MIDDLE EAST TECHNICAL UNIVERSITY
DEPARTMENT OF ARCHITECTURE / BUILDING SCIENCE PROGRAM

BS 536
STUDIES ON TALL BUILDINGS: DESIGN CONSIDERATIONS
Fall 2017-2018

Case Study: **Chengdu Greenland Tower**
by
Guxim Rrudhani

Submitted to: Assoc.Prof.Dr. Mehmet Halis Günel
Assist.Prof.Dr. Bekir Özer Ay

CHENGDU GREENLAND TOWER

Source: Mark Fisher

Case Study: **Chengdu Greenland Tower** by Guxim Rrudhani
Submitted to: Günel, Ay – Fall 2017

Photo source: [1]

CHENGDU GREENLAND TOWER

GENERAL INFORMATIONS:

- Official Name: Chengdu Greenland Tower [1]
- Name of Complex: Chengdu Greenland Center [1]
- Structure Type: Building [1]
- Status: Under Construction [1]
- Country: China [1]
- Height To Tip: 468 m / 1,535 ft [1]
- Height: Architectural: 468 m / 1,535 ft [1]
- Height: Occupied: 448.2 m / 1,470 ft [1]
- Floors Above Ground 101 [1]
- Building Function: Hotel/office [1]
- Structural System: Outrigggered Frame System [2]
  Dual System: [3]
  Outriggered Frame System + Exterior Bracing System [3]
- Slenderness ratio: 9.5 < n
- Structural Material: Composite [1]
  -Core: Reinforced Concrete [1]
  -Columns: Composite (Concrete Encased Steel) [1]
  -Braces: Steel [1]
  -Floor Spanning: Steel [1]
- Proposed: 2011 [1]
- Construction Start/End: 2014/2019 [1]
- Developer: Greenland Group [1]
- Architect: Adrian Smith + Gordon Gill Architecture [1]
- Structural Engineer: Thornton Tomasetti [1]

[1] Skyscraper Center
[2] BS536 Studies on tall buildings: Design Considerations – Course (METU Dep. of Architecture)
[3] Dennis Poon, Research Paper "Designing a Non-Coplanar Exoskeleton Supertall Tower that Transforms the Skyline of Chengdu" CTBUH-New York Conference 2015
[4] Calculated by Guxim Rrudhani

OVERVIEW OF THE PROJECT

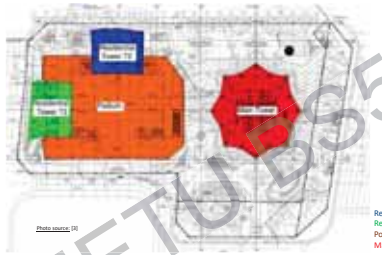


Photo source: [3]

Residential Tower T2 – 167 meters
Residential Tower T3 – 174 meters
Podium – 30 meters
Main Tower – 468 meters

- The Chengdu Greenland Center project has an overall site area of 24,530 square meters. Apart from the main tower, the two high-rise residential towers are 167 meters and 174 meters, respectively. Both towers also have faceted geometry, but to a lesser degree of complexity. Between the main tower and the two shorter towers, there is a four-story podium with a height of 30 meters. The podium also adopts a faceted design surface to be consistent with the rest of the project, and it mainly houses a conference center and meeting rooms. [3]

[3] Dennis Poon, Research Paper "Designing a Non-Coplanar Exoskeleton Supertall Tower that Transforms the Skyline of Chengdu" CTBUH-New York Conference 2015

STRUCTURAL SYSTEM

Photo source: [3]

- Structural system: Outriggered Frame System. [2]
- Dual System:
  Outriggered Frame System+ Exterior Bracing System. [3]
  (Unlike American building codes, China has a mandatory stiffness requirement for a dual system with central cores. In general, the perimeter frame, as the second line of defense, is required to be stiff enough (not just strong enough) to take at least 10% of the base shear.[3])

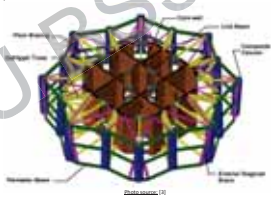
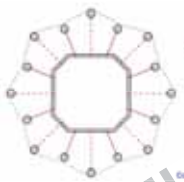


Photo source: [3]

[2] BS536 Studies on tall buildings: Design Consideration
[3] Dennis Poon, Research Paper "Designing a Non-Coplanar Exoskeleton Supertall Tower that Transforms the Skyline of Chengdu" CTBUH-New York Conference 2015

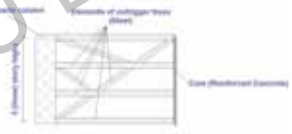
- Outrigger application



Level 25 typical MEP floor

Drawn by Guxim Rrudhani, based on [3].

