THE JIN MAO TOWER

XU TENG, YUE WANG, FEI HUANG, JIAYU CHEN, MENGYUAN ZHANG

Overview

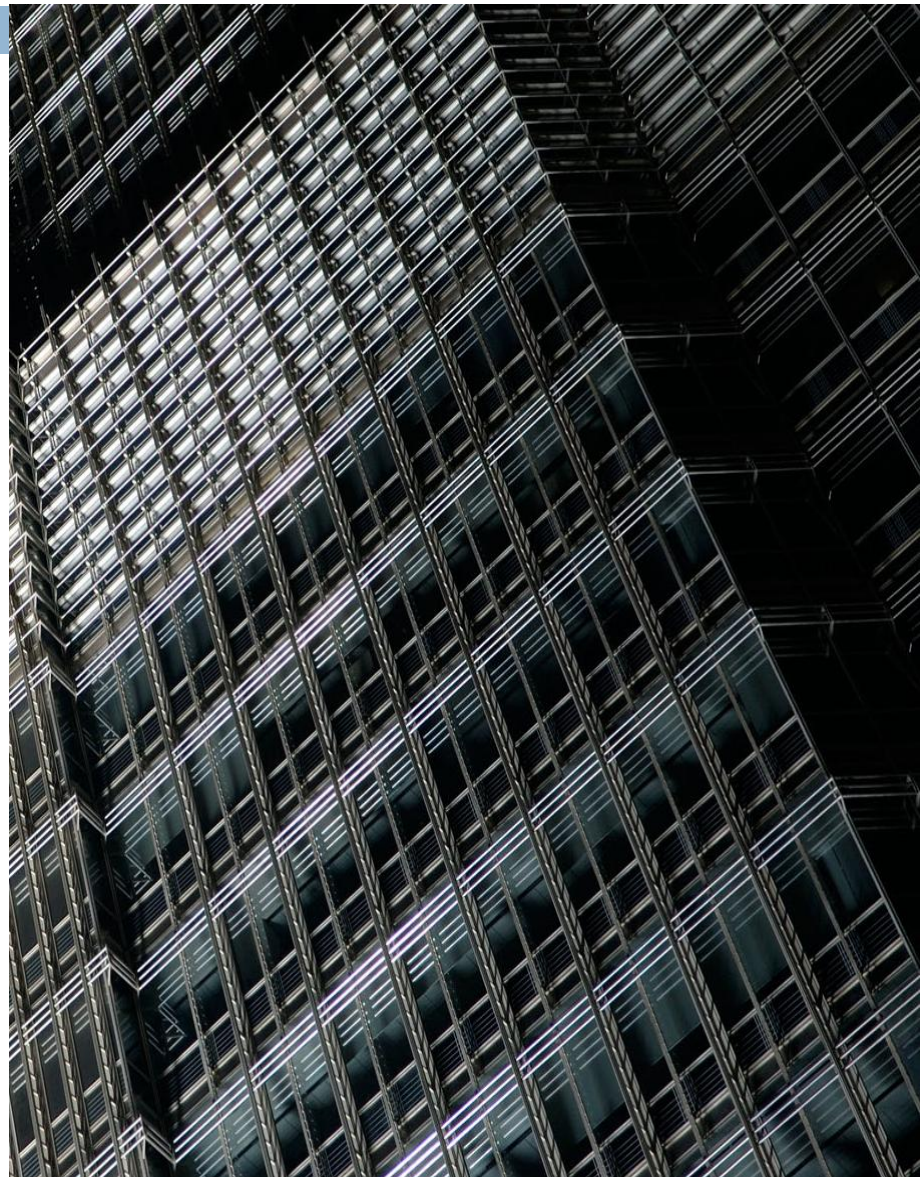
Jin Mao tower, in the Pudong new area of Shanghai is one of the highest skyscrapers.

Made of ornately formed stainless steel, aluminum, and glass, the materials and decoration fashion an fantastic experience.

The structure design also enabled the engineers to hollow out that portion of the central core to create the tower’s centerpiece – a 650-foot-high atrium, tallest and highest in the world, extending up from the 56th floor.

Sufficient Identification Evidence

- Reaching to the heavens, the tower's pinnacle extends to further intensify the design while the glass reflects the gray sunshine, adorning the tower with a sacred atmosphere.



Description of main structural system

The Super-High-rise structure boasts an entire vertical deflection of only two centimeters, with it's roof shifting less than half a meter. Stability is ensured with up to 108 miles per hour wind and can withstand a level seven scale earthquake. This resistance is possible in part by the tough glass skin of the outer walls.

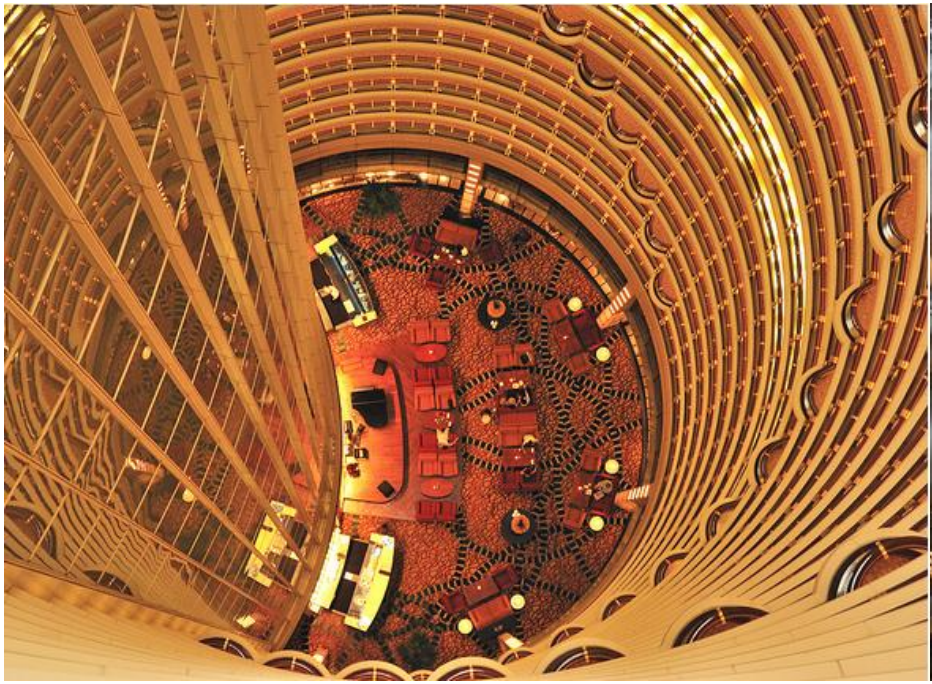
Background

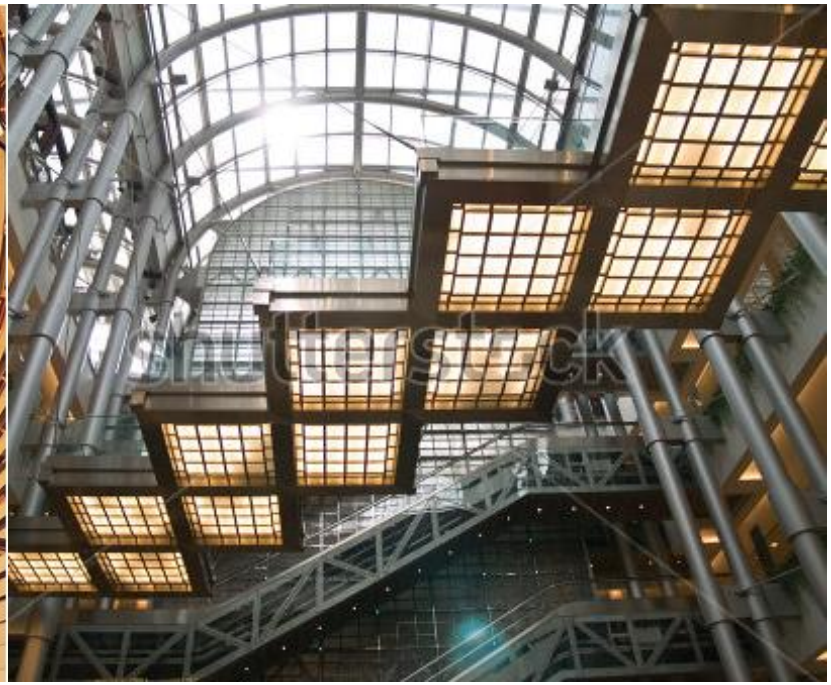
This building includes modern offices, a deluxe 5-star hotel - the Grand Hyatt Shanghai, exhibition halls, banquet halls, an observation deck, and entertainment facilities.

