

The China pavilion of Shanghai Expo

Case Study
ARCH 631 - Fall 2018

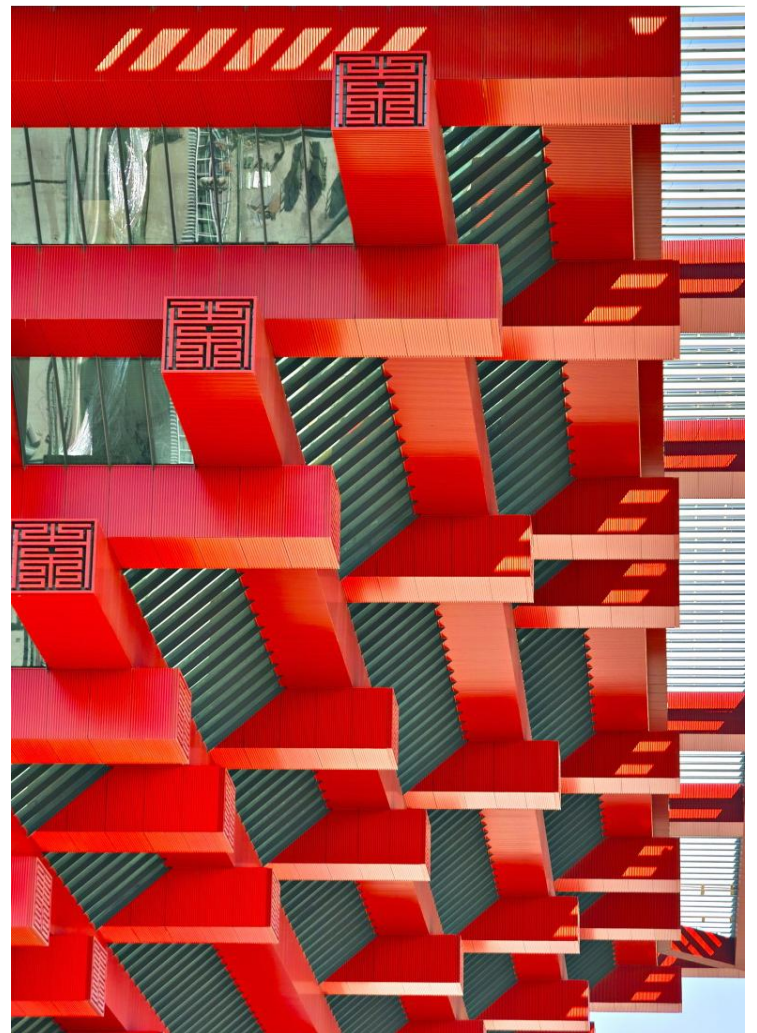


Group Members

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- Ruiwen Tang

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- Overview
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- Loading Analysis
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Overview

- Location : Shanghai, China
- Project Duration : 2007-2010
- Gross Floor Area : 160,126m²
(1,720,000ft²)
- Designer : Jingtang He
- Current function: Expo theme museum



Background

The China Pavilion of the 2010 Shanghai Expo demonstrates the spirit and wisdom of Chinese culture.

While using red as the main external color, the building fully embodies the concept of red appreciation in Chinese culture since ancient time, which is corresponding to the expo theme of hospitality and culture expression.



Background

— architect & construction

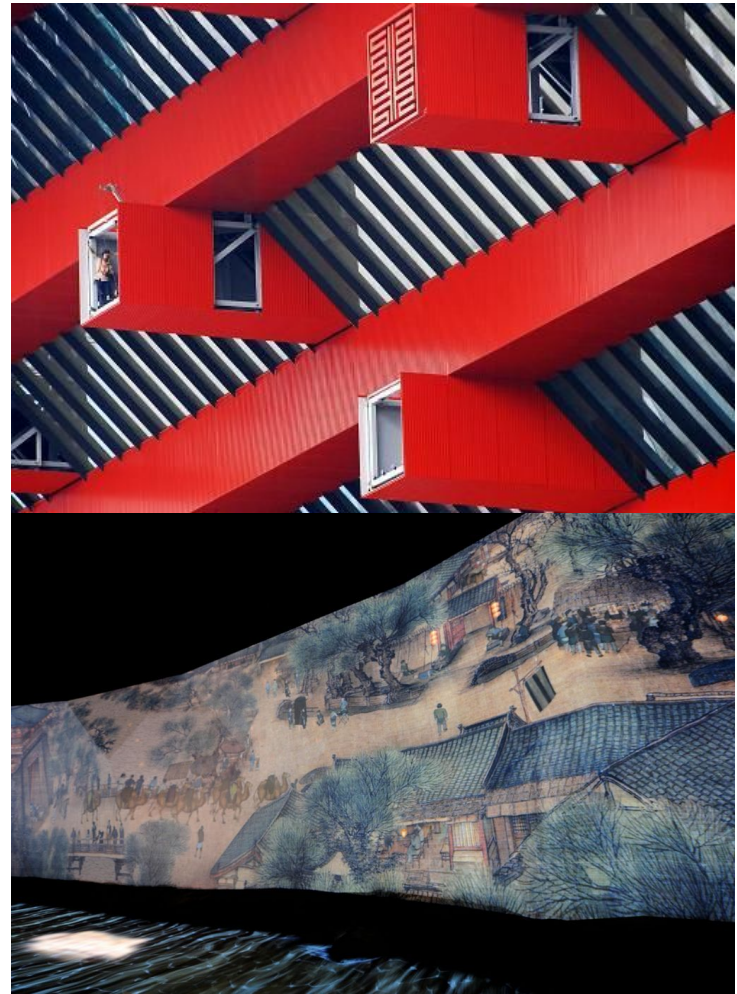
- Jingtang He——chief architect
- status: Dean of the Design Institute of South China University of Technology, Vice Chairman of the Chinese Architectural Society
- Design Competition: Apr 25, 2007
- Construction: Dec 18, 2007-Feb 08, 2010



Background

— —cultural aspects

- The whole structure: “The Oriental Crown”
- Roof structure: “Dougong”(symbolic)
- Roof garden: new representation of the old Chinese garden
- Interior 4 cores: four themes which imply the four seasons

