Recent Research and design on Steel TV Towers in China

Renle MA
College of Civil Engineering, Tongji University
August 19, 2013
Contents

1 Development of tower structures in China

2 Superhigh steel towers built in recent years

3 Research and design of steel towers
Chinese pagodas are a traditional part of Chinese architecture. They are used for religious purposes, especially by Buddhists.

They are square, circular or octagonal in plan.

Wood, brick and stone are the most common material of pagodas.
The Songyue Pagoda located in Dengfeng Country, Henan, is the earliest extant brick pagoda in China.

Built in 523 AD

Structure in plan: circular

Materials: brick

Height: 37.6m
Chinese pagoda — Liaodi Pagoda

Liaodi Pagoda located in Dingxian, Hebei province, is the highest ancient Chinese pagoda.

Built in 1055 AD
Structure in plan: octagonal
Materials: brick and stone
Height: 84 m
1 Development of tower structures

Chinese pagoda — **Yingxian Wooden Pagoda**

The Pagoda located in Ying County, is the oldest existent wooden pagoda. It has survived several big earthquakes and battles.

Built in **1056 AD**
Structure in plan: **octagonal**
Materials: **wood**
Height: **67 m**
1 Development of tower structures in China
— Concrete TV Tower

With the development of Broadcast and Television in 1980’s, TV towers were built in every Province.

Because concrete construction technique was better at that time, a few high towers were built in concrete.
Concrete TV Tower

Built in 1991
Height: 415.2m
Materials: concrete
Structural system: single tube
Concrete TV Tower

Built in 1994
Height: 468m
Materials: prestressing concrete
Structural system:
3 tubes, grand frame

Shanghai Oriental Pearl TV Tower
Concrete TV Tower

Built in 1994
Height: 405m
Materials: concrete
Structural system: single round tube

China Central TV Tower
More and more steel towers were built with the improvement of construction technique and corrosion treatment technique of steel structures.
Steel TV Tower

1 Development of tower structures

built in 1965
height: 200m
materials: steel lattice column
structural system: space truss in octagonal

built in 1973
height: 210.55 m
materials: steel tube
structural system: space truss in hexagonal

Old Guangzhou TV Tower
Old Shanghai Steel TV Tower
Steel TV Tower

Built in 1994
Height: 230m
Materials: steel
Structural system:
space truss

Foshan TV Tower

Built in 1997
Height: 236 m
Materials: steel
Structural system:
space truss

Qingdao TV Tower
2 Superhigh steel towers built in recent years

Development trend of steel towers

**Multi-functions:** TV, broadcast, communication, sightseeing, monitoring, entertainment, exhibition……

**Architectural appearance:** abundant……

**Corrosion protection:** long tern
2 Superhigh steel towers built in recent years

Shijiazhuang TV Tower
- Built in 2000
- Height: 280m
- Materials: steel
- Structural system: space truss

Heilongjiang TV Tower
- Built in 2000
- Height: 336 m
- Materials: steel
- Structural system: space truss
2 Superhigh steel towers built in recent years

**Guangzhou New TV Tower**
- Built in 2009
- Height: 600m
- Materials: steel and concrete
- Structural system: composite structure

**Henan TV Tower**
- Built in 2010
- Height: 388 m
- Materials: steel
- Structural system: complex space rigid frame
2 Superhigh steel towers built in recent years

Built in 2011
Height: 326 m
Materials: steel
Structural system: complex space rigid frame

Will be finished in 2014
Height: 280 m
Materials: steel
Structural system: complex space rigid frame

Linyi TV Tower
Daqing monitoring Tower
3 Research and design of steel towers

- **New styles of member section and connection**
  - Irregular member section
  - Connection of equal strength and rigidity for over-long columns
  - Complicated spatial connections

- **Techniques of high-strength bolt connection**
  - Reverse balance flange
  - Hydraulic bolt tensioner of double barrels

- **Design Parameters of complicated high-rise steel structures**
  - Parameters of wind loads based on wind tunnel test and numerical modeling
  - Seismic resistant performance based on shaking table test
  - Experimental research on load-bearing capacity of connections and members
  - Technique of vibration control and field measurement
3 Research and design of steel towers

Heilongjiang TV Tower

(1) Technique of vibration control
(2) Field measurement
Heilongjiang TV Tower

Technique of vibration control

The wind-induced vibration response is big because of its significant height and slender structural characteristic. So it is very important to control the wind-induced vibration of the tower.

In Heilongjiang tower the hanging water tank is used to reduce the wind-induced dynamic response.
Heilongjiang TV Tower

Technique of vibration control

Height: 336m
weight of steel structure: 3300 ton
Total weight: 5500 ton
Technique of vibration control

PTTMD system consists:
① Water tank (35 ton)
② Dampers
③ Flexible suspension cables
④ Flexible water pipes (infall)
⑤ Flexible water pipes (outfall)

PTTMD
Pendulous Tank as turned mass damper

Advantages:
No additional mass,
Less space occupy,
Simple structure,
Cost-saving
Heilongjiang TV Tower

Field measurement to get to know the effect

Measurement on site

(1) Cut the stressed cable to excite vibration
(2) Measured acceleration response
(3) Calculated vibration characteristic
(4) Got efficiency: 25%
Henan TV Tower

(1) Irregular member section
(2) Connection of equal strength and rigidity for over-long columns
(3) Complicated spatial connections
(4) Parameters of wind loads based on wind tunnel test and numerical modeling
(5) Seismic resistant performance based on shaking table test
(6) Experimental research on load-bearing capacity of connections and members
Irregular member section
Connection of equal strength and rigidity for over-long columns
Henan TV Tower

Complicated spatial connections

Transverse flange  Longitudinal flange

High strength zinc coated bolt

Transverse flange  Longitudinal flange

High strength zinc coated bolt
Parameters of wind loads based numerical modeling

Shape coefficient and gust response factor of wind loads on the complex surface were obtained by CFD numerical simulation.
Henan TV Tower

Parameters of wind loads based on wind tunnel test
A 1/40 scale shaking table model test was implemented for evaluating the seismic performance of Henan TV Tower. Iron blocks and plates were used as artificial mass and fixed on each floor of the model structure.
The static tests and finite element analyses of X-connections of “Anyetang” novel tube used for Henan Broadcast and TV Tower were carried out and the main influencing factors on load-carrying capacity were obtained.
The reduced-scale test and finite element analysis about three kinds of stiffened sections including truss, with ribbed plate and without ribbed plate are carried out. On the whole, experimental results coincided with numerical results. The bearing capacity of Anyetang column with rib stiffener can be improved about 20% at least. The effect of stiffening truss was unapparent though the stress distribution on tube wall was further reasonable. So the suggestion on rib stiffener adopted in Anyetang column is proposed.
3 Research and design of steel towers

Daqing Monitoring Tower

(1) Reverse balance flange
(2) Flange along member’s longitudinal direction
(3) Bolt tensioner of double hydro-Cylinder
3 Research and design of steel towers

Daqing Monitoring Tower

Reverse balance flange

Tube Wall

Flange

Stiffening plate

Balancing surface
3 Research and design of steel towers

Daqing Monitoring Tower

Flange along member’s longitudinal direction
3 Research and design of steel towers

Daqing Monitoring Tower

Bolt tensioner of double hydro-Cylinder

Construction site
Daqing Monitoring Tower

3 Research and design of steel towers
Thanks for your attention!