Background

The 51st and 52nd floors are the mechanical and electrical facilities center, which are restricted for the tower's working staff; the 53rd to 87th floors are reserved for the deluxe Grand Hyatt Hotel of which, the 86th floor houses a club exclusive for the hotel guests and the 87th floor lodges the hotel restaurant; and, the 88th floor-the highest floor, is reserved for the tower's observation deck, which can hold 1000 people at one time.

Background

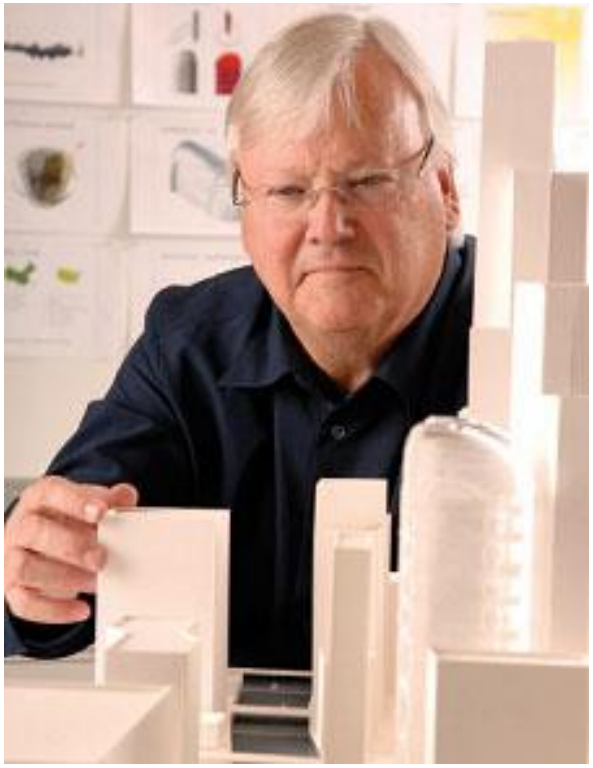




The tower has the best elevators available. Two direct elevators operate at the speed of 9.1 meters (nearly 30 feet) per second that can send visitors from the ground floor to the 88th floor for only 45 seconds. There are also five to six elevators every 10 floors, which reduce waiting-time to 35 seconds even during rush hours.

The Architect

Skidmore, Owings & Merrill, founded in 1936, is one of the largest and most influential architecture firms in the world.



Head architect Adrian D and head engineer Stanton Korista, lead the design process from 1993 until completion in 1998. Over 30 architects and engineers worked on the project.

SOM
SKIDMORE, OWINGS & MERRILL LLP

The Concept

With its postmodern form, it evokes the architecture of the traditional Chinese pagoda by creating a rhythmic pattern growing in height. The proportion of the building revolves around the number 8. In Buddhism 8 is a lucky number, associated with prosperity, economy, gold and trade.

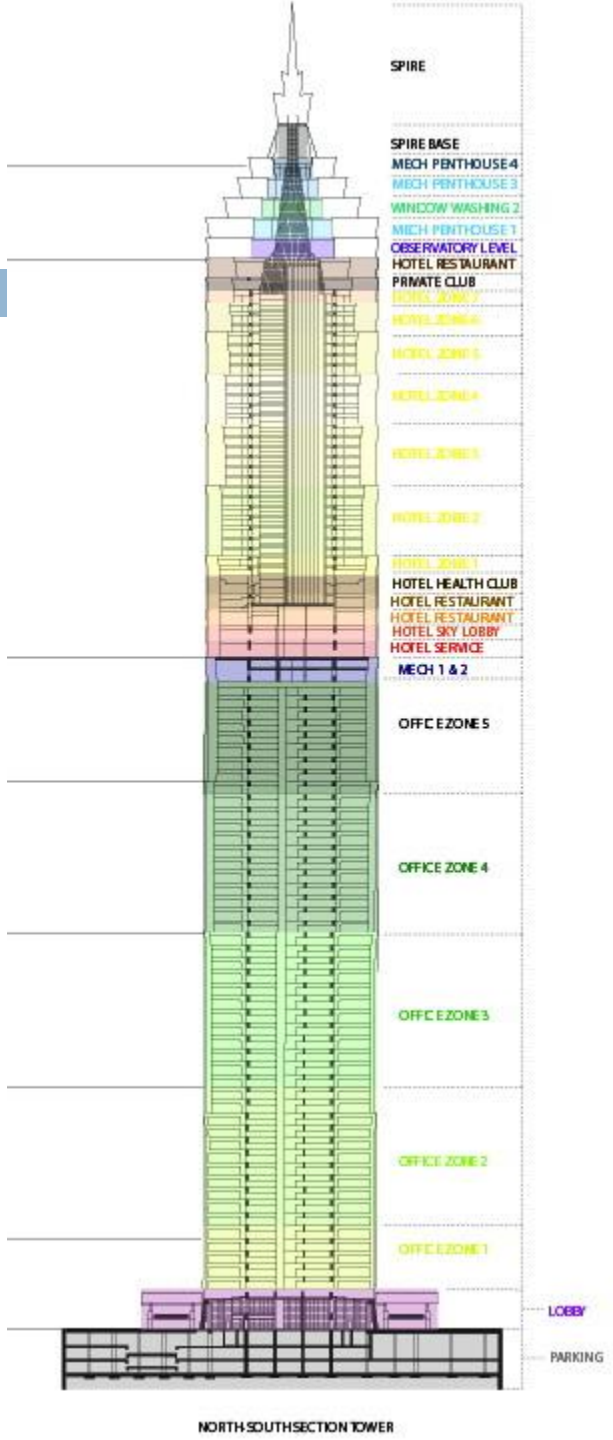
Building Layout

The basement of the tower is parking area, which can hold 800 cars and 2000 bicycles.

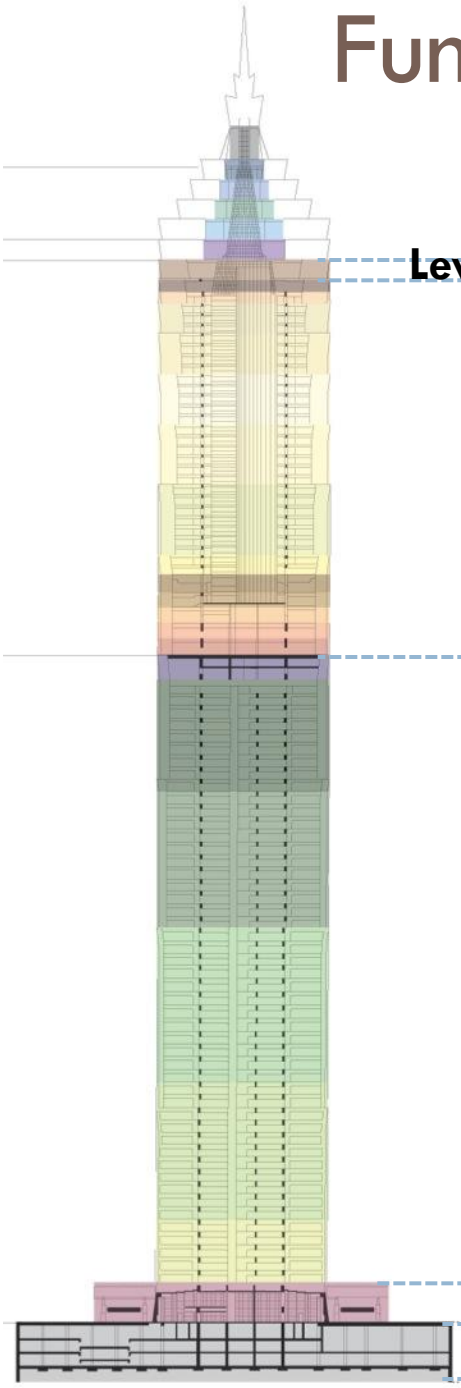
The parking area is equipped with 360-degree surveillance cameras as a security feature of the building.

Building Layout

- This is a section diagram of the function of each level. There is a lobby, five different office zones, a double height mechanical level and hotel.
- The major tenant of the building is the five-star 555-room Shanghai Grand Hyatt hotel which occupies floors 53 to 87. The barrel-vaulted atrium starts at the 56th floor and extends upwards to the 87th.