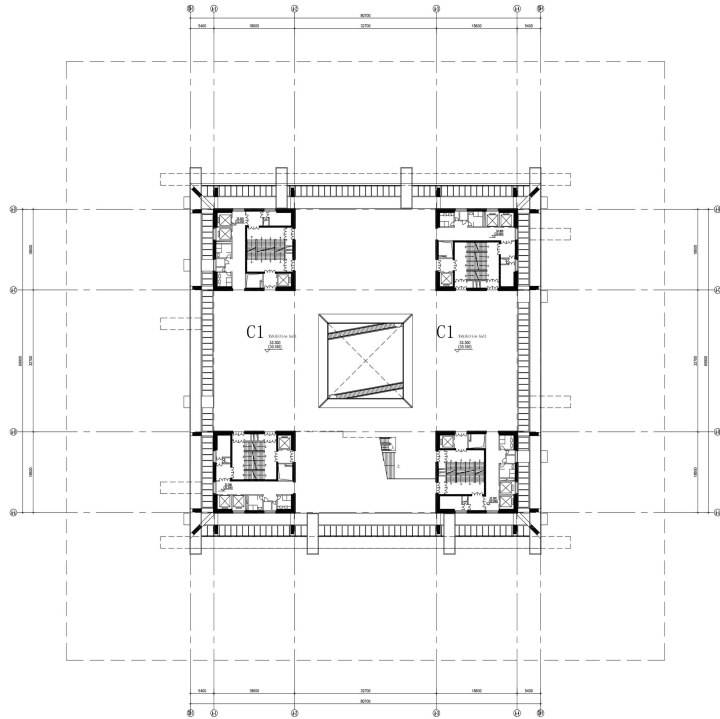


Structure Abstract

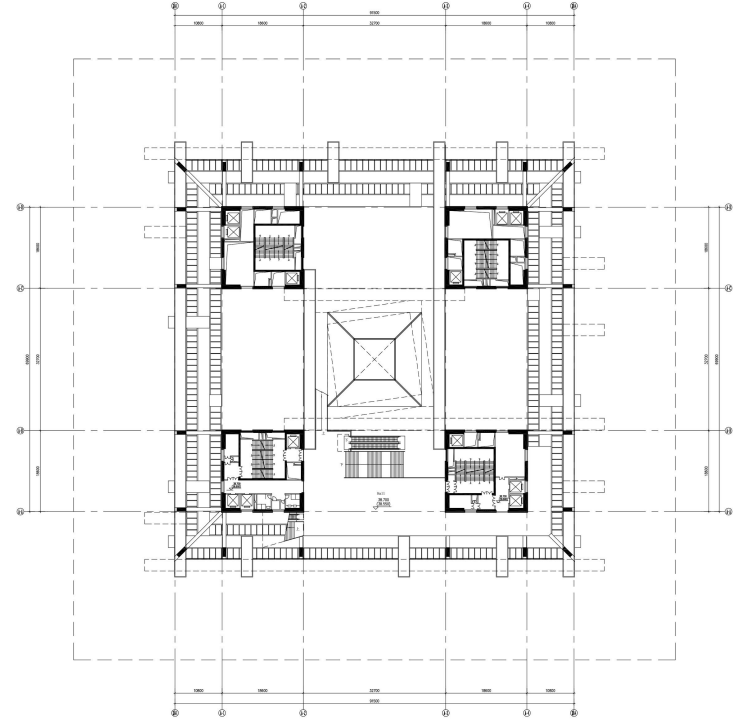
- Steel frame shear wall system
- The amount of steel used is 23,000 tons
- Deep Piled raft concrete foundation
- In the middle are four concrete core tubes, 68m
- Stiffness Steel Batter Posts & Core Tubes
- Red Water-Roof External Painting



