MIDDLE EAST TECHNICAL UNIVERSITY
DEPARTMENT OF ARCHITECTURE / BUILDING SCIENCE PROGRAM

BS 536
STUDIES ON TALL BUILDINGS: DESIGN CONSIDERATIONS
Spring 2014-2015

Case Study: **Pearl River Tower**
by
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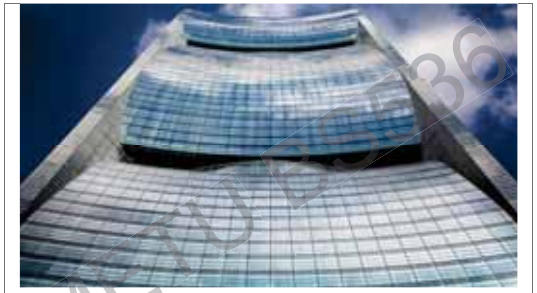
Submitted to: Assoc.Prof.Dr. Mehmet Halis Günel
Assist.Prof.Dr. Bekir Özer Ay



PEARL RIVER TOWER
GUANGHZHOU, CHINA

Image: http://www.som.com/FILE/19407/pearlriver_1575x900_timgriffith_08.jpg?h=800&s=17

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Submitted to: Günel, Ay – Spring 2015

PROJECT FACTS

Official Name: Pearl River Tower
Location: Guangzhou, Guangdong, China
Construction Period: 2006-2013
Building Function: Commercial + Office
Height: 309.4 m
Stories: 71 above ground
5 below ground
Project Area: 214.100 m2
Structural Material: Composite
Structural System: Outriggered frame system
Rankings (2015): Global ranking #65
Regional ranking #33
National ranking #27
City ranking #5
Architect: Skidmore, Owings & Merrill (design),
Guangzhou Design institute (architecture of record)
Structural Engineer: Skidmore, Owings & Merrill
MEP Engineer: Skidmore, Owings & Merrill
Main Contractor: Shanghai Construction Group

CTBUH – Council on Tall Buildings and Urban Habitat
Image: http://smithgill.com/media/images/project_images/534/pearl_4.jpg

AWARDS

- 2015 Award of Excellence: Sustainable Design Category
  Structural Engineers Association of Northern California
- 2014 Commercial High-Rise Architecture,
  China International Property Awards
- 2014 Green Good Design Award
  Chicago Athenaeum
- 2014 Architizer A+ Award: Office Building High-Rise, Finalist Architizer
- 2014 Most Innovative Project: Mechanical Systems Design
  AEI Affiliated Engineers
- 2013 Best Innovative Green Building
  MIPIM Asia
- 2013 Best Tall Building Asia & Australia: Finalist
  CTBUH
- 2012 Excellence in Engineering
  ASHRAE Illinois Chapter
- 2010 Green Good Design Award
  Chicago Athenaeum
- 2008 Green Carbon-Lowering & Environmental Category:
  Gold Award, Spark Awards

Image: http://21stcenturyarchitecture.blogspot.com.tr/2012/05/pear-river-tower-huallen-beach-resort.html

INTERIOR VIEWS

The building's main entry is on its south side, where projecting louvers create a portico-like space and bounce daylight deep into the lobby. Inside the double-story lobby, metal ceiling panels and fritted glass enhance the light and airy effect. The office floors benefit from a coordinated set of systems, including a curved double-skin curtain wall with integrated shades, a coved radiant ceiling, and raised-floor displacement ventilation.

Fig1: Main entrance

Fig2: Typical office floor

Fig3: Lobby

Fig4: Lobby

Fig1 retrieved from http://architecturalconstruction.com/projects/portfolio/2014/03/1403-Pearl-River-Tower-Skidmore-Owings-and-Merrill-slideshow.asp?slide=3
Fig2 retrieved from http://architecturalconstruction.com/projects/portfolio/2014/03/1403-Pearl-River-Tower-Skidmore-Owings-and-Merrill-slideshow.asp?slide=7
Fig3 retrieved from http://www.som.com/FILE/13729/pearlcitytower_1400x800_si.yezhan_03.jpg?h=800&s=17
Fig4 retrieved from http://architecturalconstruction.com/projects/portfolio/2014/03/1403-Pearl-River-Tower-Skidmore-Owings-and-Merrill-slideshow.asp?slide=4

SITE CHARACTERISTICS

The city of Guangzhou experiences some of the worst air pollution on the planet. China's growing economy has increased their energy consumption; this in turn has led to a rapid growth in carbon emissions. In response to these problems, high-performance buildings become a necessity.[1] The Pearl River Tower is one of many tall buildings that have recently sprouted in Guangzhou's new business district. It is located according to the dominant wind direction.

