RESEARCH ON THE NEW FERRIS WHEEL STRUCTURE FORMS IN
CHINA

Ming Ma 1*, Junjin Liu 1 and Tao Song 1

1 China Academy of Building Research, Beijing, China
E-mails: maming@cabrtech.com liujunjin@cabrtech.com songtao@cabrtech.com

Abstract: Ferris wheels have been the landmark of many cities. More and more people worked hard to
design unique Ferris wheel. The progress on the Ferris wheel in China is introduced and some thinkings
on the core definition of Ferris wheel are discussed, too. As representative works, the design details of
Tianjin Eye and Weifang Bailang river bridge wheel are introduced in the paper. The Weifang Bailang
River Bridge Wheel is a totally new kind wheel. In this project a fixed steel wheel is used instead of the
traditional rotating wheel. By the added driving system, the cabins carry the tourist to rotating around
the wheel. A space structure was used as the wheel and displayed more architectural expressions. The
complex and large slew bearings were saved. More design details and analysis results are introduced
in the document, too. In the end of the document, the prospects of the Ferris wheel are also given out.

Keywords: Ferris wheel; Structure form; Fixed wheel

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1 INTRODUCTION

Ferris wheel is an amusement facility to bring the peoples to rotate around a certain axis. The great Ferris wheel is always the most attractive building for the tourists. The first modern Ferris wheel was built in Chicago in 1893, the diameter is only 76.2m. Since the Ferris wheel is beauty and attractive, many cities competed to build higher and larger Ferris wheels. In 1900, a Ferris wheel was build in Paris, with a height of 100m. The world wars destroyed many Ferris wheels and barriered the development of the Ferris wheel.

Till 1989, the Ferris wheel reached the same level of 1900, and the London Eye built in 2000, which is 135m high and 121m in diameter. The complete of London Eye stimulated the world a trend to build higher Ferris wheels. Since then many Ferris wheels, higher than 100m, were built. Now the largest Ferris wheel in the world is the High Roller in Las Vegas, completed in 2014, reached 167.6m high and 158.5m in diameter.

In China, the first Ferris wheel was built in 1980s, which was only 55m high. As the people’s requirement increased with the economic development, new and greater wheels appeared. In 2002, a 108m tall Ferris wheel was completed in Shanghai. In 2006, the Nanchang star, 163m high and 153m in diameter, was built. It is also the tallest Ferris wheels in China till now.

Generally, the steel space truss is used for the support structure (Fig.1 (a)). In some Ferris wheels, huge bars and cables are used to simplify the support structure, such as London Eye or High Roller. Cable, trusses are the main structure styles for wheel structure. While building a cable support wheel, some temporary trusses are also required in the build process. So, in the design of some Ferris wheel, some trusses are kept in the wheel as the support structures. Fig.
1 shows the typical projects of different structure styles. Table 1 listed some of the most attractive Ferris wheels.

![Typical Ferris wheel structure styles](image)

(a) Truss wheel + Space truss support (Cosmo Clock 21, Yokohama, Japan)
(b) Cable wheel + Bars support (High Roller, Las Vegas, USA)
(c) Cable + Truss wheel + Space truss support (Shanghai Jinjiang Ferris wheel, China)

<table>
<thead>
<tr>
<th>NO.</th>
<th>Name</th>
<th>Location</th>
<th>Completed</th>
<th>Height (m)</th>
<th>Diameter (m)</th>
<th>Structure Style</th>
<th>Note</th>
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<tr>
<td>1</td>
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<td>Yokohama, Japan</td>
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<td>107.5</td>
<td>112.5</td>
<td>Wheel: Truss Support: space truss</td>
<td>The tallest of the year</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Rebuilt, 1999</td>
<td></td>
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<td>2</td>
<td>Sky Dream Fukuoka</td>
<td>Fukuoka, Japan</td>
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<td>120</td>
<td>112</td>
<td>Same to NO. 1</td>
<td>The tallest of the year</td>
</tr>
<tr>
<td>3</td>
<td>London Eye</td>
<td>London, British</td>
<td>2000</td>
<td>135</td>
<td>121</td>
<td>Wheel: Cable Support: Cable and Bars</td>
<td>Innovative structure design</td>
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<td>Star of Nanchang Singapore Flyer</td>
<td>Nanchang, China</td>
<td>2006</td>
<td>160</td>
<td>253</td>
<td>Same to NO. 1</td>
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<tr>
<td>5</td>
<td>Star of Nanchang Singapore Flyer</td>
<td>Singapore</td>
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<td>150</td>
<td>Same to NO. 3</td>
<td>The tallest of the year</td>
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<td>Tianjin Eye</td>
<td>Tianjin, China</td>
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<td>110</td>
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<td>High Roller</td>
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<td>167.6</td>
<td>158.5</td>
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<td>Weifang, China</td>
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<td>Space Structure</td>
<td>Fixed wheel the Inovative Ferris wheel design Over a bridge</td>
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<td>9</td>
<td>Melbourne Star</td>
<td>Melbourne, Australia</td>
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<td>120</td>
<td></td>
<td>Wheel: Truss Support: Bars</td>
<td>Huge truss support the wheel.</td>
</tr>
</tbody>
</table>

Table 1: Some famous Ferris wheels list

Different Ferris wheel adopted different structure system, and the form of the structure decided the architectural style of the Ferris wheel. To be an attractive Ferris wheel, the support structure and the wheel structure should be harmonious and innovative, such as London Eye. In China, designers also tried a lot to give out some special things.
2 TRYING ON THE HYBIRD OF THE FERRIS WHEEL AND OTHER BUILDINGS

In the most time, we can find the Ferris wheels in the amusement parks. The London Eye made the Ferris wheel a scenic spot. In China, designers tried to combine the Ferris wheel and other buildings to get better effects.