Plans

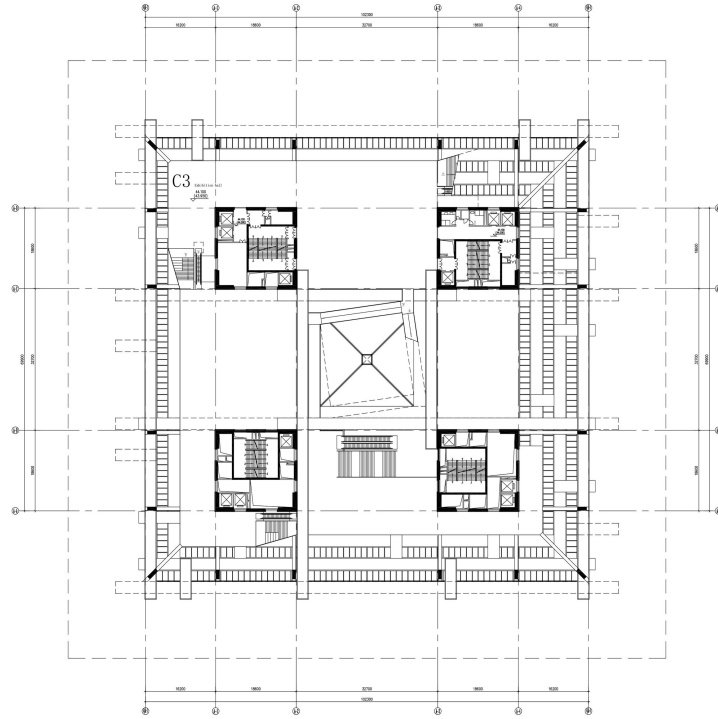


33.3m Floor plan

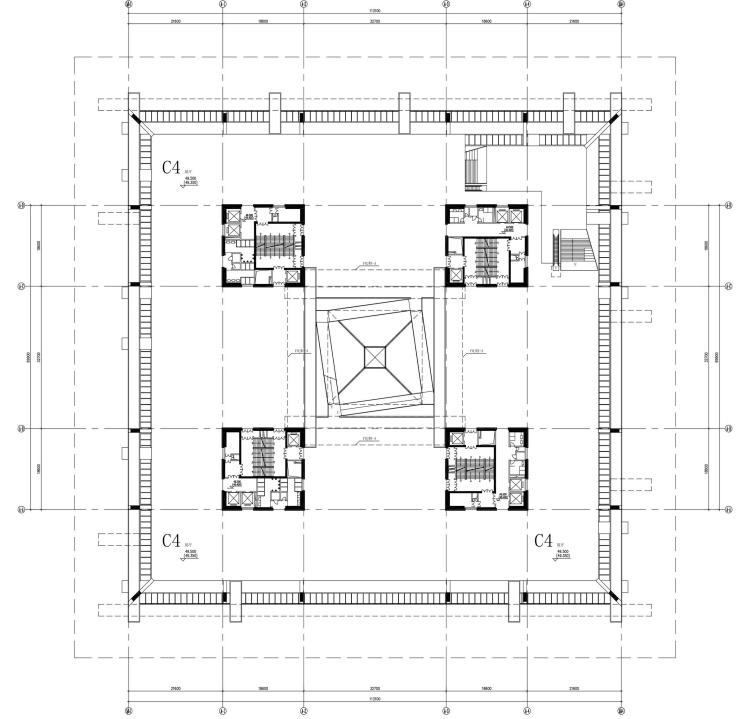


38.7m Floor plan

Plans

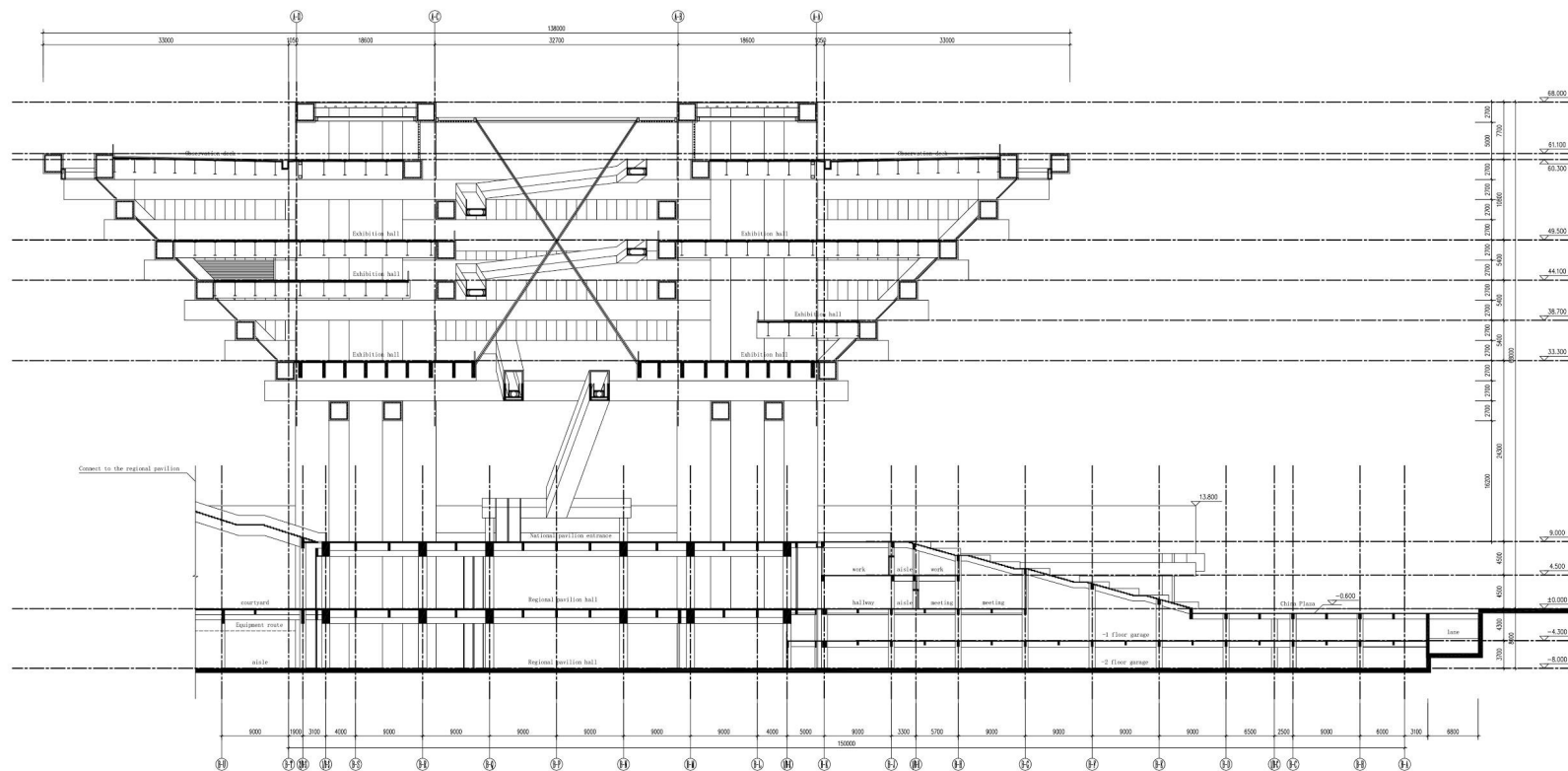


44.1m Floor plan

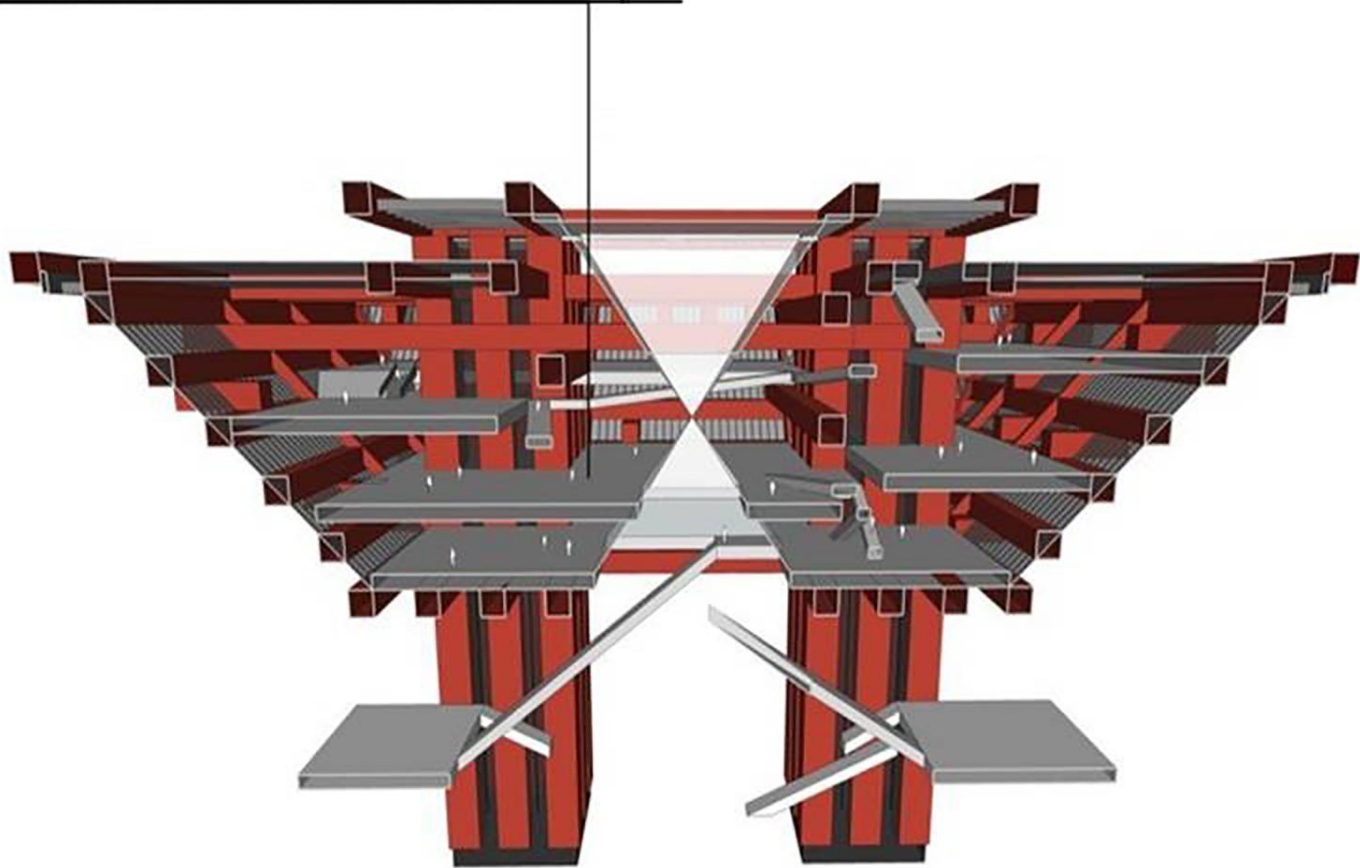


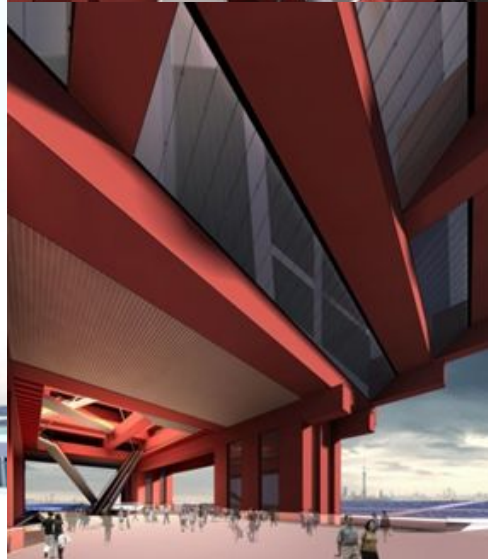
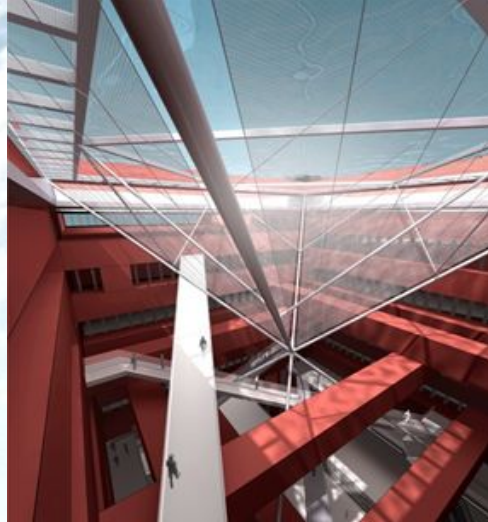
49.5m Floor plan