Fig5: Site plan view

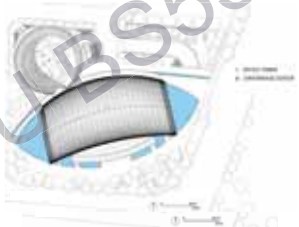


Fig6: Site plan drawing

[1] Frechette, R. Gillchrist, R. (2008).*Case Study: Pearl River Tower, Guangzhou, China.* CTBUH 2008 8th World Congress, Dubai.
Fig5 retrieved from CTBUH 2008 Dubai Congress presentation
Fig6 retrieved from http://archrecord.construction.com/projects/portfolio/2014/03/1403-Pearl-River-Tower-Skidmore-Owings-and-Merrill-slideshow.asp?slide=11

DESIGN PRINCIPLES

- The initial design concept was to develop a supertall building capable of having a 'net-zero' annual energy impact on the city. As the design progressed, due to economical considerations and regularity challenges, the building is no longer be able to meet net zero standards. Yet, it consumes %60 less energy than an equivalent building.[1]
- All morphological features of the building designed aerodynamically to enhance turbine performance. East and west elevations are straight, while the south façade is concave and the north façade is convex.[2]
- Due to these innovative efforts, the building is currently acknowledged as the most energy efficient supertall building in the world.[2]

Fig7: Design idea diagram

[1] Frechette, R. Gillchrist, R. (2008).*Case Study: Pearl River Tower, Guangzhou, China.* CTBUH 2008 8th World Congress, Dubai.
[2] Tomlinson, R. Baker, W., Leung, L.,Chien, S. & Zhu, Y.(2014).Case Study: Pearl River Tower, Guangzhou, China. CTBUH Journal , 14(2).
Fig7 retrieved from http://educazionetecnica.dantect.it/wp-content/uploads/2012/08/11-Pearl-River-Tower.jpg

BUILDING FUNCTIONS

The Pearl City covers an area of 10636 m2 and includes an office tower and podium with a floor area ratio of 16.[3]

- The tower was developed into a 71-story building with height of 310 m and total gross area of 210,000 m2 of which 40,000 m2 for 5-story basement for parking garage.[3]
- The podium with associated conference facilities is a 3-story building with height of 27 m.
- Two mechanical floors are located on 23th-27th and 49th-53th floors where two pairs of building-integrated vertical axis wind turbines (VAWTs) inserted.[3]
- The core surrounds elevators, elevator lobbies, exit stairs, washrooms, mechanical shafts and storage rooms. The core occupies approximately %20 of the floor area. (Floor efficiency ratio is ~ 0.8)

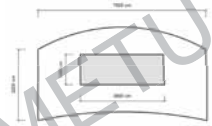


Fig8: Typical floor schematic plan drawing
drawn by **Havva Nur Tümbaş**

1 MAIN LOBBY
2 OFFICE SPACE
3 CORE
4 MECHANICAL
5 BUSINESS CLUB
6 CONFERENCE CENTER
7 PARKING

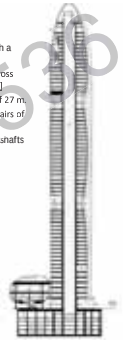
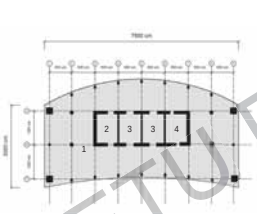


Fig9: Section drawing

[3] Mazen, B., Radwan, M. & Abdel-Samiea, M. (2015, June 2). *Utilization of Wind Energy in Fast Developing High-Rise Buildings: A Case Study of the Pearl River Tower, Guangzhou, China.*p.1.
Fig9 retrieved from http://archrecord.construction.com/projects/portfolio/2014/03/1403-Pearl-River-Tower-Skidmore-Owings-and-Merrill-slideshow.asp?slide=13

ARCHITECTURAL DRAWINGS



1 OPEN OFFICE SPACE
2 SERVICE SHAFTS
3 ELEVATORS
4 WET SPACES AND SERVICE SHAFTS

Fig10: Typical floor plan
drawn by **Havva Nur Tümbaş**

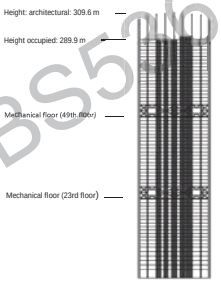


Fig11: South elevation
drawn by **Havva Nur Tümbaş**

STRUCTURAL SYSTEM

Interior reinforced concrete "supercore" shear wall system, which is linked to the exterior columns by a series of outrigger and belt trusses and composite mega columns linked by diagonal end bracing.
Shear wall thicknesses of the core range from approximately 700 to 1,500 millimeters over the height of the building.
Exterior columns are linked to the reinforced concrete core wall and corner mega columns by a system of outrigger and belt trusses at two mechanical areas in the building, levels 23–27 and levels 49–53.
The belt trusses at the outrigger levels provide uniform distribution between exterior columns and link them to the corner mega columns. [4]

The tower's structural system consists of;

- Central reinforced concrete supercore
- The exterior steel columns
- Steel spanning beams
- Steel floor framing that links exterior columns to the concrete core
- Steel end-bracings

[4] Tomlinson, R.,Baker, W., Leung, L.,Chien, S. & Zhu, Y.(2014).Case Study: Pearl River Tower, Guangzhou, China. *CTBUH Journal* ,14(2), p.14.