Function Analysis



Level 88 OBSERVATORY DECK

Level 53 – level 87

HOTEL ZONE

Level 3 – level 52

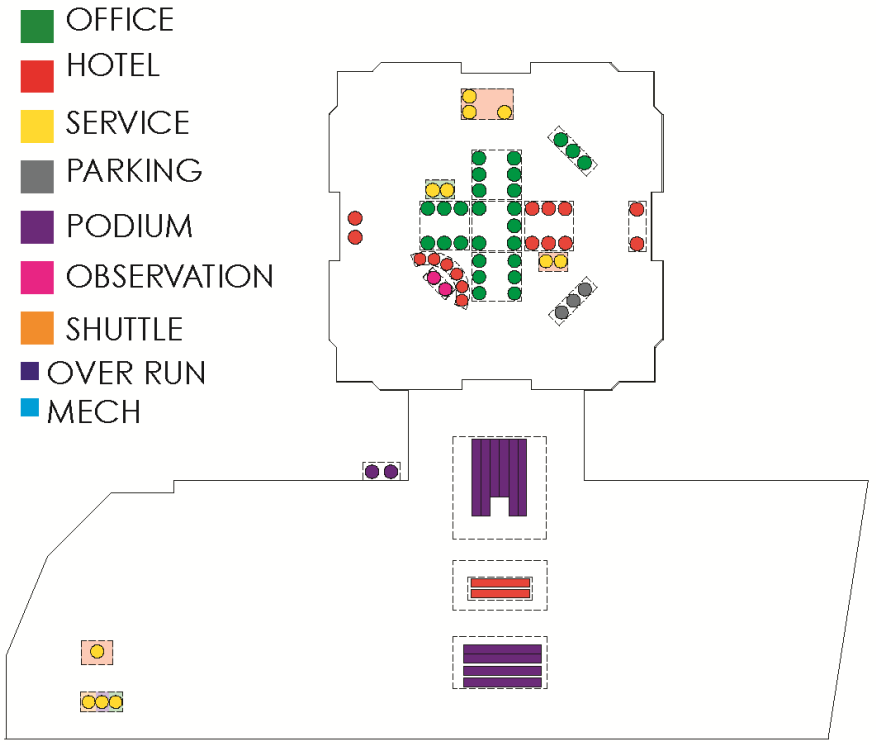
OFFICE ZONE

Level 1 – level 2 LOBBY

UNDER GROUND PARKING

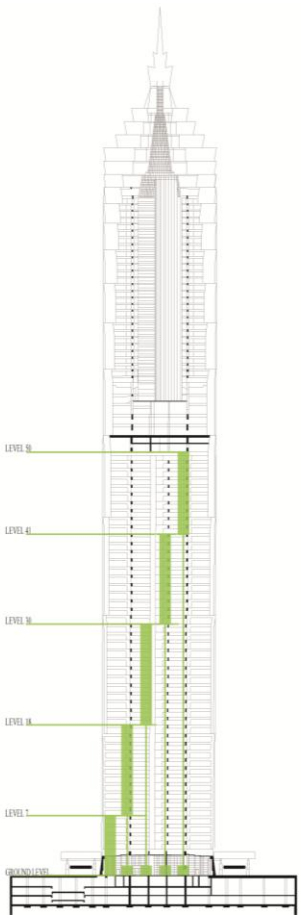
Vertical Transportation

- The elevator system is very complex.There are more than 130 elevators in Jin Mao Tower.
- Office zones are serviced by 26 elevators in five zones.
- A hotel express shuttle elevator bay
- An observation deck served by 2 elevators, 10 service elevators,
- 7 sets of escalators for podium
- 10 elevators for the hotel