Sections

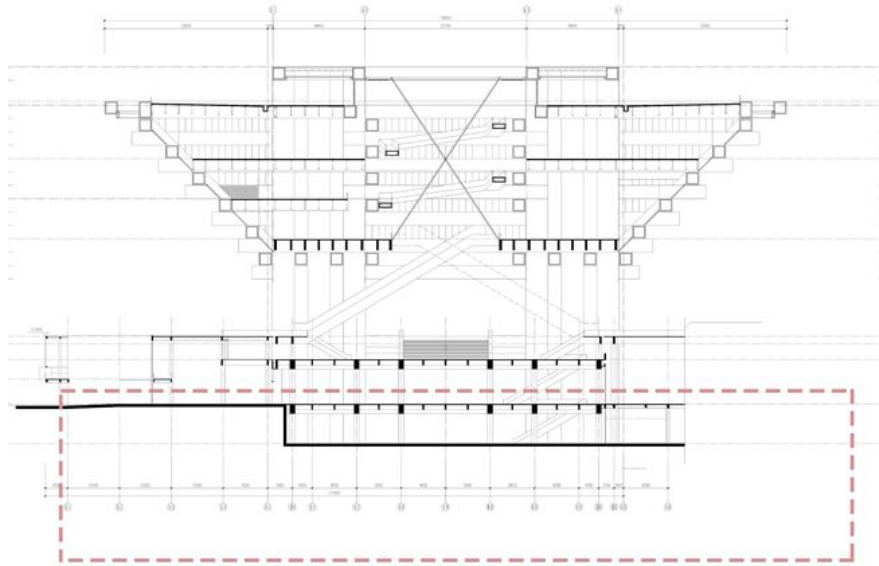


The gallery features : Split layer layout, gradually enlarged

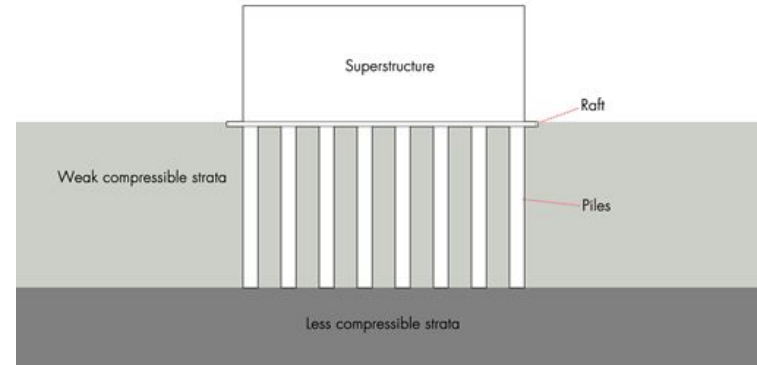




Foundation



- Piled raft foundation
- Weak compressible strata
- Large, deep excavation



Foundation

Pile length: 65m

Pile diameter: 850mm

Pile cap thickness: 2m

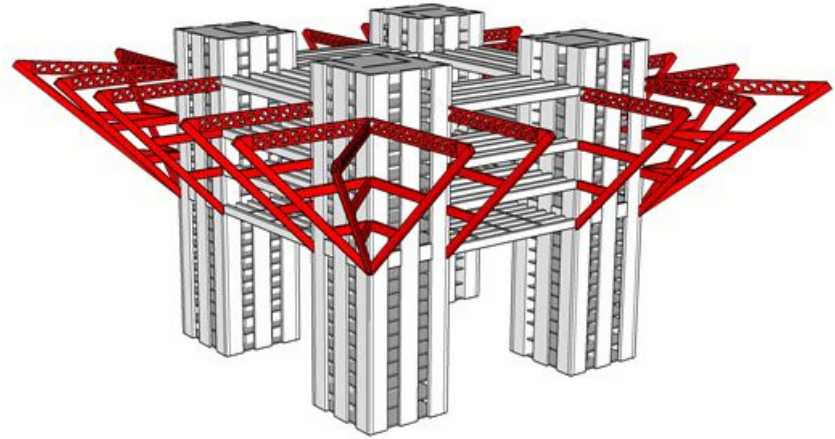
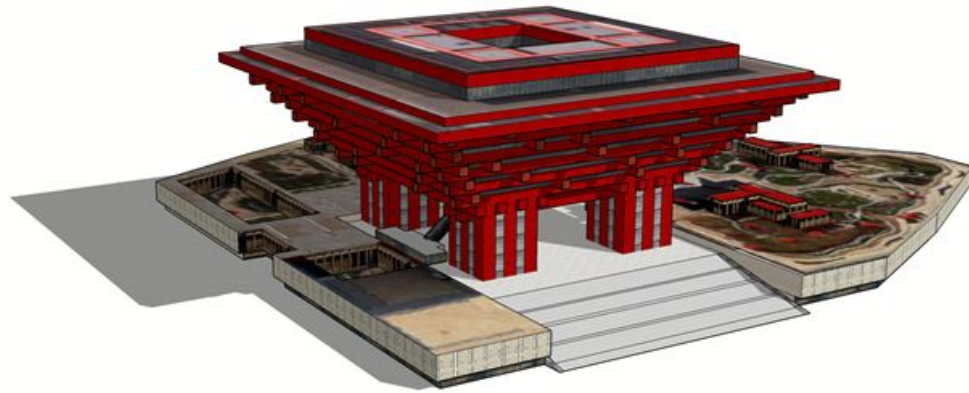
Ultimate bearing capacity of pile: 3500 KN

Advantage:

- Increasing the effective size of a foundation
- Helping resist horizontal loads
- Improving the performance of the foundation

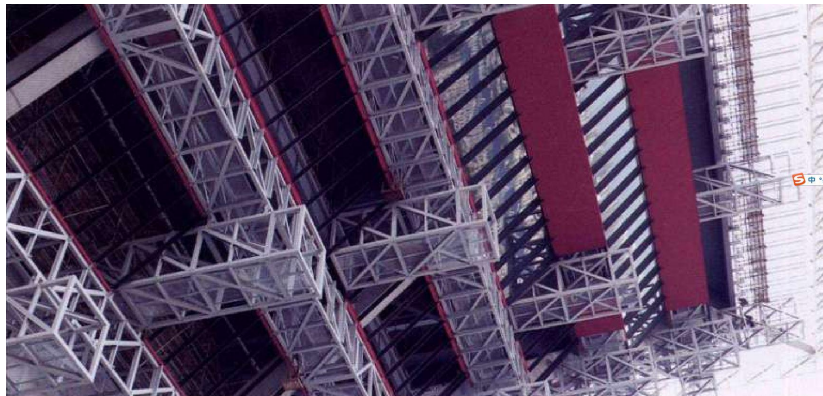


Body

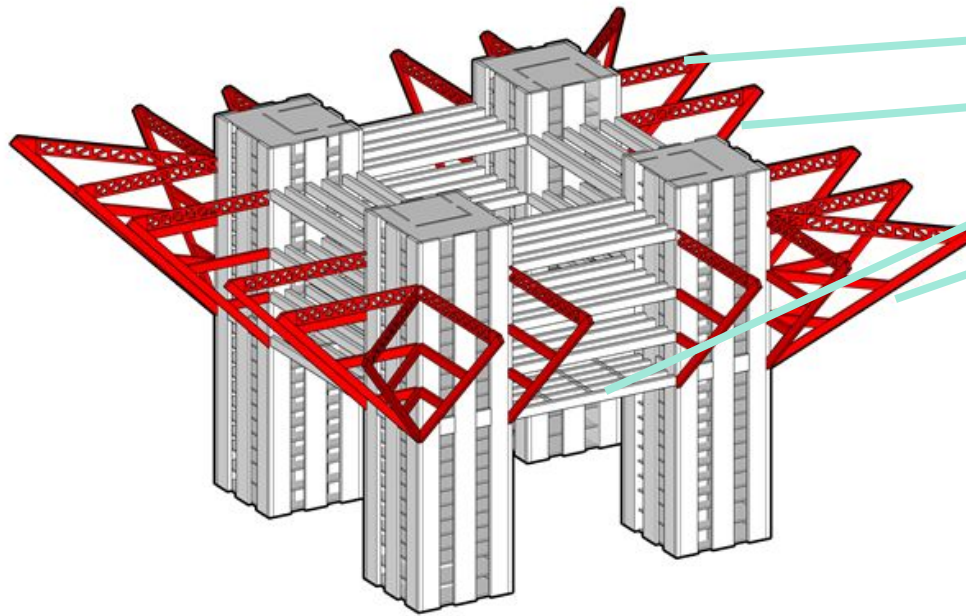


“Dougong”

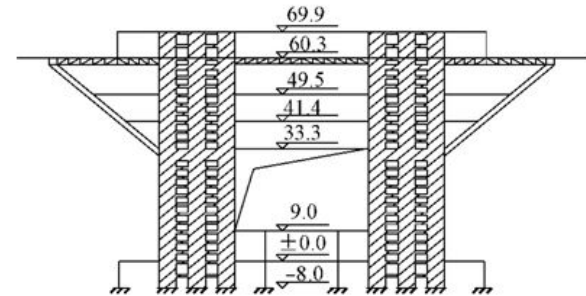
In fact, the traditional structure “Dougong” used here is not the main stress structure.



Batter Post + Core Tube

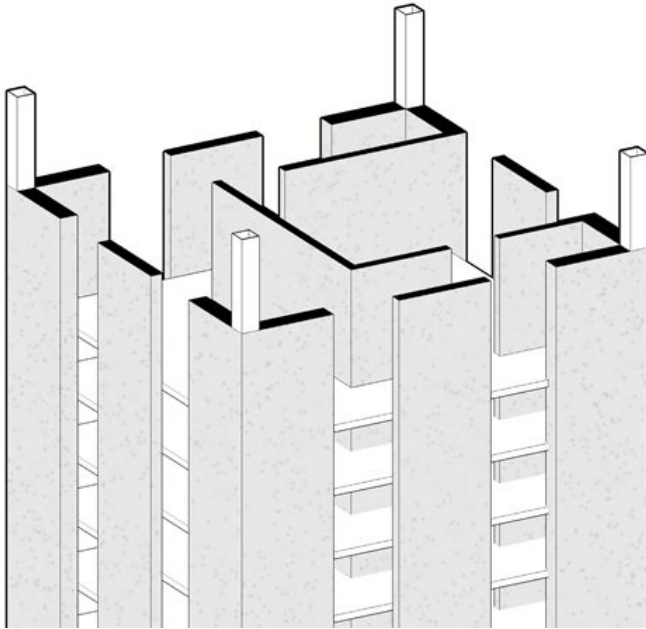


- Roof truss
- Steel brace (batter post)
- Stiffness steel frame
- Horizontal steel beam

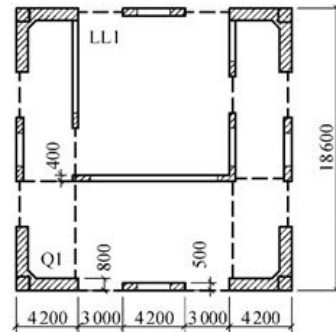


Computation sketch of structure section plane (unit: m)