2.1 Tianjin Eye

In 2003, Tianjin city government wanted to enhance the environment along the Haihe River, and some bridges were planned. Kawaguchi gave out his Ferris wheel scheme for the Cihai bridge project. In the scheme, a Ferris wheel was designed upon the bridge. At first, the scheme aimed to build a cable-stayed bridge and add a wheel at the cable tower. More technical problems were given out in the following designing, and the scheme was revised for several times.

China Academy of Building Research (CABR) and the Tianjin Municipal Engineering Design & Research Institute led the design of this project and developed this scheme. In the final design, the Ferris wheel and the bridge are separated structurally, and the Ferris wheel was built upon the bridge. The bridge has 2 decks. The top deck split to 2 parts for the wheel, and the peoples get into the capsule from the bottom deck. Fig.2 and Fig. 3 shows the photo and the vertical view. This project was completed 4 years later and was called Tianjin eye.

Tianjin Eye is a success project in the urban renewal. The complete of the Ferris wheel makes this area the hotspot of Tianjin. Modern styles are added to this traditional area, and more chances were gotten in this area. Since the Ferris wheel were put into operation, millions of
people were attracted there. In the weekend, the queue for the wheel can be longer than 1 kilometer.

Traditional cable structure is used for the wheel, and the inverted Y-type frame system are used for the support structure. No bars or cables are used to help the support structure, which is different from most of the Ferris wheels and forms a unique architectural effect.

Different from the space truss or cable and bars support structure, the support structure of Tianjin Eye works similar to the gabled frame system, the columns and the main spindle bear more bending moment than the tradition space truss support. The section of the inverted Y-type frame is □4000×3500×40, and the section of the main shaft reaches φ2800×60. To drive the wheel, the diameter of the bearing at the outside of the main spindle reaches 3444mm, which brought some troubles in the manufacture. Because of the high manufacture precision and high-quality requirements, few factories can produce these kinds of bearings. The construction company casted more than a year to find factory and brought those to Tianjin[1][3].

2.2 Ferris wheel on top of buildings

Fig.4 is Liaocheng Ferris wheel. In the design of an administrative business center, an idea was raised that is to add a Ferris wheel in the middle of 2 towers. The Ferris wheel is 130m high, and the diameter of the wheel is 105m. Both cable and truss are used in the wheel structure. It’s a successful try, The Ferris wheel and the building are looked harmonious architecturally, the Ferris wheel seems to grow up from the building naturally. Now this building and the Ferris wheel have become the landmark of this city [3].

Figure 4: Photo of Liaocheng Ferris wheel

Figure 5: Ferris Wheel on the Roof of a Shopping Mall
Fig. 5 is another try. A small Ferris wheel was built at the top of a shopping mall. Nowadays the traditional shopping malls changes themselves to commercial complex. The entertainment is a important part of the complex. In Shanghai, a Ferris wheel was added and attracted many peoples.

3 RESEARCH ON THE NEW STRUCTURE FORM OF FERRIS WHEEL DESIGN

After completed the Tianjin Eye, discusses continued. A giant Ferris wheels, is not only a giant structure, but also a giant equipment. The structure support itself and the equipment make itself rotate. Considering the dual attribute, the following problems are nonnegligible while design a Ferris wheel:

1) The higher a Ferris wheel is, the larger the bearing is required. The main shaft is the structure bears the weight, wind load, prestress load and the seismic actions of the wheel structure. The bearings are key parts, that fixed outside the main shaft, transferring the load from the wheel structure to the main shaft and make the wheel rotatable.

In the Tianjin Eye, the bearing’s size is 3.444m and in High Roller, it’s 2.3m. Design and manufacture such a bearing cast more when the size of the wheel increases.
2) As the Ferris wheel runs, the bearing wears out every day. When the Ferris wheel completed, the bearing is irreplaceable. The bearing’s working condition depends on the precision installation and the carefully maintains. If the bearing is bad matched, the wear will be aggravated. Though there are successful examples, there are failure examples, too. The owner can’t help to worry about those problems.

3) Almost all the Ferris wheel looks alike. The basic structure forms can be found in Fig.1. Everyone, who want to build a new Ferris wheel for a remarkable project, required to design a distinctive wheel.

Let’s return to the definition of the Ferris wheel. A definition about what is a Ferris wheel was brought out. We believe that the Ferris wheel’s kernel function is to bring persons rotate slowly in a circle track and enjoy the scenery in the cabin, so if wheel rotate or not is not the most important thing. In the conceptual design of the Bailang River Bridge Ferris wheel, this innovational idea and was accepted. This Ferris wheel was completed before the Spring Festival, 2018 and opened in May 16th, 2018.