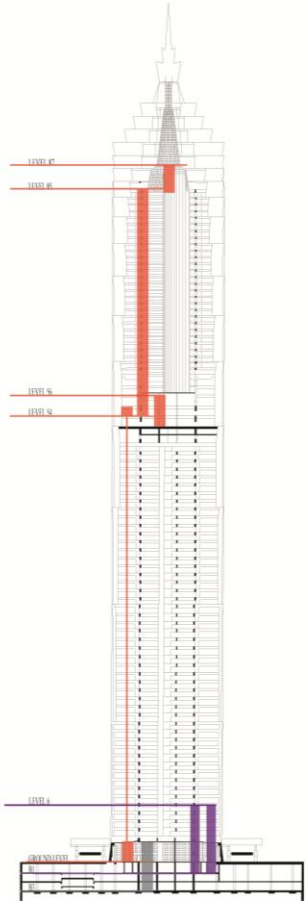


elevator riser diagram plan

Vertical Transportation

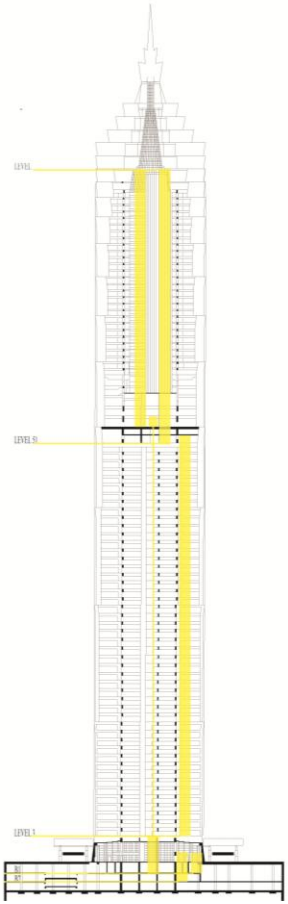


office



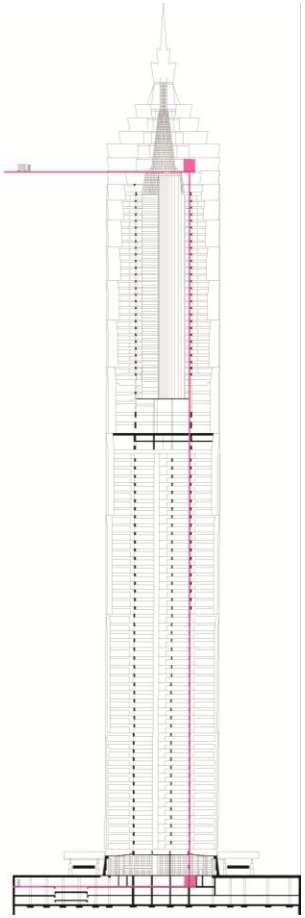
hotel

elevator riser diagram



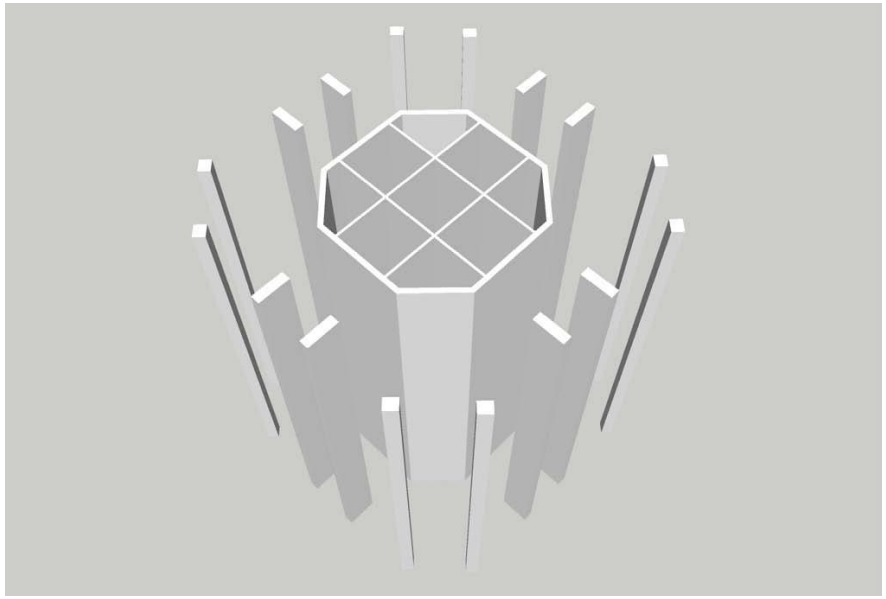
emergcy/ service

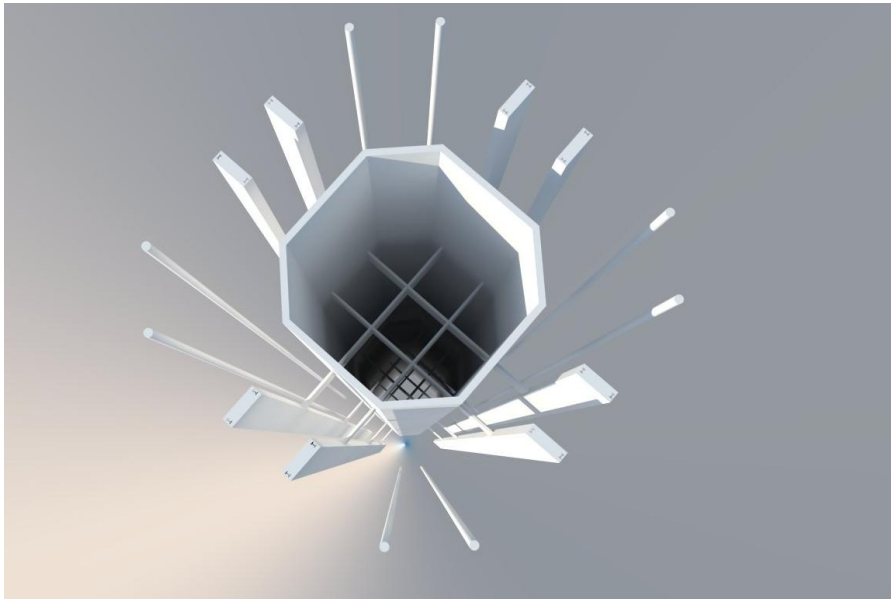
elevation



observation deck

Description of main structural system





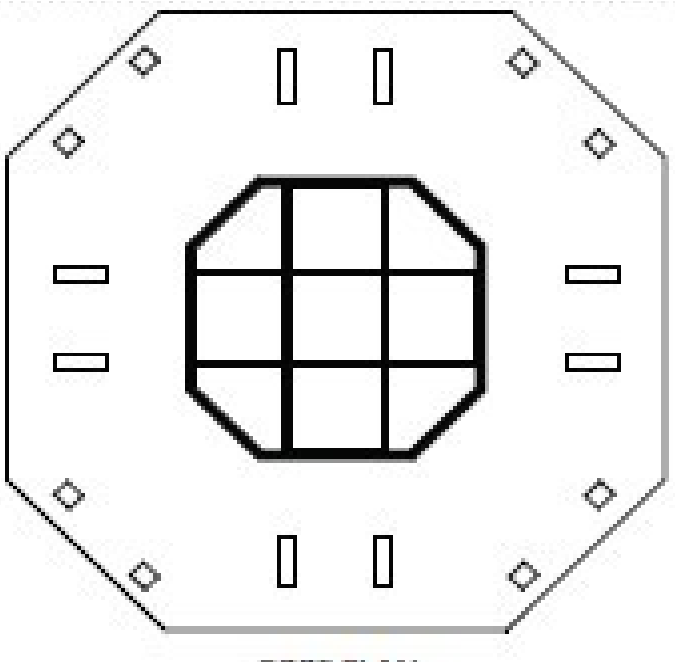
- Adhering to the theme of eight, which signifies good luck in China, the structure of the tower contains an octagonal central reinforced concrete core.
- Eight concrete and steel perimeter supercolumns, and eight steel built-up columns.

Identification of components

- Crucial to Jin Mao’ s form is the success of its core. The structural engineering of the center is a reinforced concrete protective structure. The upgrade is made up of high strength concrete and steel. Under the framework are a 4m thick reinforced concrete raft foundation, encasing 429 root hollow steel reinforcements piled into the sand clay layer 65 m deep. Sand clay can provide some bearing capacity, but the building’ s bearing relies mainly on the pile friction resistance.

Core

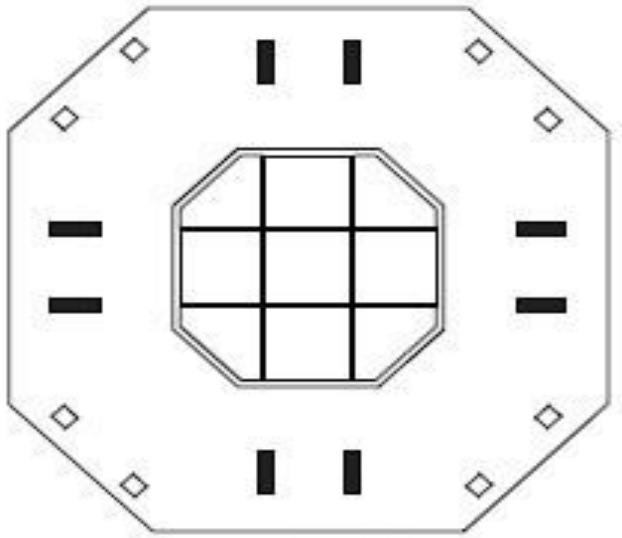
The concrete core provides excellent stiffness, while the structural steel floor framing allows to use long, column-free spans with minimal weight. This, in turn, reduces the size of the vertical members and the foundation, creating a system that resists winds and earthquakes with the fewest possible structural elements.



core plan

Supercolumns

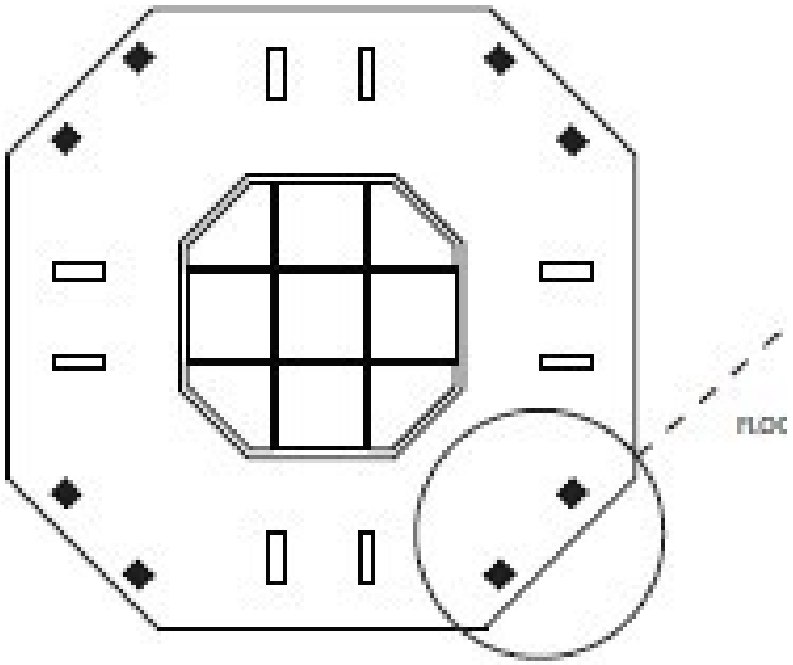
- **The supercolumns are comprised of steel and concrete.**
- The use of both steel and concrete created a dilemma during construction however, as some deformations occured due to its self weight. While this process usually occurs over a greater length of time this was expediated in Jin Mao because concrete and steel both deform elastically.



supercolumn plan

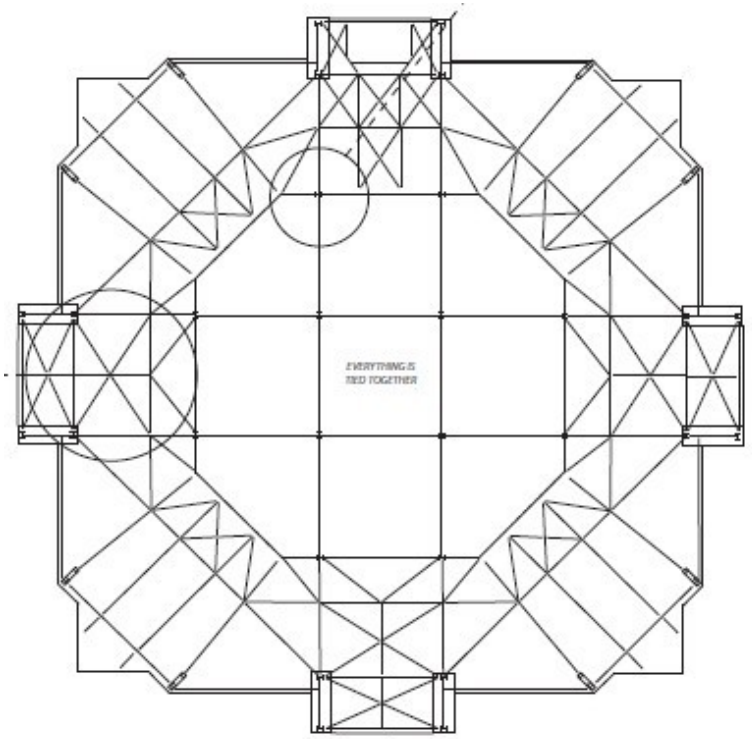
Supercolumns

- Gravity loads are resisted by the composite floor member’ s frames, called structural steel columns. The central core and composite supercolumns provide additional support counteracting the gravity loads.