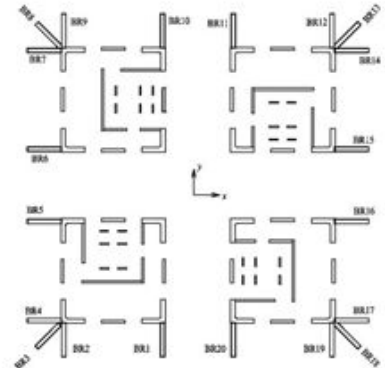
Core Tube



- Core Tube
- Shear wall
- 800*800*40 steel column



Plan of shear wall in tube (unit: mm)

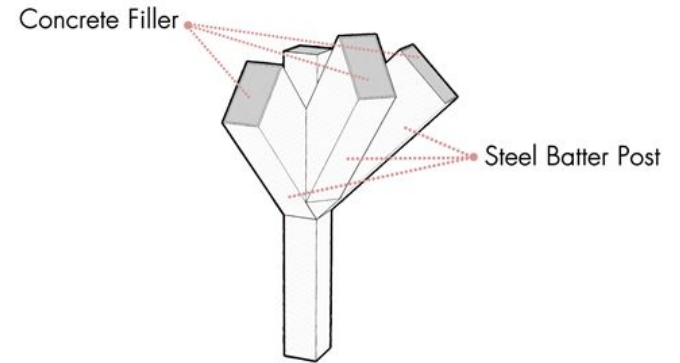
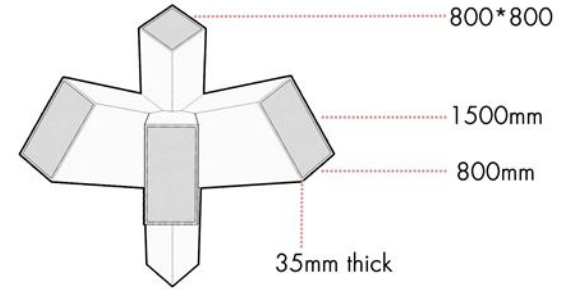
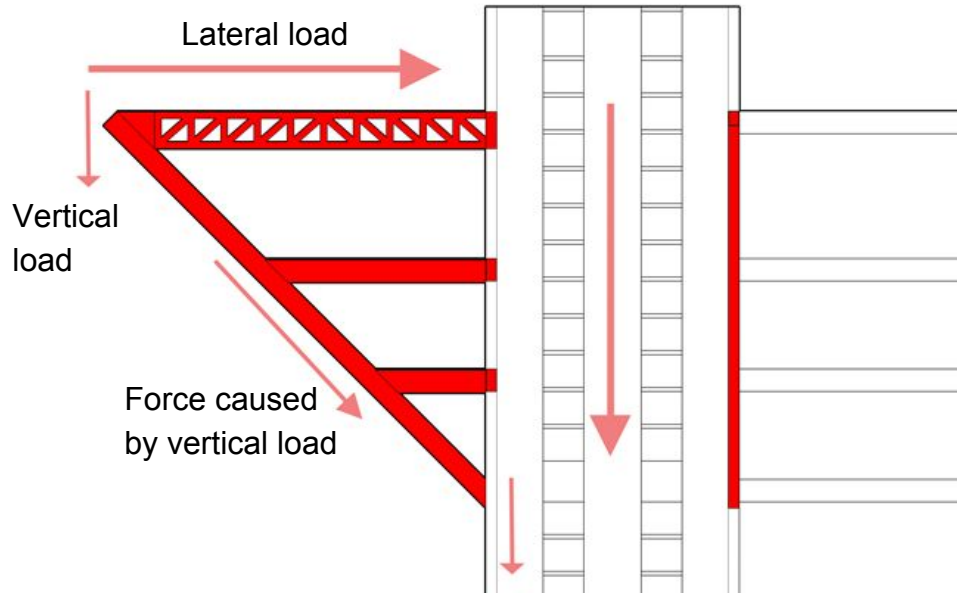


Stiffness steel column

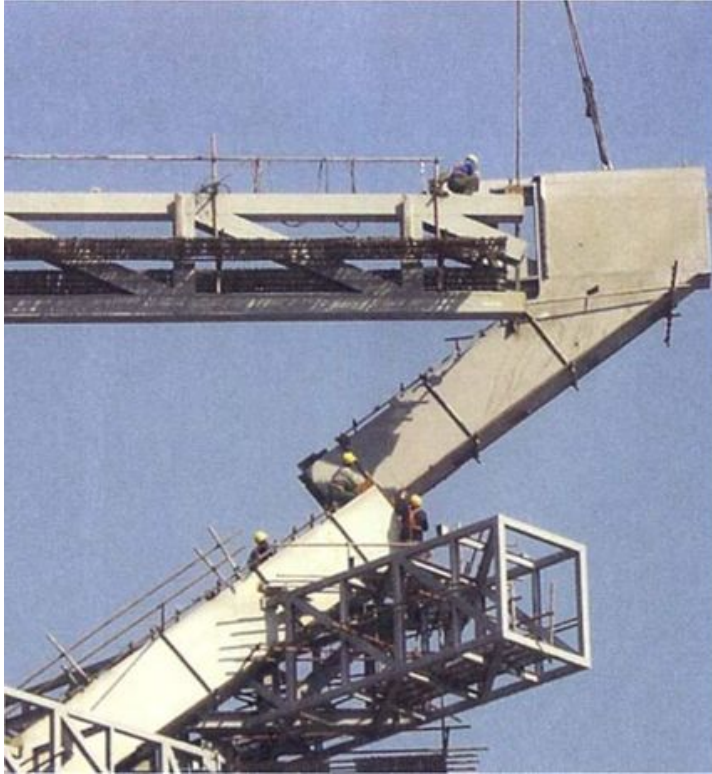


These stiffness steel columns are not only used to support batter posts, but also to raise the earthquake resistant capability.

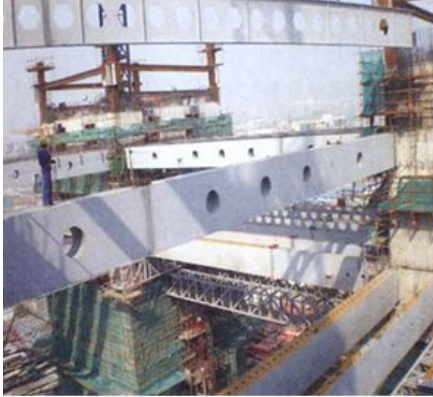
Batter Post



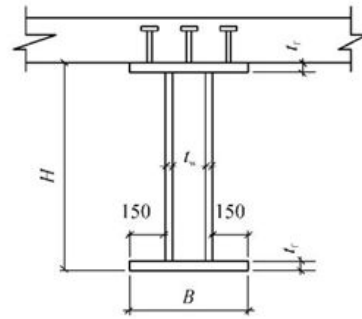
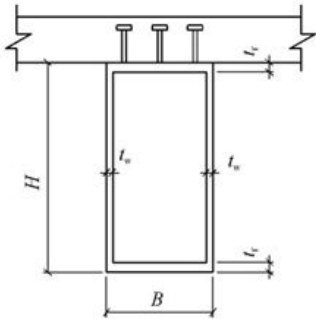
Batter Post



Stiffness Steel Frame



The stiffness steel frame consists of box steel beams and flanged beams.



