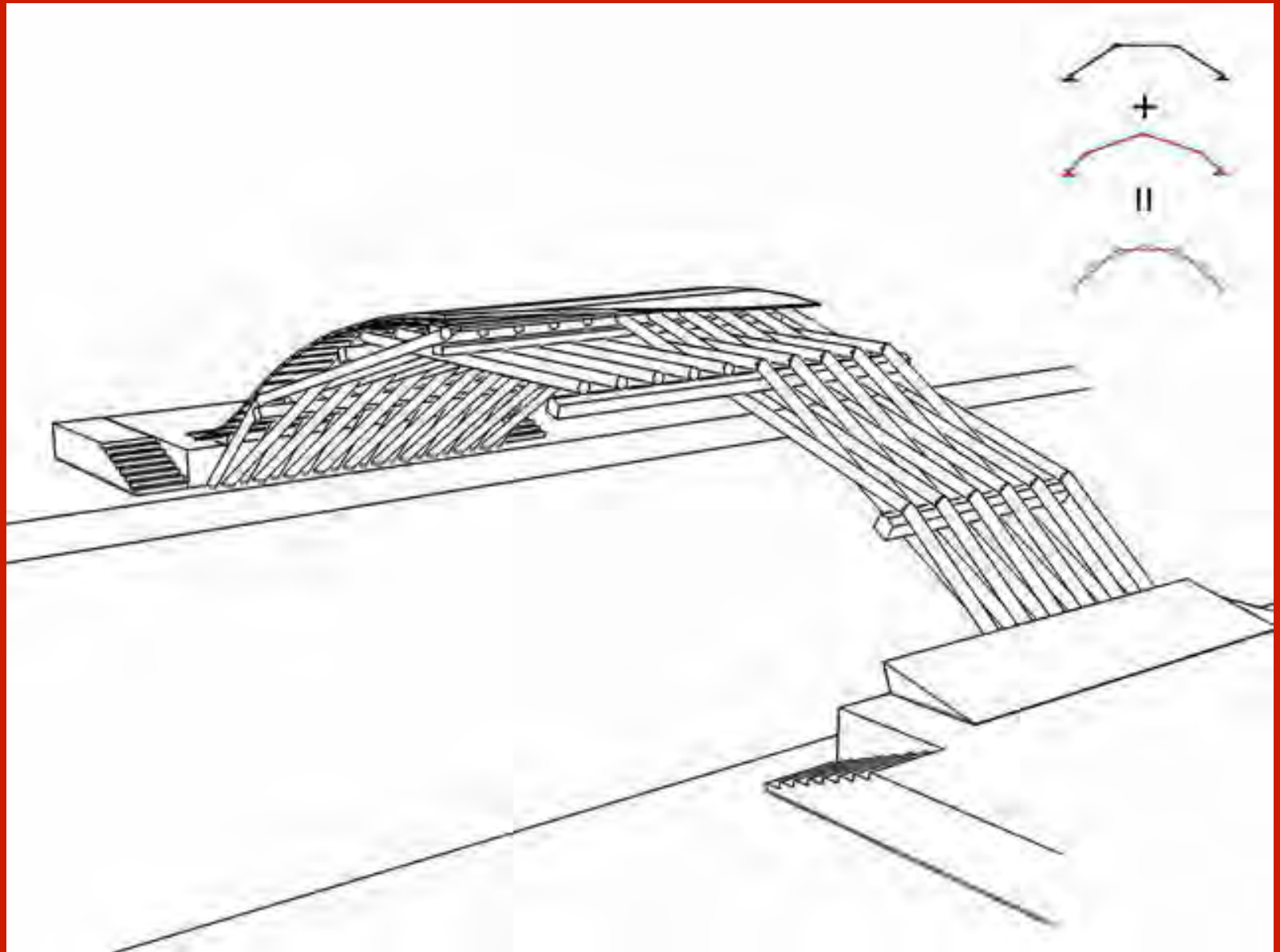
The structure of Rainbow Bridge was composed of