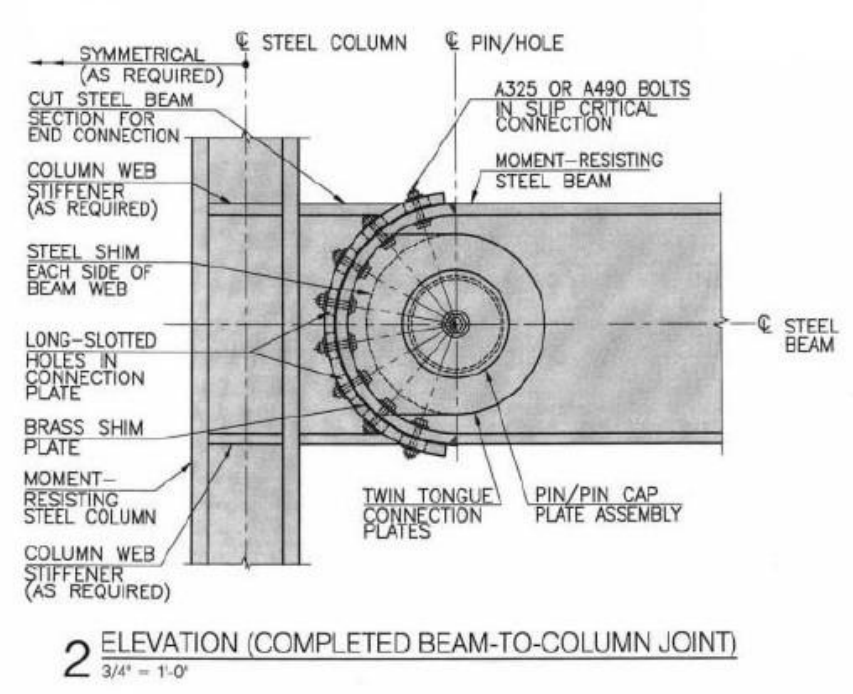
Outrigger Truss

- The final structure that enables Jin Mao to function uniquely is it’s outrigger truss system. This provides resistance of lateral loads through a central reinforced concrete shear-wall core interconnected with the composite supercolumns.



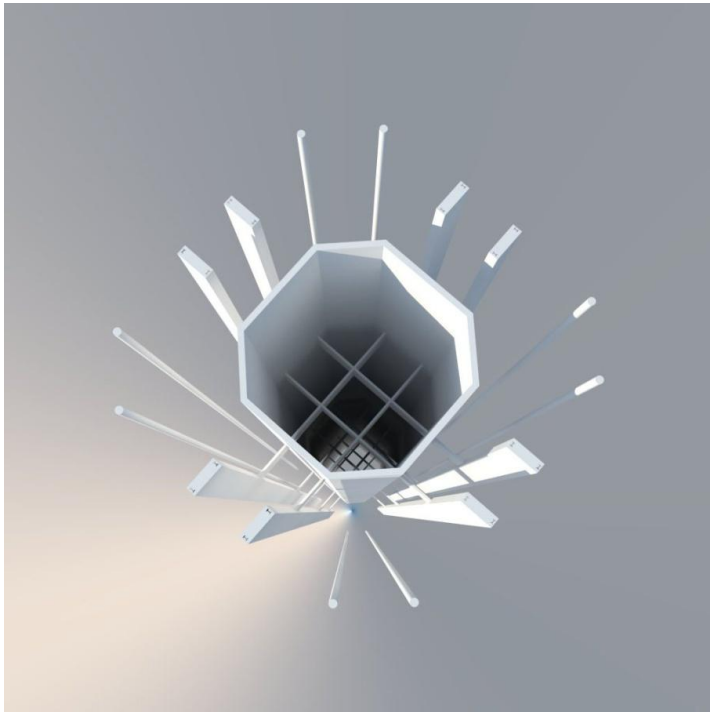
Connection description

- Jin Mao implanted a distinctive system of pins within the joints, forming a sort of hinge. These pins allow rotation and more flexibility during construction.



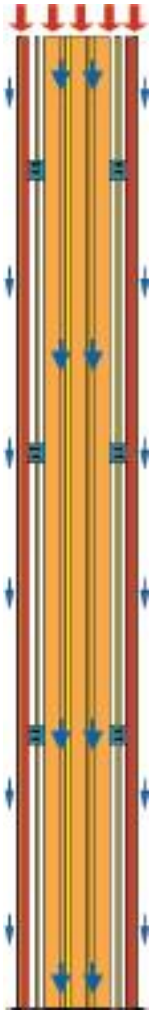
Loading Summary

- Jin Mao Tower weight 30t. The type of steel is H flange steel which has strong resistance on lateral forces and bending stress. The main components resisting lateral forces include reinforced concrete core. And through the stick-out trusses, the core connects with outsider super columns.



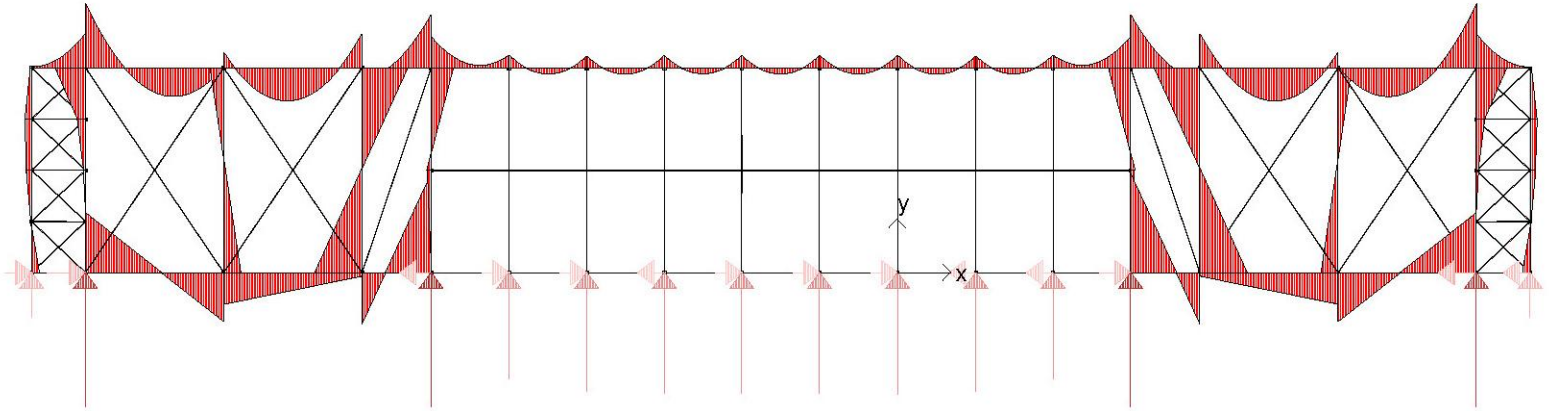
Loading Summary

- From the basement to 87th floor, the thickness of the core wall range from 850mm~450mm, while strength from C60 to C40. The overhang trusses provided efficient lateral resistance. It makes the building reach highest depth under deflection. Eight faces' wall provide special strength for twisting.



Loading Summary

- The overhang trusses locate at 24~26th levels, 51~53th levels and 85~87th levels. And at the 85~87th levels there is a three-dimensional frame, which has a shape of pagoda.

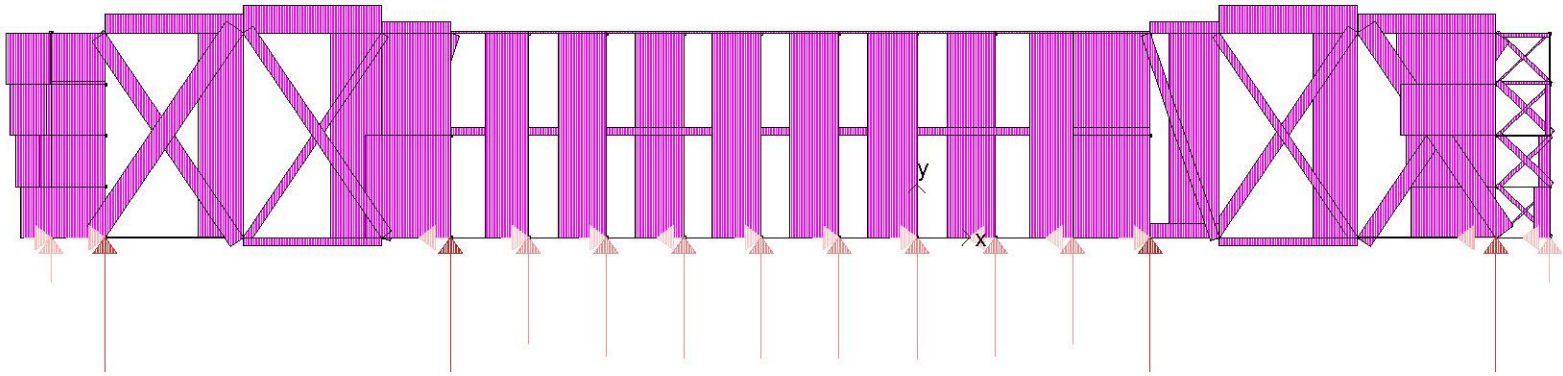


Bending Moment Diagram

Loading Summary

- It will sufficiently transfer the lateral forces from core and super columns.