- Outrigger truss



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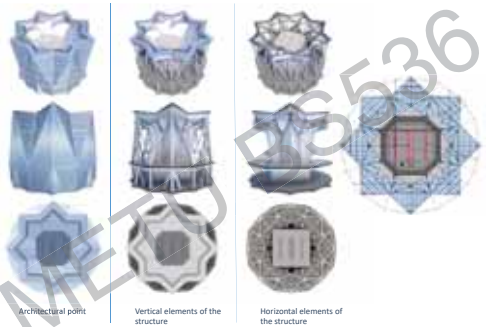
[3] Dennis Poon, Research Paper "Designing a Non-Coplanar Exoskeleton Supertall Tower that Transforms the Skyline of Chengdu" CTBUH-New York Conference 2015



Architectural point | Vertical elements of the structure | Horizontal elements of the structure

Photo source: Adrian Smith + Gordon Gill Architects [5]

TOWER ELEVATION

Three sets of outrigger trusses are placed at levels 23 to 26, levels 47 to 50, and levels 98 to 100 respectively. All three zones are mechanical equipment floors, minimizing the impact of the outrigger trusses on occupied building space. When connected to the core through outriggers, the exoskeleton provides very large stiffness against tower flexure. [3]

Three Sets of Outrigger Trusses:
- Levels 23-26
- Levels 47-50
- Levels 98-100

Note: Height numbers are scaled down by Guxim Rrudhani, and they are not confirmed by author.

Photo source: [3]

[3] Dennis Poon, Research Paper "Designing a Non-Coplanar Exoskeleton Supertall Tower that Transforms the Skyline of Chengdu" CTBUH-New York Conference 2015

FUNCTION OF BUILDING

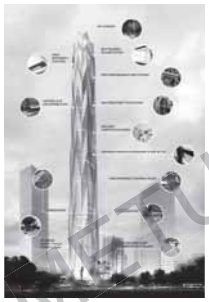


Photo source: Pinterest [6]

Photo source: Adrian Smith + Gordon Gill Architects [5]

FLOOR PLAN

- OCTAGON BASE FLOOR SHAPE

Level 14 typical refugee floor

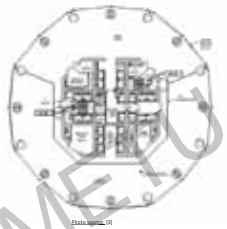


Photo source: [3]

- A nine-cell octagonal core is placed at the center of the plan. The shape of the core is similar to that of the tower floor plate.
- Core: Reinforced Concrete (28x28 meters to 24x24 meters from bottom to top. [4]

[3] Dennis Poon, Research Paper "Designing a Non-Coplanar Exoskeleton Supertall Tower that Transforms the Skyline of Chengdu" CTBUH-New York Conference 2015

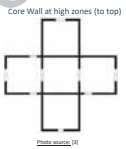
CORE WALL

Photo source: [3]

- The core reduces dimension by having a segment of sloping walls from levels 50 to 61, making the tower the first high-rise building in China to have a sloping core. [3]

Core Wall at low zones

Photo source: [3]



Core Wall at high zones (to top)

Photo source: [3]

[3] Dennis Poon, Research Paper "Designing a Non-Coplanar Exoskeleton Supertall Tower that Transforms the Skyline of Chengdu" CTBUH-New York Conference 2015

- 16 perimeter columns.
- The diameter of the circular columns is 2.8 meters at the bottom and reduces to 1.2 meters at the top. [2]

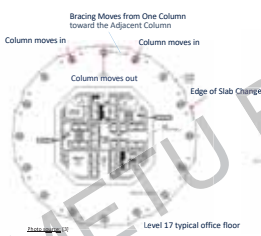


Photo source: [3]

Level 17 typical office floor

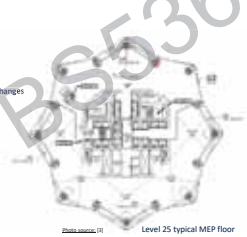


Photo source: [3]

Level 25 typical MEP floor

[3] Dennis Poon, Research Paper "Designing a Non-Coplanar Exoskeleton Supertall Tower that Transforms the Skyline of Chengdu" CTBUH-New York Conference 2015