3-segment frames

4-segment frames

transverse girders





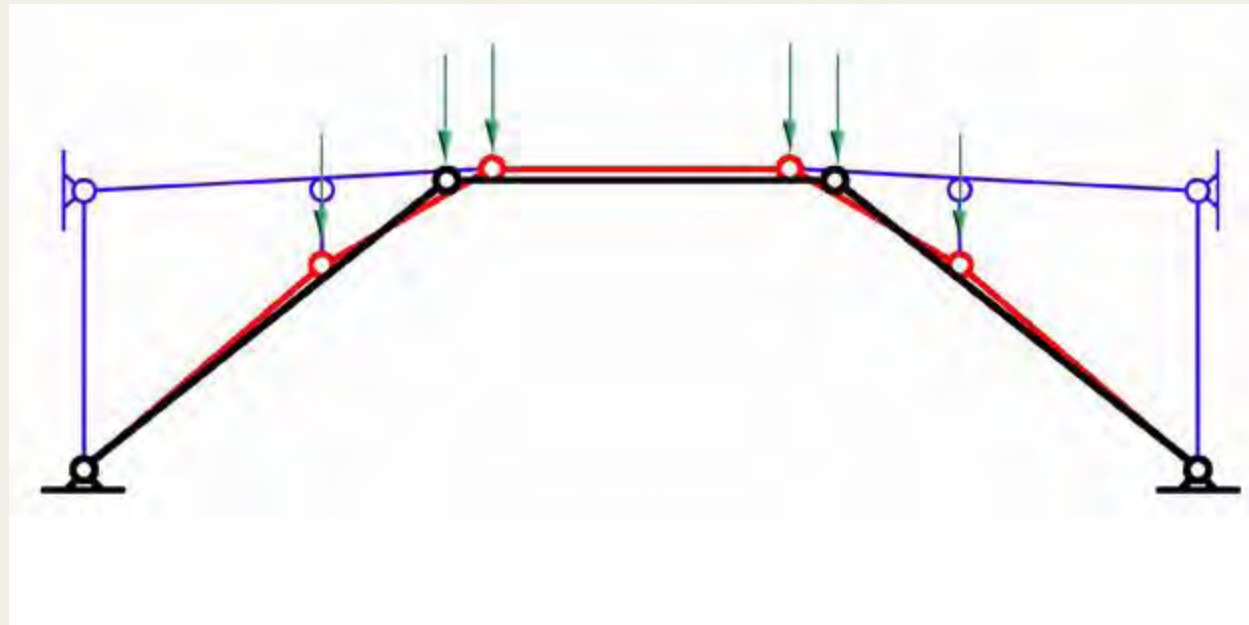
3.2 Woven Timber Arch-Beam Bridge

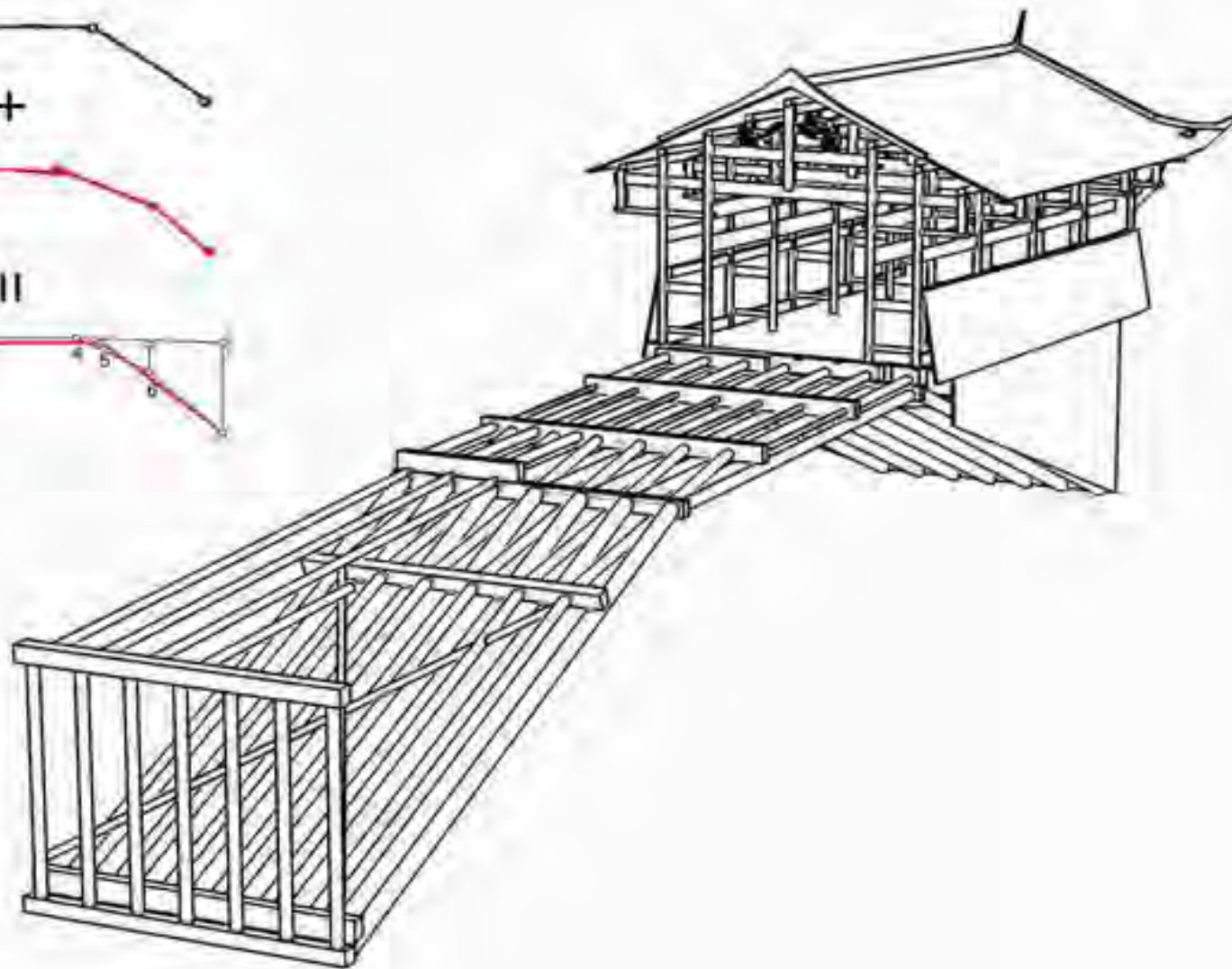
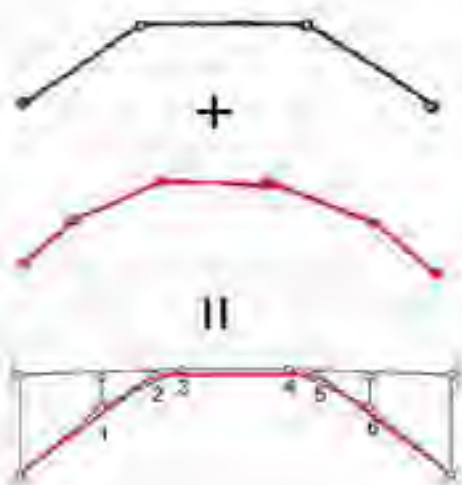
–Special Structure of Timber Arch Lounge Bridges