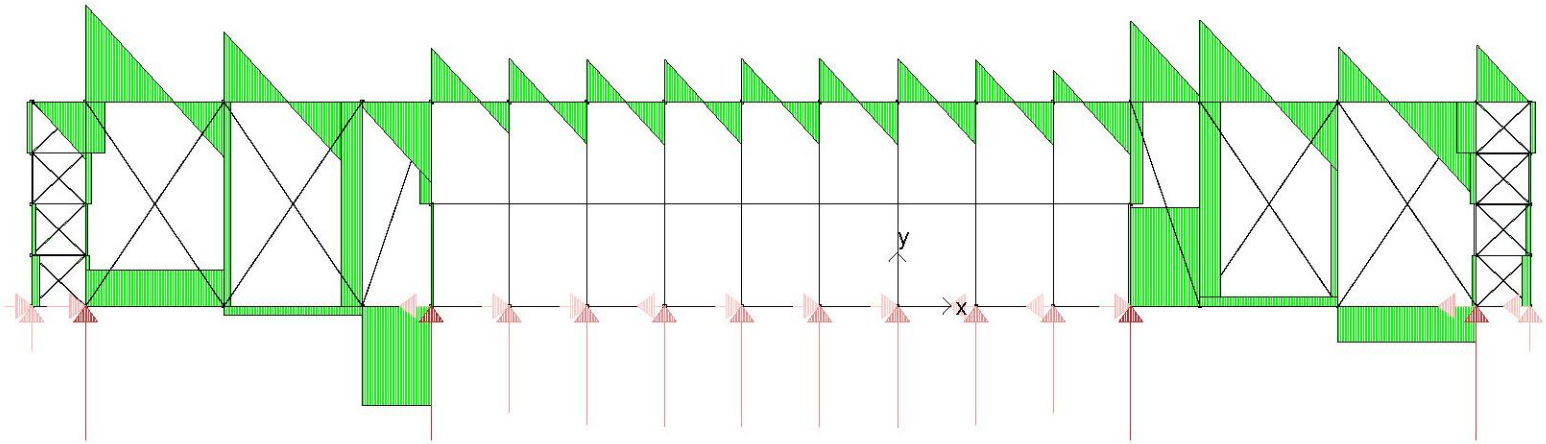
Meantime, this structure also solves the problems of partial horizontal systems, allowing the loads transferred to atrium.



Axial Forces Diagram

Loading Summary

- For self-weight, there are eight super columns and composite beams and truss beams. It also has composite contour plates with 76mm to 83mm normal weight panel.



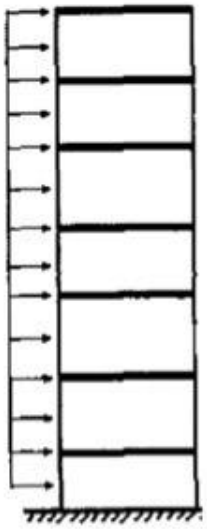
Shear Forces Diagram

Lateral Load analysis

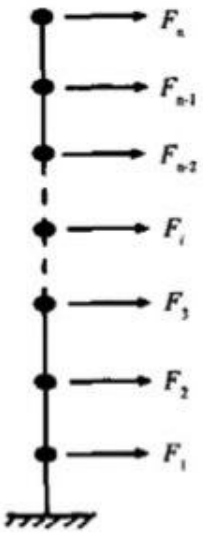
Design requirement

- Wind loads: 200km/h
- Seismic loads: 7 on the Richter scale.

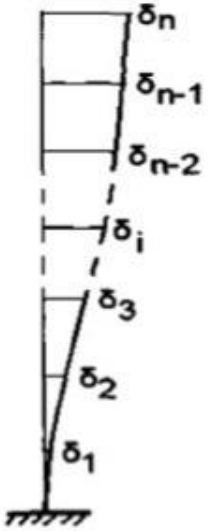
Deformation – side sway analysis



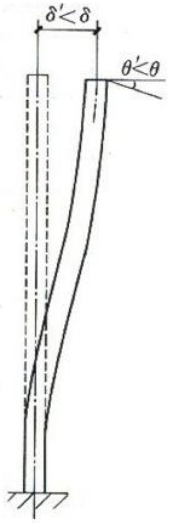
(a)Wind force load



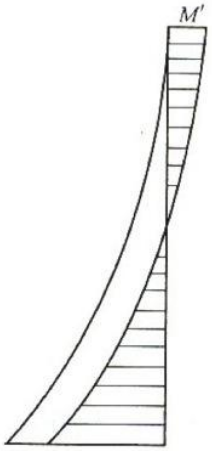
(b)calculate diagram



(c)displacement



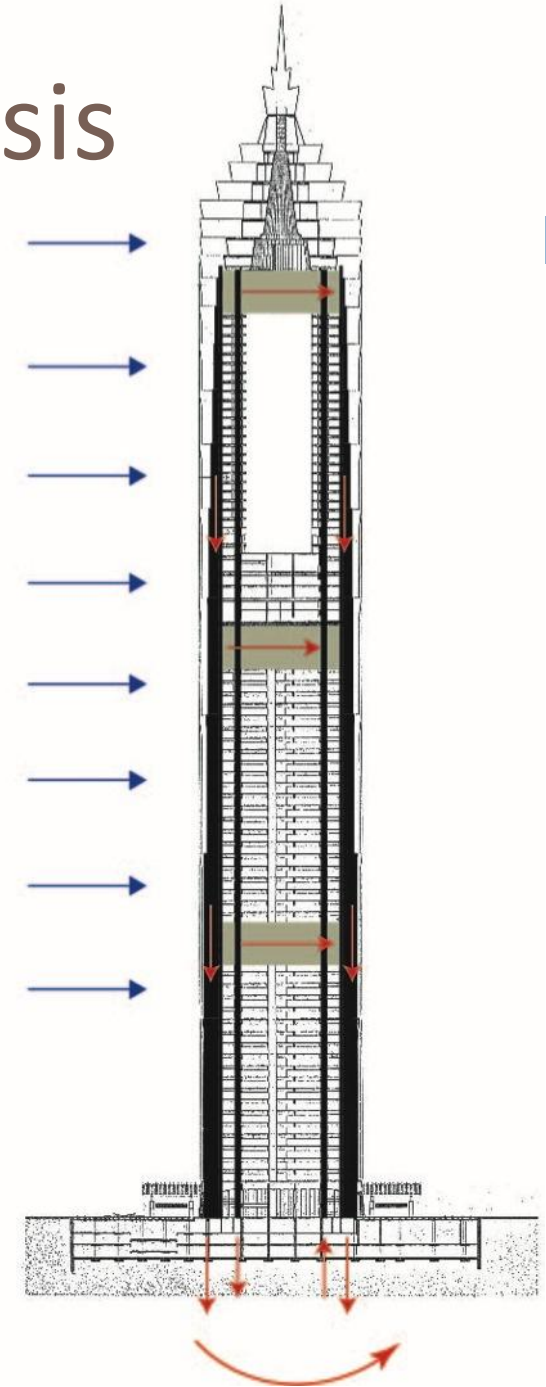
(d)deformation



(e)overturning moment

Lateral load transfer analysis

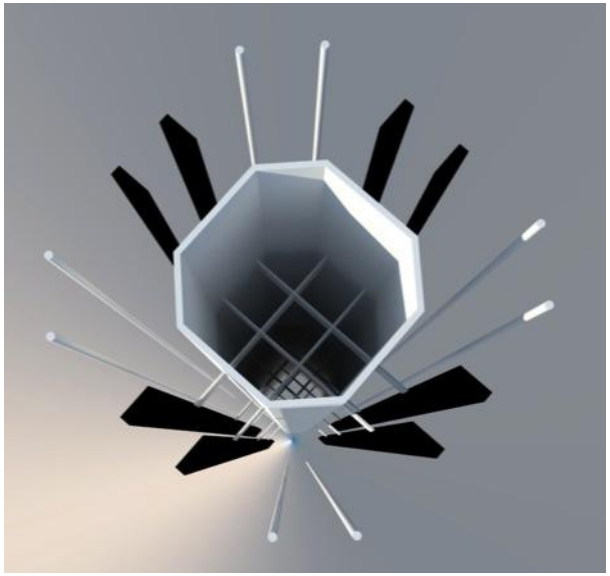
- Wind load works on the surface of the building, then transferred to super columns. With the trusses connection between super columns and core, the load finally reaches to the core and gets to the foundation.
- While horizontal forces working on the structure, the whole system generates inner inertial forces resisting the overturning and torsion induced. The outside symmetry super columns constitute of the force couple to resist the bending moment.