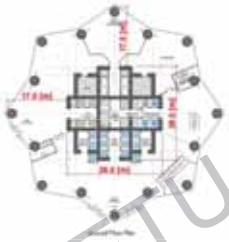


Photo source: Architectural Magazine DeZeen

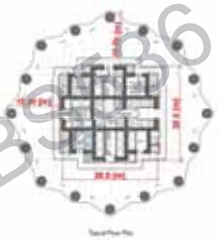
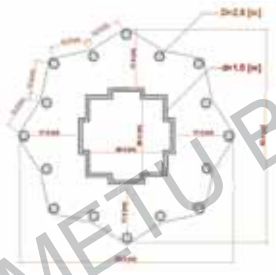


Photo source: Architectural Magazine DeZeen

Note: The dimension 17 [m] and 15.50 [m] are scaled down by Guxim Rrudhani, based on the core dimensions, which are known 28x28 [m]. These scaled down dimensions are not confirmed by author.



Drawn by Guxim Rrudhani, based on [3].
Note: The dimensions 17.0 [m]; 12.0 [m]; 2.8 [m] and 1.0 [m] are scaled down by Guxim Rrudhani, and they are not confirmed by author.

[3] Dennis Poon, Research Paper "Designing a Non-Coplanar Exoskeleton Supertall Tower that Transforms the Skyline of Chengdu" CTBUH-New York Conference 2015

FLOOR SYSTEM

Typical Floor Framing Plan

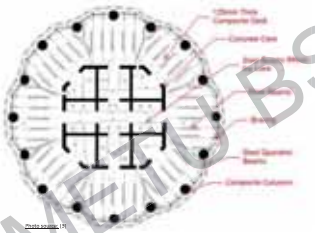


Photo source: [3]

Photo source: [3]

Photo source: [3]

[3] Dennis Poon, Research Paper "Designing a Non-Coplanar Exoskeleton Supertall Tower that Transforms the Skyline of Chengdu" CTBUH-New York Conference 2015

BASE FLOOR

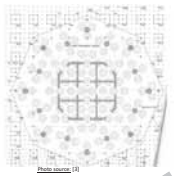


Photo source: [3]

GROUND FLOOR

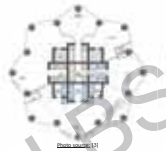


Photo source: [3]

LEVEL 14

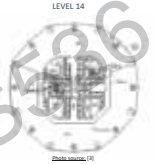


Photo source: [3]

LEVEL 17

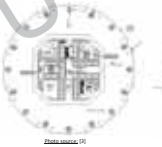


Photo source: [3]

LEVEL 25

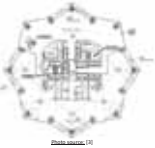


Photo source: [3]

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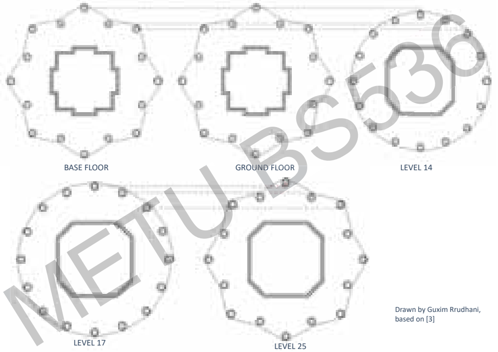

Drawn by Guxim Rrudhani, based on [3]

[3] Dennis Poon, Research Paper "Designing a Non-Coplanar Exoskeleton Supertall Tower that Transforms the Skyline of Chengdu" CTBUH-New York Conference 2015

BUILDING MODE SHAPES

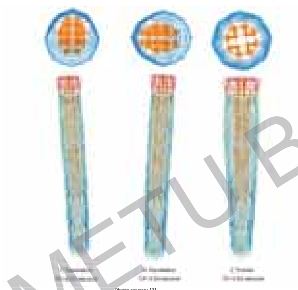

Photo source: [3]

- The outrigger trusses and the exoskeleton help provide a structural system stiff enough to meet the stringent story drift ratio limit required by China building codes. The maximum story drift is about h/500 under frequent earthquake seismic load (a 50-year return period seismic event) and h/1200 under the 50-year return period wind load. The fundamental first three building periods of the tower represents the X-direction translation, Y-direction translation and torsion, respectively. [3]

[3] Dennis Poon, Research Paper "Designing a Non-Coplanar Exoskeleton Supertall Tower that Transforms the Skyline of Chengdu" CTBUH-New York Conference 2015

NON-COPLANAR EXOSKELETON

- Columns + bracing + spandrel beams = non-coplanar exoskeleton

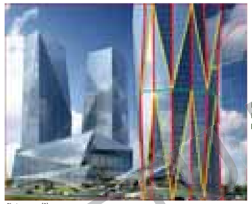

Photo source: [3]

COLUMNS Zigzag along the Tower Height.