Gravity Loads

LRFD basic combination: $1.2D + 1.6L + 0.5(L_r \text{ or } S \text{ or } R)$

- D: Dead loads
- L: Live Loads
- L_r or S or R: Snow Loads

Gravity Loads : Dead loads

- Concrete:
 - 164,500 m³
 - C50 concrete density: 2.5 ton/m³
 - Total weight: 411,250 tons
- Steel:
 - Total weight: 21,888 tons
- Glass:
 - 1232 glass blocks
 - 1.35m*4.25m 0.387ton for every block
 - Total weight: 476.8 tons
- Total weight : Concrete + Steel + Glass: 433,615 tons
- Gross Floor Area : 160,126m²
- Dead loads: **26.54 kN/m²**

Gravity Loads : Live loads

- According to the reference of *Fang, X., Wei, H., Chen, F., Xu, M. & Zhou, H.(2009). Structural research and design for the China National Pavilion at the World Expo Shanghai*
- Live Loads: **9 kN/m²**

Gravity Loads: Snow Loads

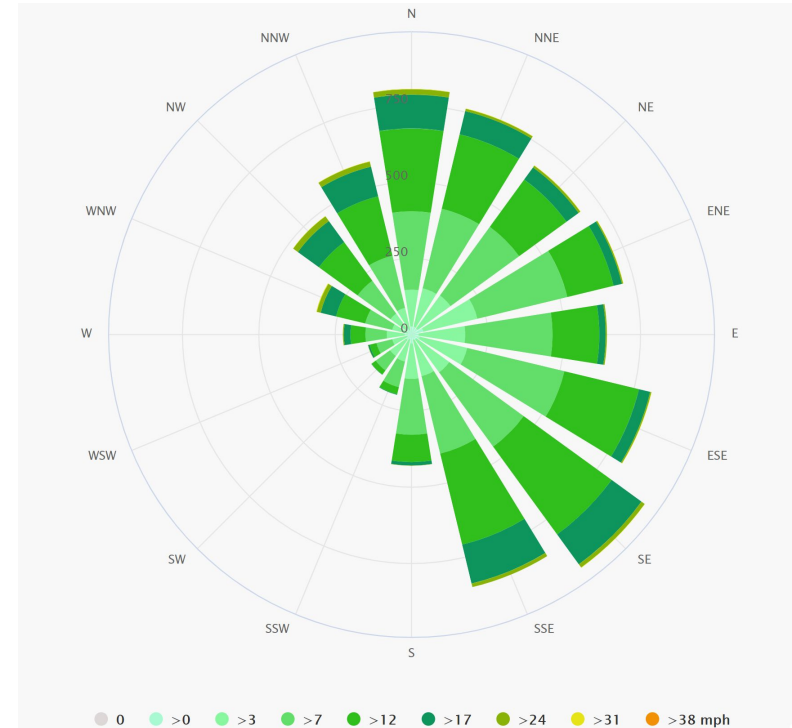
- This project is located in Shanghai, China
- According to the *Statistics of snow loads and wind loads in Chinese cities*
- Snow Loads: **0.25 kN/m²**

| 全国各城市的50年一遇雪压和风压 | | | | | | | | |
|------------------|---------|------------------------|------|-------|------------------------|------|-------|-----|
| 省市名/城市名 | 海拔高度(m) | 风压(kN/m ²) | | | 雪压(kN/m ²) | | | 雪荷载 |
| 准永久值系数分区 | | n=10 | n=50 | n=100 | n=10 | n=50 | n=100 | |
| 北京 | 54 | 0.3 | 0.45 | 0.5 | 0.25 | 0.4 | 0.45 | II |
| 天津 | | | | | | | | |
| 天津市 | 3.3 | 0.3 | 0.5 | 0.6 | 0.25 | 0.4 | 0.45 | II |
| 塘沽 | 3.2 | 0.4 | 0.55 | 0.6 | 0.2 | 0.35 | 0.4 | II |
| 上海 | 2.8 | 0.4 | 0.55 | 0.6 | 0.1 | 0.2 | 0.25 | III |
| 重庆 | 259.1 | 0.25 | 0.4 | 0.45 | | | | |

| Average snow load and wind load in Chinese cities for 50 years | | | | | | | |
|--|----------|--------------------------------|------|-------|--------------------------------|------|-------|
| City | Altitude | Wind load (kN/m ²) | | | Snow Load (kN/m ²) | | |
| Quasi-permanent value coefficient partitioning | | n=10 | n=50 | n=100 | n=10 | n=50 | n=100 |
| Shanghai | 2.8m | 0.4 | 0.55 | 0.6 | 0.1 | 0.2 | 0.25 |

Lateral Loads

- The main lateral loads of the building in Shanghai is wind load
- According to the wind rose diagram, the main direction of the wind load is from **EAST**.



Lateral Loads

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- According to the wind rose diagram, the main direction of the wind load is from **EAST**.
- According to the *Statistics of snow loads and wind loads in Chinese cities*
- Wind Loads: **0.6 kN/m²**

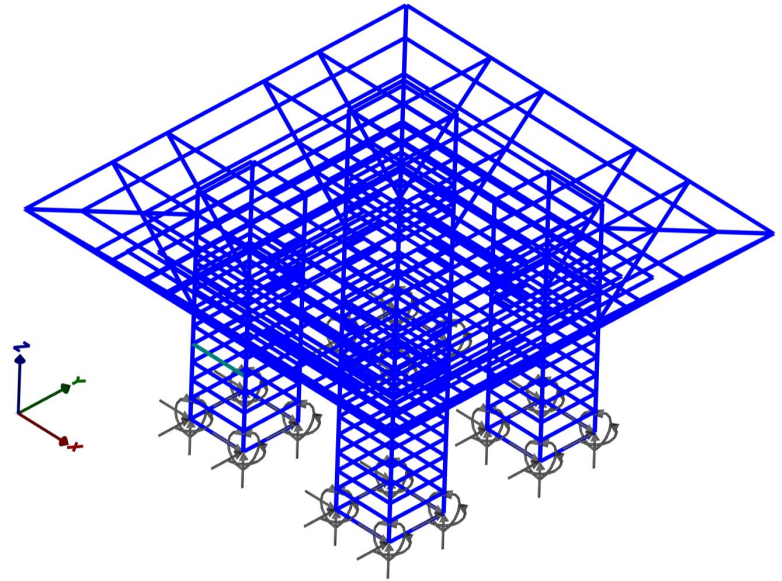
| 全国各城市的50年一遇雪压和风压 | | | | | | | | |
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| 省市名/城市名 | 海拔高度(m) | 风压(kN/m ²) | | | 雪压(kN/m ²) | | | 雪荷载 |
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Average snow load and wind load in Chinese cities for 50 years

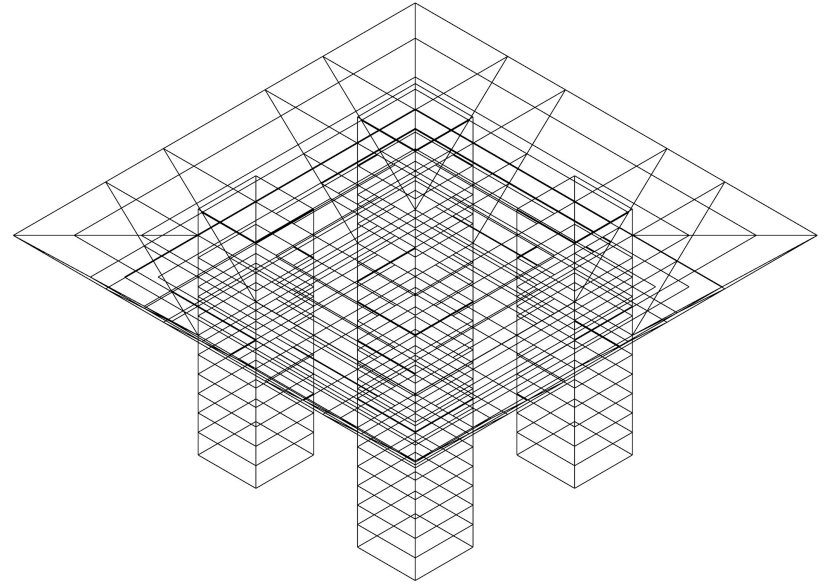
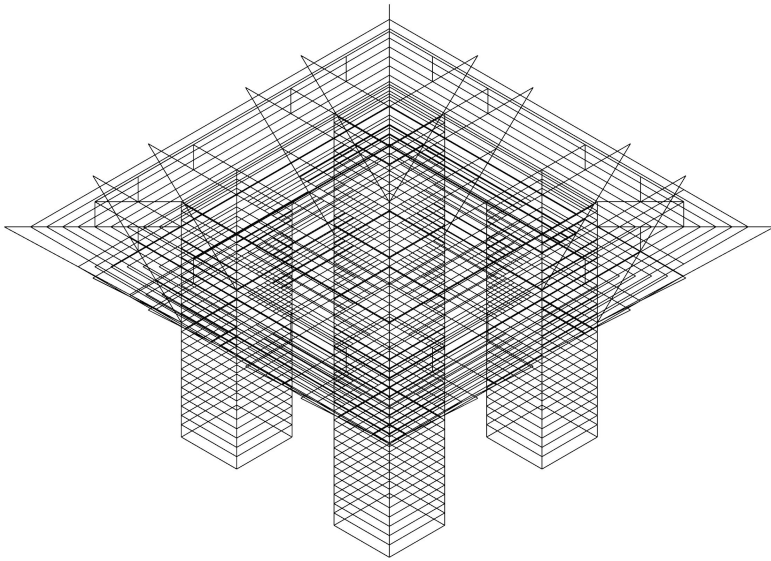
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| Quasi-permanent value coefficient partitioning | | n=10 | n=50 | n=100 | n=10 | n=50 | n=100 |
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Analysis - Gravity & Lateral