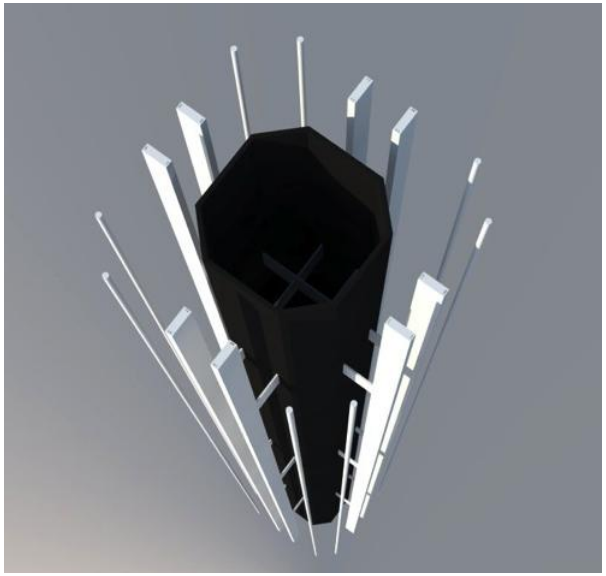
Lateral load components

Consist of

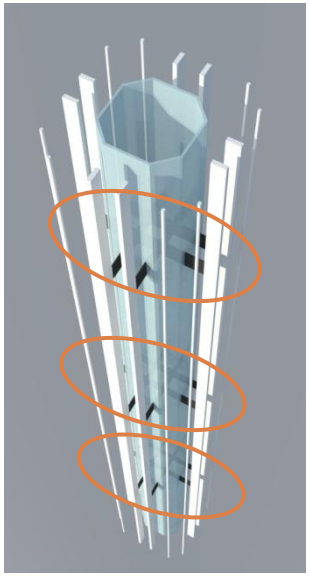
- braced frames in the core,
- outriggers from core to perimeter,
- super-columns and moment resisting frames in the perimeter



Super columns



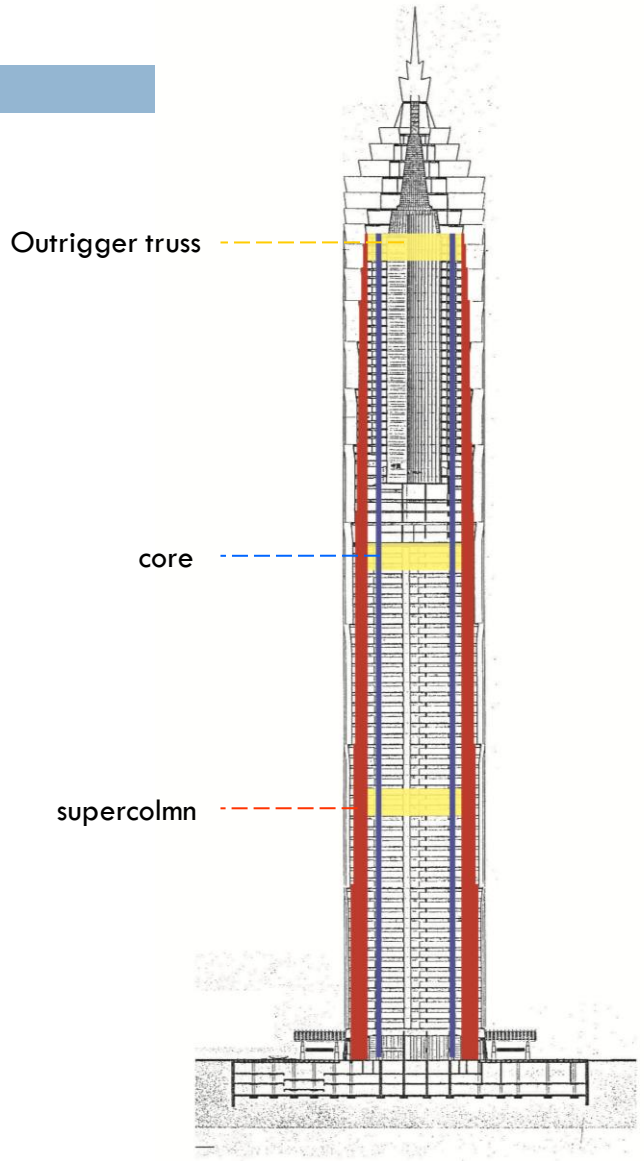
core



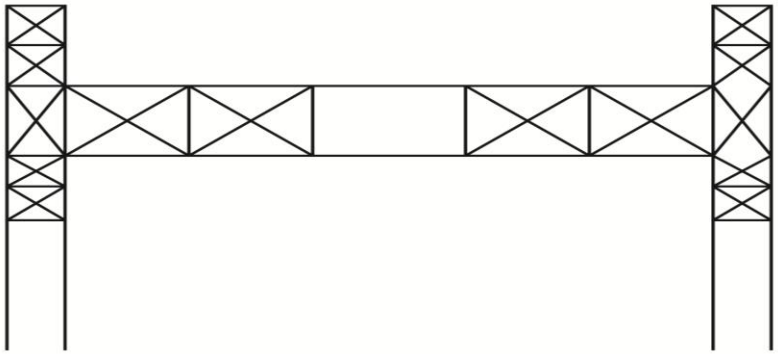
outriggers truss

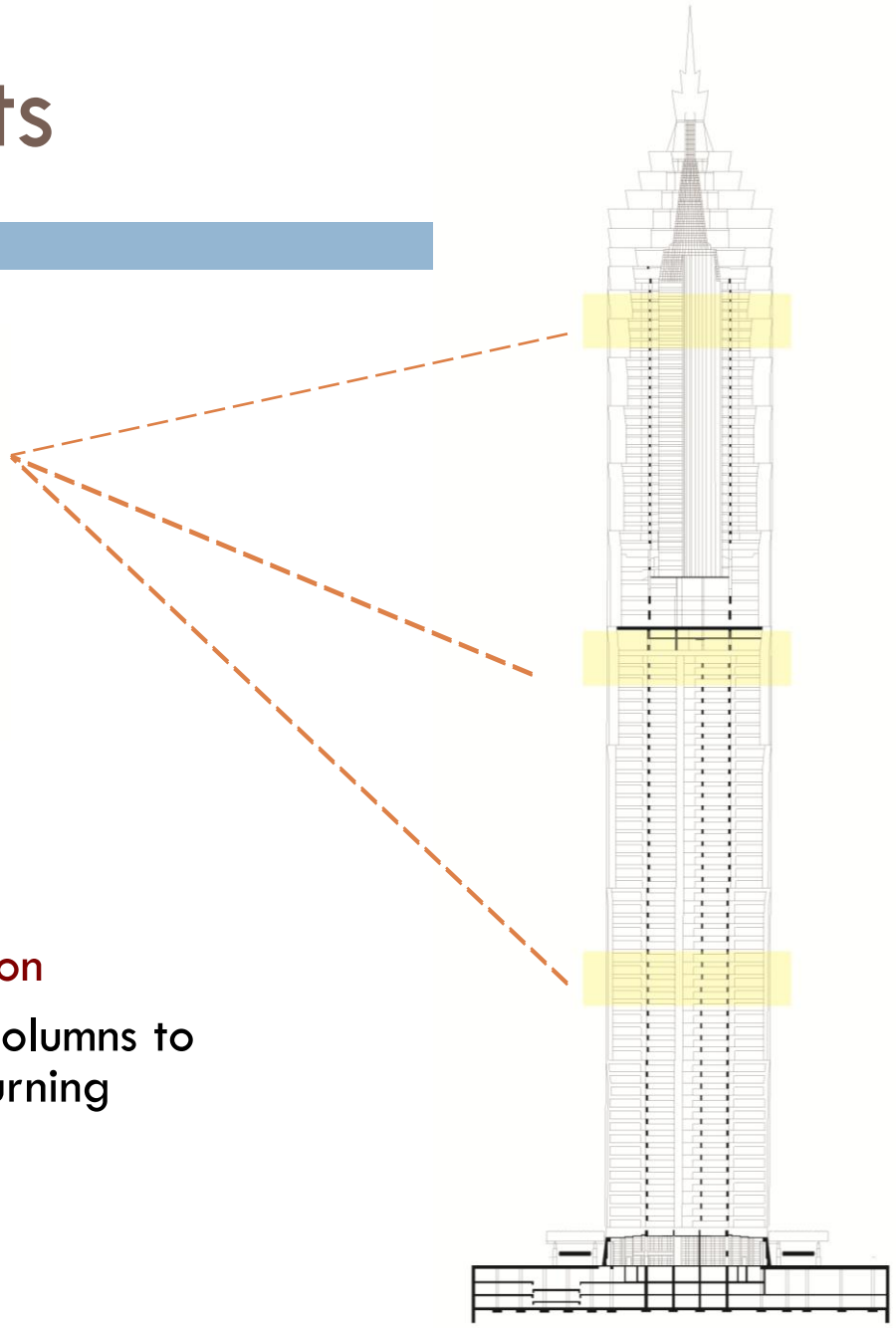
Lateral Load resisting system

- How to resist load?
- Core and super columns connect through main beams on each floor and Outrigger Truss steel beams to form a space integrate structure resist to lateral loads.
- Core play the most important role on resisting moment, 8 super- columns are good for balancing overturning moment by outrigger truss connecting with core.