BRACING on the edges between the adjacent triangles.

Heavier SPANDREL BEAMS at the kink Points.

- The mega-braces are all square steel tubes. The long mega-braces are braced at certain floors by floor beams to limit the maximum unbraced length to five floors. The sizes of the braces range from [400 mm x 400 mm] to [800 mm x 800 mm]. [3]
- 3D Exoskeleton with Column, Bracing, and Spandrel Provides an integrated stable lateral system for the Tower. [3]

Photo source: [3]

[3] Dennis Poon, Research Paper "Designing a Non-Coplanar Exoskeleton Supertall Tower that Transforms the Skyline of Chengdu" CTBUH-New York Conference 2015

Photo source: [3]

- The exoskeleton comprises of hundreds of triangular "units". Every unit is made up of one column, one mega-brace and one horizontal perimeter steel beam at the kink floor, which is reinforced to resist its share of the horizontal force caused by the mega-braces [3]
- The tower surface is multi-faceted surface made up of triangular pieces. [3]
- Every pair of adjacent triangles are not in the same plane. [3]

Photo source: [3]

- Typical Connection between Horizontal Beams/Braces and Column

Photo source: [3]

[3] Dennis Poon, Research Paper "Designing a Non-Coplanar Exoskeleton Supertall Tower that Transforms the Skyline of Chengdu" CTBUH-New York Conference 2015

FOUNDATION SYSTEM

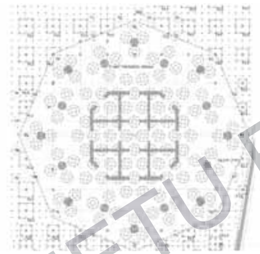

Photo source: [3]

- The foundation system of Chengdu Greenland tower is a 4.5-meter-thick reinforced concrete mat foundation supported on 112 piles. [3]
- 180 [cm] diameter piles bell out to 370 [cm] at the bottom. [3]
- 60 [cm] thick slab out of the Tower Region. [3]

[3] Dennis Poon, Research Paper "Designing a Non-Coplanar Exoskeleton Supertall Tower that Transforms the Skyline of Chengdu" CTBUH-New York Conference 2015

CONSTRUCTION UNDERGOING

Site preparation

Photo Source: www.forum.skyscraperpage.com [7]

Excavation

Photo Source: www.forum.skyscraperpage.com [7]

Excavation

Photo Source: www.forum.skyscraperpage.com [7]

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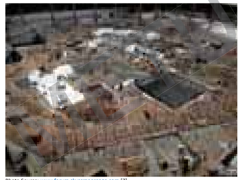

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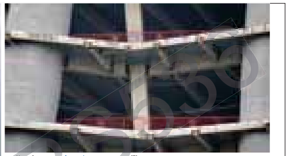

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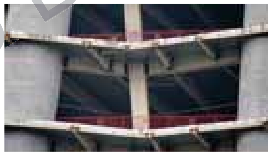

Photo Source: www.forum.skyscraperpage.com [7]

WHEN WILL BE COMPLETED !

Photo Source: www.forum.skyscraperpage.com [7]

Photo Source: www.forum.skyscraperpage.com [7]

REFERENCES

[1] Council on Tall Buildings and Urban Habitat, Skyscraper Center.
http://www.skyscrapercenter.com/building/chengdu-greenland-tower/12845

[2] BS536 Studies on Tall Buildings: Design Considerations.
(Course in Department of Architecture/Building Science, Middle East Technical University)

[3] Dennis Poon, Research Paper "Designing a Non-Coplanar Exoskeleton Supertall Tower that Transforms the Skyline of Chengdu" CTBUH-New York Conference 2015.

[4] Calculation of Slenderness ratio and drawings by Guxim Rrudhani.

[5] Adrian Smith + Gordon Gill Architects.
http://www.smithgill.com/work/greenland_tower_chengdu
https://www.youtube.com/watch?v=hoR-1DG9Fp0

[6] Pinterest.
https://www.pinterest.com/pin/770326711232416816

[7] Forum of Chengdu Greenland Tower on Skyscraper page.
http://forum.skyscraperpage.com/showthread.php?t=209798