- Gravity Loads:
 - Dead Loads: **26.54 kN/m²**
 - Live Loads: **9 kN/m²**
 - Snow Loads: **0.25 kN/m²**
- Lateral Loads:
 - Wind Loads: **0.6 kN/m²**
 - From **EAST**



Analysis - Visual Analysis

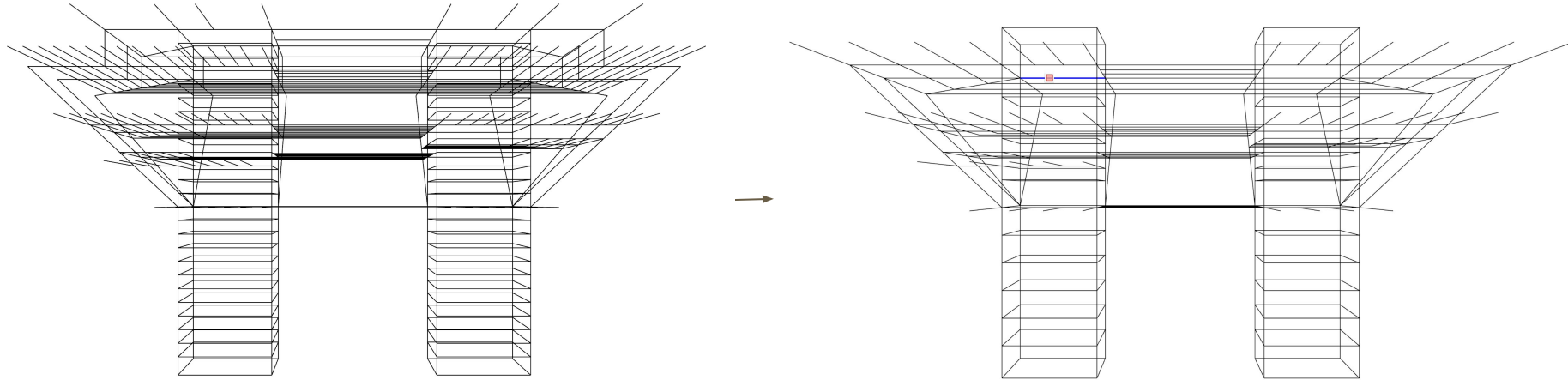


Analysis

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- Simplify the structure model in SketchUp

Analysis - Visual Analysis



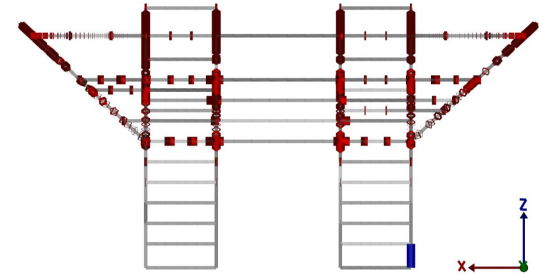
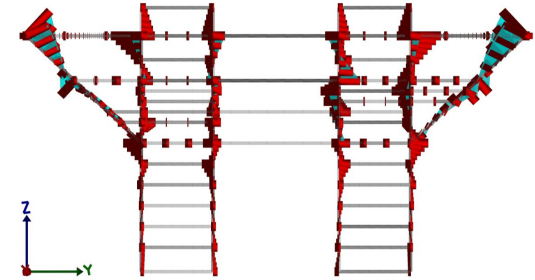
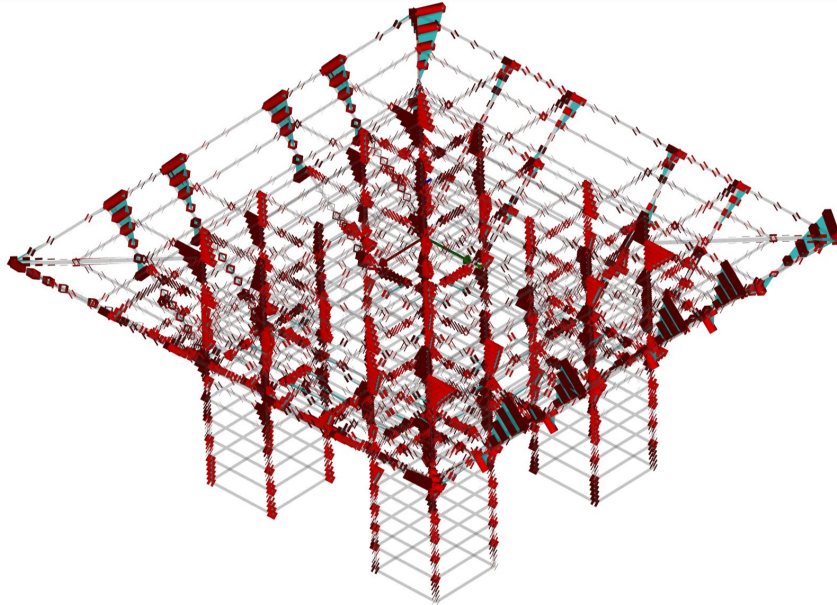
Analysis

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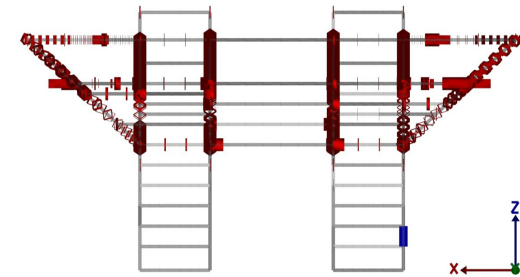
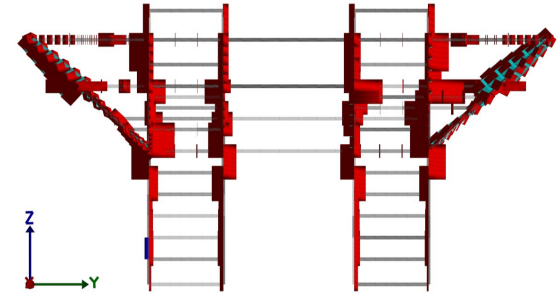
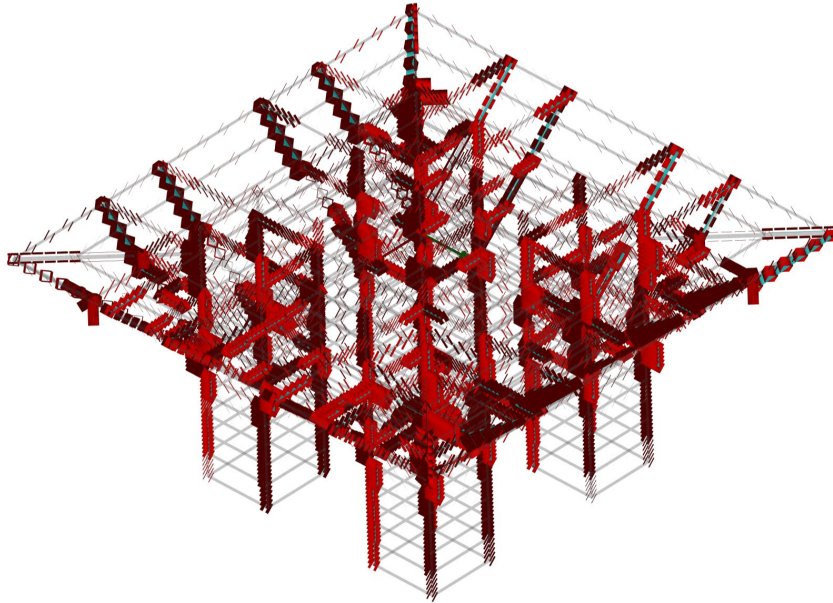
Analysis - Visual Analysis