Structural Elements



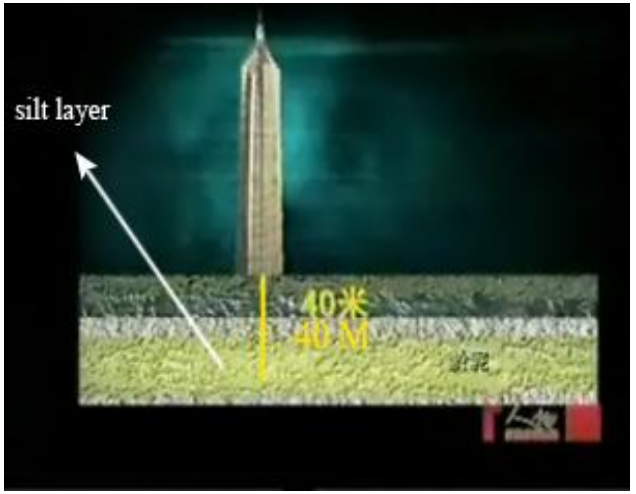


Outrigger truss

- carry on lateral loads
- improve whole ability to resist torsion
- transfer the floor gravity to super columns to balance the force caused by overturning moment.

Foundation

Shanghai is located in alluvial plain, whose forty meters underground is full of silt. So it must have enough bearing foundation to build skyscrapers there. Then, this situation needs Jin Mao Tower's foundation must traverse the silt layer and reaches the hard sand bed. In a general way, the depth of skyscrapers' foundation is equivalent to one over fifteen of the building height.



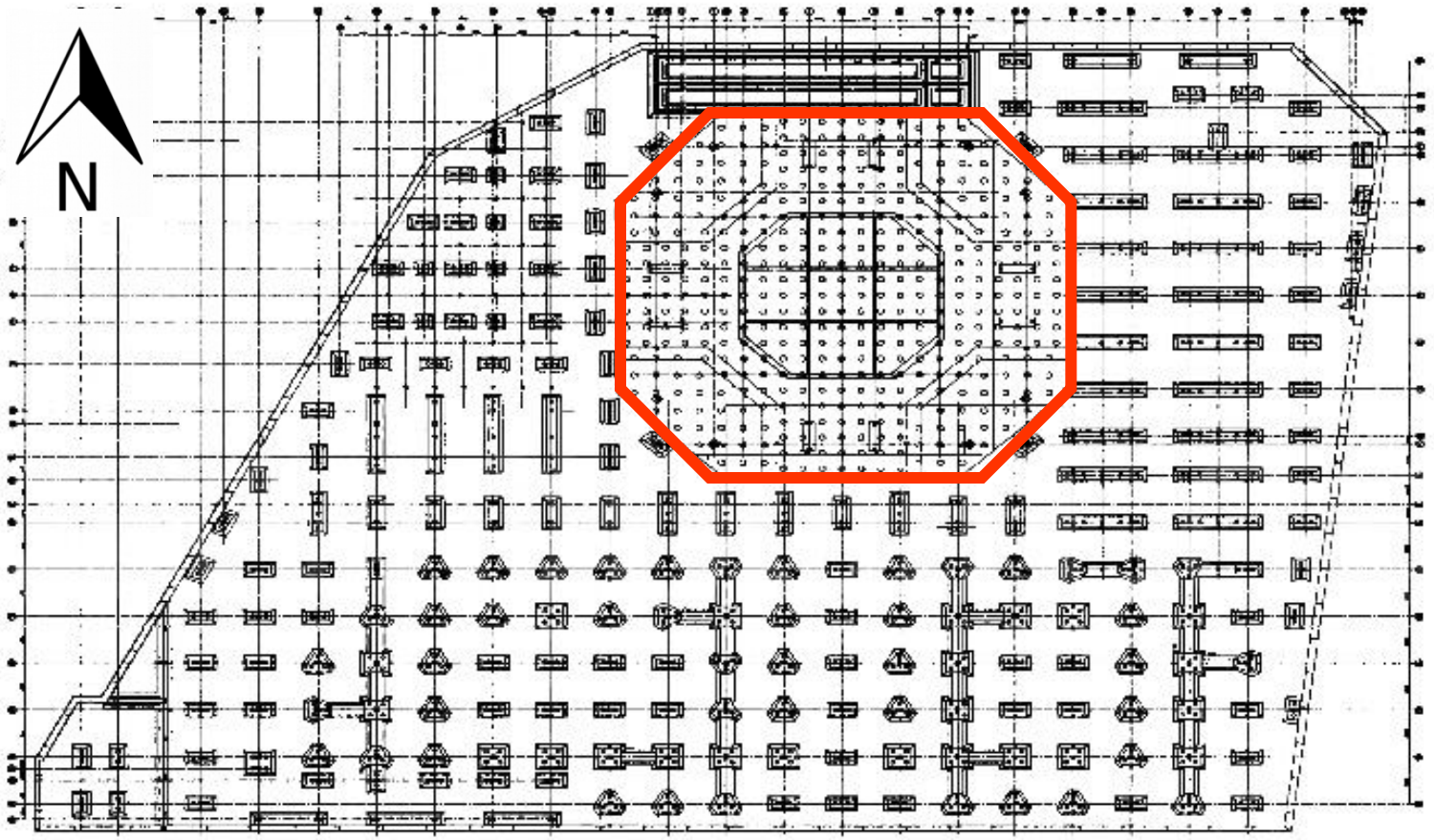
Foundation

Around the center part of the skyscraper, structural engineers design a reinforced concrete protective structure; and upgrade is high strength concrete and steel structure composite structure. Under the skyscraper's framework, there is a 4 meters thick reinforced concrete raft foundation and 429 roots Ø900m hollow steel piles.
The foundation under the podium uses small steel pipe piles, which reach the seventh soil layer.

Foundation

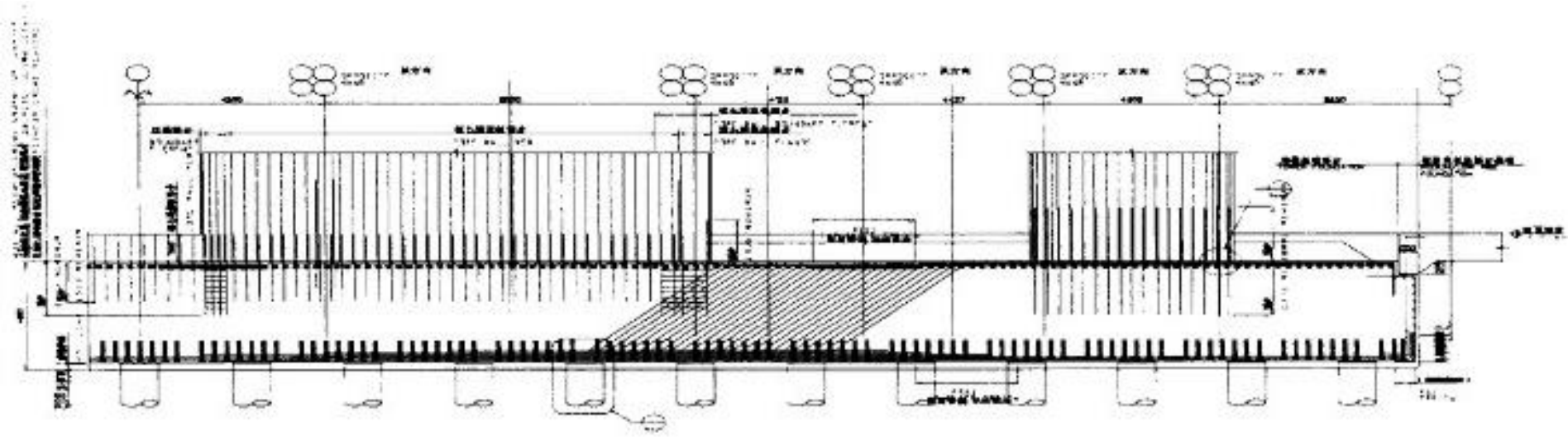
The foundation pit perimeter of this project is 568 meters, the depth is 15~19 meters, the area is nearly 2X104 m2, and the total earth cutting quantity is 32X104 m3. The foundation slab of the main building is 4 meters thick, and the total amount is 13500m^3, the strength of concrete is C50.

Foundation



Foundation Plan

Foundation



Pad Section