3.1 Design brief of Bailang River Bridge Ferris wheel

The Bailang river bridge locates in Weifang, Shan Dong province, China, and is about 500m long. A Ferris wheel is designed in the middle of the bridge. Different from the traditional Ferris wheel, a fixed steel ring is used as substitute for the rotatable wheel, driving devices are added to cabins to enable them walking along the tracks, rotating around the wheel. The drive principle is the same to the train. 30 minutes are needed for tourist rotated around for a circle.

The front elevation view and the 3d view of the wheel can be found in Fig.6. The diameter of the wheel is 125m, and the height is 144.6m. Many schemes have been compared and finally a space structure with diamond grid is used as the main structure of the wheel. This diamond grid and the inclined columns makes the wheel looks like that a Chinese dragon is flying to the shy from the river. The grid is formed by the following mathematic manipulation.

First let’s form a diagonal grid with a length of 80m and width of 4m(Fig.7, (a)), then roll this grid into semicircular cylinder. Mirror this semicircular cylinder to form a whole cylinder.
The next step is to do a linear transformation as (c) in Fig. 6, the diameter in the middle of the cylinder is 15m, and 5m in the 2 ends. The last step is to map the top straight line in (c) to a circle of 125m in diameter, then we get the final grid of the wheel. When we cut the wheel with a line from the center of the circle, we get a circle.

Steel pipes are used for the wheel, and the diameter of the pipes ranges from 351mm to 914mm. An inner chord with a diameter of 914mm is laid out. For the convenience of laying the tracks around the wheel, 2 outer chord pipes, spaced by 2.25m, with a diameter of 630mm are used. To make the wheel stand steadily, 12 inclined columns, with a diameter of 1.5m, are used to support the wheel and stand on the bridge pier. 12 stable cables are used to keep the wheel’s stability. Limited by the size of the bridge space, the space left for the passing of the cabins 4.9m.

3.2 Structure Analysis

The main load of the Ferris wheel is dead load, crowd load, wind load, temperature action and seismic action. As an amusement device, the crowd load is limited, only 10 persons are allowed in every cabin. The structure of this Ferris wheel can be analyzed as a common steel space structure. Since the Ferris wheel is built in the middle of a river, pile foundations are used in this project and simulated in the structure analysis model. Fig. 8 shows the structure analysis model.

According to the analysis, while the wind loads are applied, the horizontal deformation can reach 927mm, and when the wind speed is 15m/s, which is the maximum wind speed for the opening of Ferris wheel, the deformation is 201mm. The horizontal deformation caused by the seismic action is only 371mm. Since the weight of the structure, tracks and cabins are relatively slight, and the space structure effect, the displacement of the wheel under the deadload and crowd load is only 70mm.

![Figure 8: Analysis Model of Bailang River Bridge Wheel](image)

Another favorable factor for the fixed Ferris wheel structure, is that when we do fatigue analysis, only the passing of the cabin and changes of the number of person can cause the stress amplitude, which is so small that can almost be omitted. Compared with the traditional Ferris wheel, the rotate of the wheel can produce high stress amplitude in the connection joint of the cable and the rim, more attentions should be paid in the design.

3.3 Structure joint design

From the layout, we can find that most of the structure joint are formed by 4 connected pipes, and in most conditions, these pipes’ sections are not the same. The joint is formed by 2 vertical interacted eclipse shape steel plates, and the pipes welded at the plates.
The joints should be calculated to meet the requirement that the spacings between the interacting lines are the minimum. To ensure the safety, all the joint in the Ferris wheel are analyzed. The Fig.9 (c) shows the stress nephogram of a joint.

At the connection joint of inclined column and the wheel structure, many structure bars are connected. To solve this problem, cast steel joint are used for both aesthetic reason and mechanical behavior reason.

### 3.4. Construction

To build such a Ferris wheel, we should ensure the safety and the installation accuracy during the construction. To keep a rational construction speed is also very important. While building the Bailang River Ferris wheel, a temporary structure is used for the safety and assemble (Fig.10 (a)).

To speed up the construction, structure assemble units are assembled on the ground to keep high accuracy and erected to the high place. Only few connection joints need to be welded at the high place.

### 4. CONCLUSION

Though the Ferris wheel has been invented for more than 100 years, people always want to build something new. In the design of Tianjin Eye and Weifang Bailang River Bridge Ferris wheel, the architecture invention of combining the bridge and Ferris wheel have been proved
successively, and the try to use fixed wheel for the substitute of rotated wheel got approvals of the user. After the try of mixing the Ferris wheel and a building in Liaocheng Ferris wheel, some other trying to build the Ferris wheel on the roof of commercial center also give many peoples a surprise.

Nowadays, the calculation method and engineering science has been developed so sophisticated that almost all kind structure can be designed and built. The fixed wheel Ferris wheel structure system is just a try on the new Ferris wheel, and wishes more and more dramatic work.

REFERENCES