3-segment frames

5-segment frames

transverse girders





4. HOW TO MAKE A TIMBER ARCH COVERED BRIDGE

- 4.1 Selecting bridge location
- 4.2 Building bridge abutment
- 4.3 Crosslink bridge arch
- 4.4 Paving bridge deck
- 4.5 Erecting bridge house



Clay Sculpter The First Step: Selecting bridge location





Clay Sculpter The Second Step: Building bridge abutment





Building bridge abutment and erecting frame and columns in the water(a kind of manual hoisting)





Construction of SanJieMiao (the 3 segment frame of the structure)



Horizon checking





Construction of San Jie Miao, horizontal Miao
(the 3 segment frame of the structure)



Setting up Wu Jie Miao, acclivitous Miao
(the 5 segment frame of the structure)





Finishing timber arch frame woven structure





Clay Sculpter: crosslink bridge arch





Arch frame system after construction completion



Clay Sculpter: paving bridge deck





Clay Sculpter: erecting bridge house





Erecting bridge house



5. CONCLUSIONS AND DISCUSSION

5.1 Conclusions

5.2 Discussion

5.1 Conclusions

- Bian-He Rainbow Bridge existed in the Song dynasty and disappeared later due to the fading of Bianjing.
- Rainbow Bridge was a woven timber arch bridge.
- There are around hundred timber arch covered bridges in the Zhejiang and Fujian provinces of China. Their structures are similar to Rainbow Bridge.
- Timber arch covered bridges are woven timber arch-beam bridges.
- The arch covered bridges in the Zhejiang and Fujian Provinces possess tremendous amount of historical, cultural, technological, and economical significance and value. They are the treasures of China and cultural heritages of the world.

5.2 Discussion ——The Relationship Between Rainbow Bridge and Timber Arch Covered Bridges

- **Assumption 1:** the Rainbow Bridge is the original root and timber arch covered bridges are its successors.
- **Assumption 2:** The Rainbow Bridge and the likes, and timber arch covered bridges were developed independently and concurrently. Or the former was the successor of the latter.
- **Reason of Assumption 2:** there exist hundreds of different kinds of bridges in Zhejiang and Fujian Provinces, from very simple beam bridges to complicated arch bridges. It seems that the timber arch covered bridges were developed gradually step by step in the local area.