- M_z



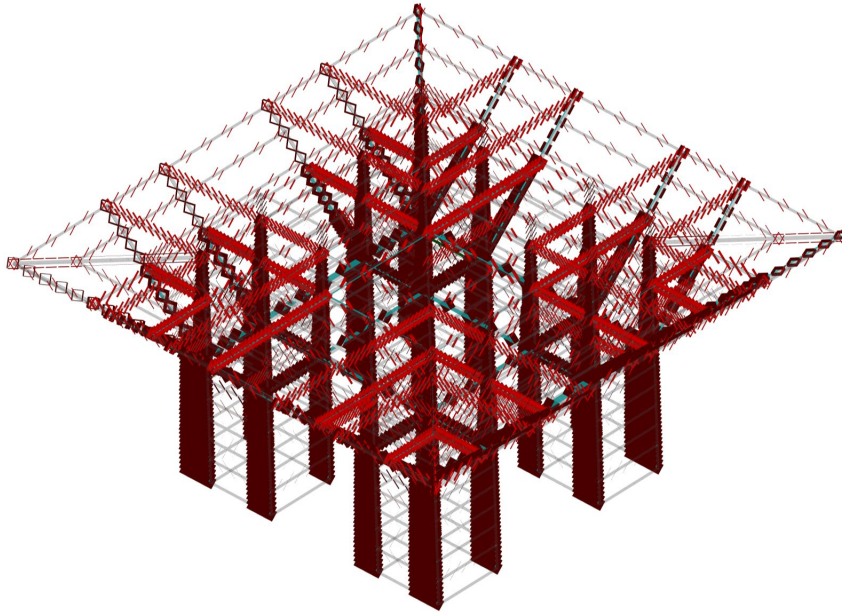
Analysis - Visual Analysis

- V_y



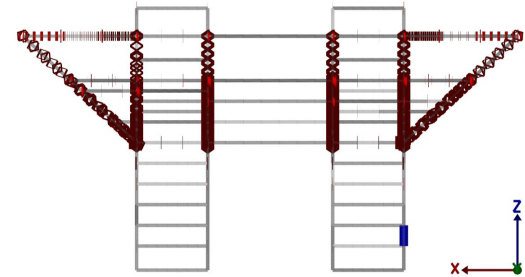
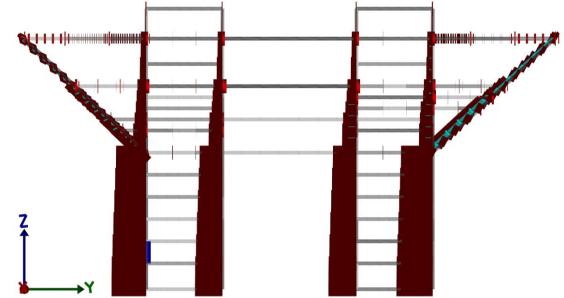
Analysis - Visual Analysis

- Px



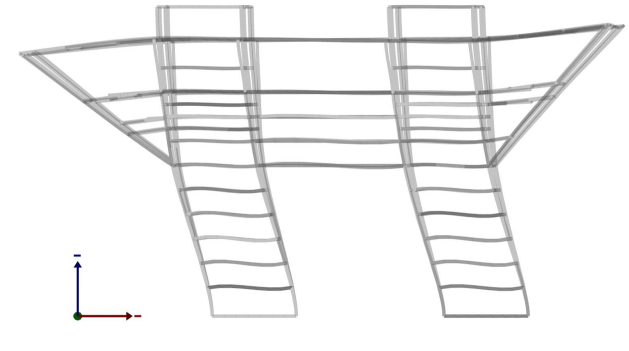
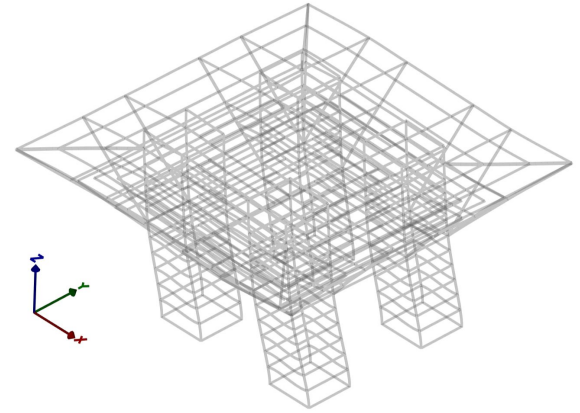
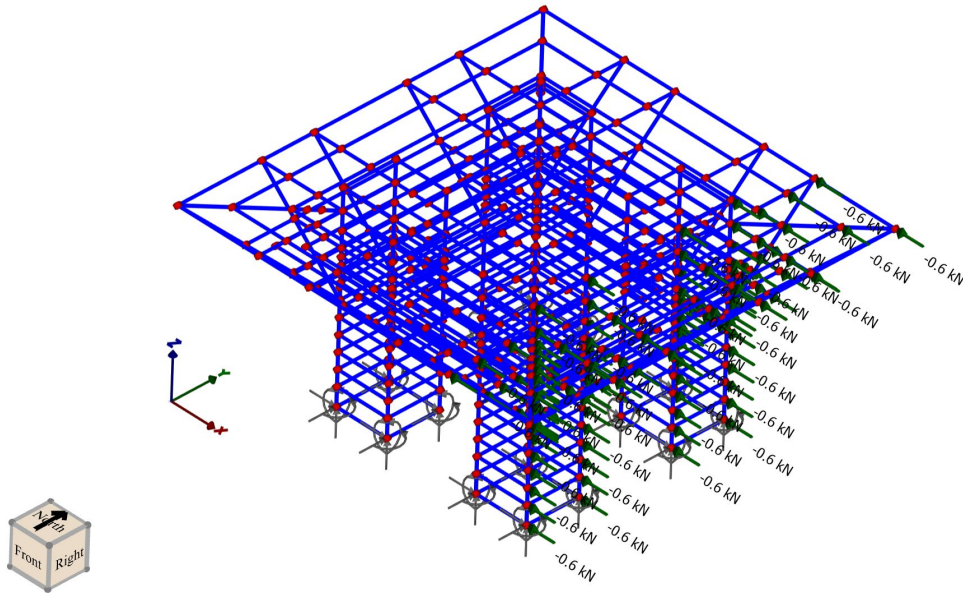
Right

Back



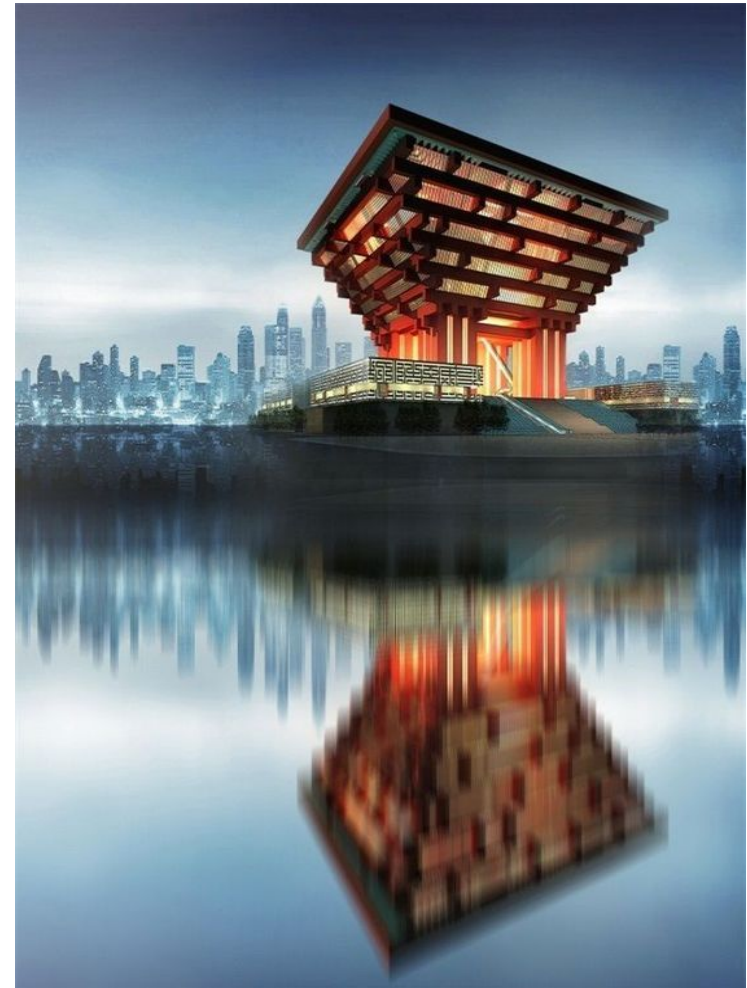
Analysis - Visual Analysis

- Defl.



Summary

- The Chinese Pavilion of Shanghai 2010 Expo is a contemporary structural and material interpretation of the ancient chinese building structure.
- The main structure consists of: Deep Piled raft concrete foundation, 4 Concrete Cores, Stiffness Steel Batter Posts & Core Tubes.
- Apart from the dead load of the building itself, the major lateral load of the building comes from the east wind of Shanghai.



Thank you for listening!

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