Simply Supported Beam Bridge





Continuous Beam Bridge with Pier



Beam Bridge with Inclined Supports



Pre-Woven Timber Arch-Beam Bridge



Woven Timber Arch-Beam Bridge





Pre-Woven Timber Arch Beam Bridge





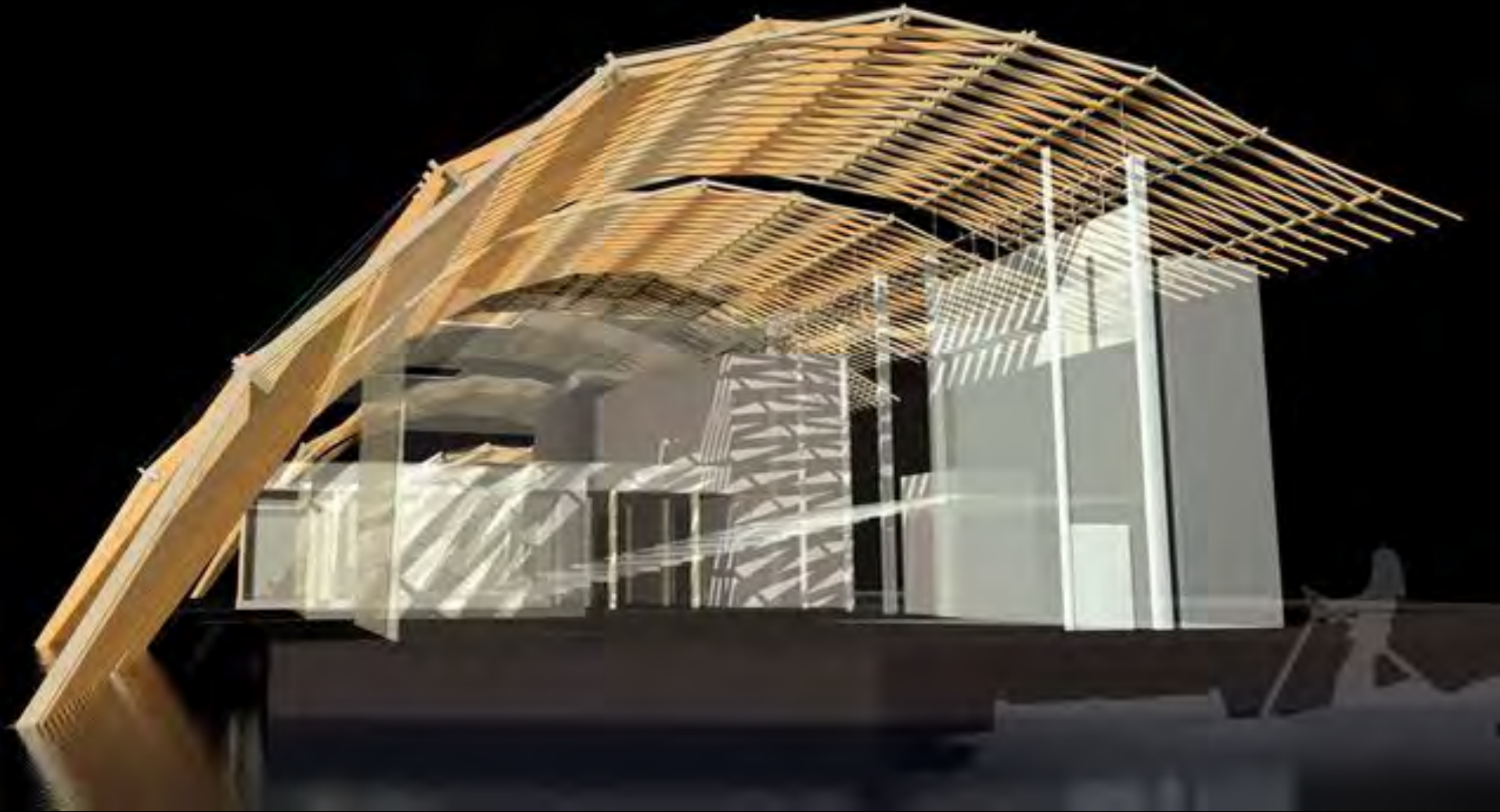
Woven Timber Arch Bridge



5.2 Discussion —— Why the “Woven Timber” Technique Has Not Been Applied to the Buildings?

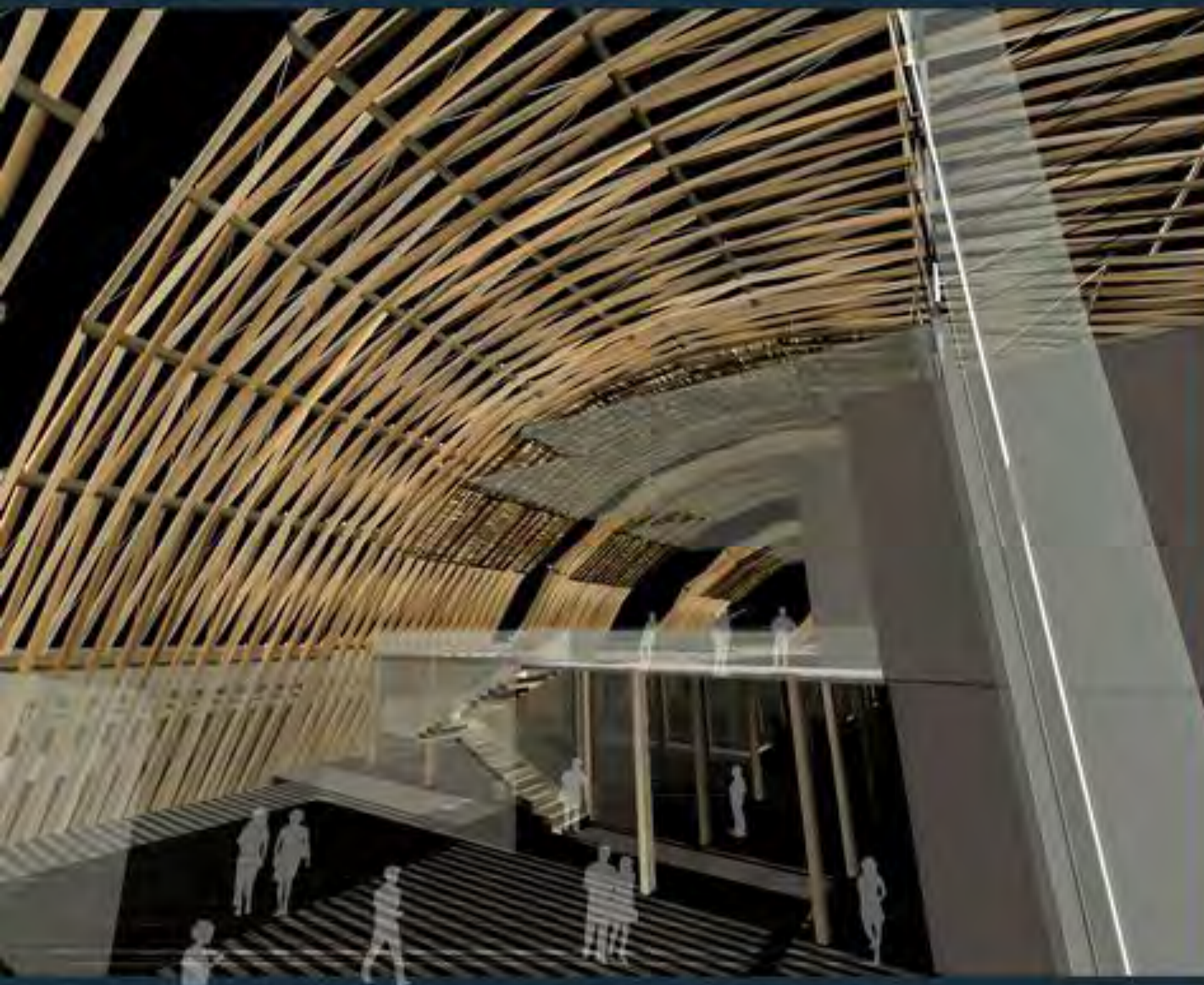
- The span of woven timber structure can reach at least 50 meters. If it were applied, a hall with several thousand square meters floor space could be built without any columns. How great this would be!
- Structure plays an important role in the form of the architecture. Large dome-shape architecture can be formed with a series of arches connected around the circumference. It would have been a real revolution in the ancient Chinese architecture. However the arch technology was never excelled to this application for over 900 years of history. **What are the reasons?**

2003-03 ACSA (Association of Collegiate Schools of Architecture) /WPC
(Wood Products Council) **STUDENT DESIGN COMPETITION**



Rainbow over the water town

RAINBOW OVER THE WATER TOWN



View from the lobby, illustrating the liner space arrangement, and roofs with adjustable louvers.



Natural ventilation system



In winter, the adjustable louvers are left open. Sunlight can pass through and heat up the entire building.



In summer, the closed louvers become heat insulation with two functions – reflecting the sunlight and scattering the interior heat.



Public space Private space
Exhibition Galleries Vertical circulation

Questions?

Contact Information

Jie LIU

Email: jackliu@sjtu.edu.cn