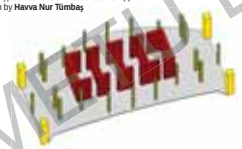
Fig12: Southwest perspective
drawn by **Havva Nur Tümbaş**

COLUMN AND SHEAR WALL APPLICATION

Fig13: Typical floor – column and shear wall application
drawn by **Havva Nur Tümbaş**

Core
Material: Reinforced concrete
Dimension: range from bottom to top: ~150 to 70cm

Mega column (4 units)
Material: Composite
Dimension: ~250x250 cm



Perimeter columns (16 units)
Material: Steel
Dimension: ~80x100 cm

Internal columns (4 units)
Material: Steel
Dimension: ~125x125 cm

Fig14: Mechanical floor – column and shear wall application
drawn by **Havva Nur Tümbaş**

MECHANICAL FLOOR - STRUCTURAL ELEMENTS

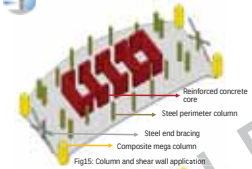


Fig15: Column and shear wall application

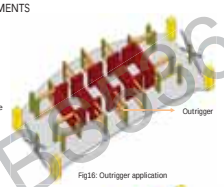


Fig16: Outrigger application

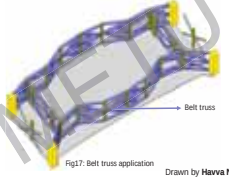


Fig17: Belt truss application

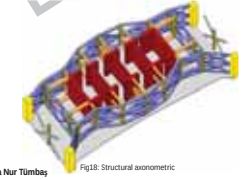


Fig18: Structural axonometric

Drawn by **Havva Nur Tümbaş**

STRUCTURAL SYSTEM

Fig19: Organization of structural system
drawn by **Havva Nur Tümbaş**

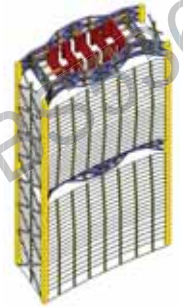


Fig20: Organization of structural system
drawn by **Havva Nur Tümbaş**

STRUCTURAL PERSPECTIVES

Fig21: Partial of northwest perspective
drawn by **Havva Nur Tümbaş**

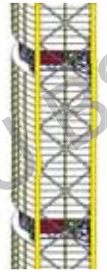


Fig22: Partial of west perspective
drawn by **Havva Nur Tümbaş**

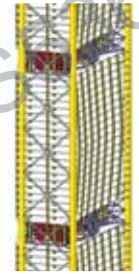


Fig23: Partial of southwest perspective
drawn by **Havva Nur Tümbaş**

CONSTRUCTION PROCESS

Fig24: Belt Truss photo - 1

Fig25: Belt Truss photo - 2

Fig26: Structural frame

Fig24 retrieved from http://i110.photobucket.com/albums/n90/shortingmo/Pearl%20river%20new%20town/2009%20aug%2009/IMG_2097.jpg
Fig25 retrieved from http://s110.photobucket.com/user/shortingmo/media/ksef%20river%20new%20town/ 2009%20aug%2009/IMG_2097.jpg.html
Fig26 retrieved from http://www.aleshoffordphotography.com/temp/files/ Guangzhou-NewCBD-04.jpg

HIGH PERFORMANCE FEATURES

The tower is one of the fist supertall buildings to be certified as a LEED® PLATINUM building by the US Green Building Council (USGBC) – the highest level of sustainable design recognized by the internationally recognized organization.[5]

- Exterior façade
- Wind turbines
- Integrated photovoltaics (pvs)
- Radiant cooling coupled with underfloor air ventilation
- Daylight-responsive controls
- Daylight reflectors
- High-efficiency lighting
- High-efficiency chiller system

[5] Tomlinson, R.,Baker, W., Leung, L.,Chien, S. & Zhu, Y.(2014).Case Study: Pearl River Tower, Guangzhou, China. *CTBUH Journal* ,14(2), p.14

Fig 27: Rendering image from southwest perspective

Fig 27 retrieved from http://www.chinesearchitecture.cn/CACN/Images/Guangzhou/PearlRiverTower-001.jpg

HIGH PERFORMANCE FEATURES/WIND TURBINES

- Energy is generated by the highly visible wind turbine system integrated into the building's design and structure .[6]
- The tower's curvilinear form enhances performance by funneling air through turbine inlets in the façade, optimizing the pressure difference between the windward and leeward side of the building.[6]
- Wind studies predict the façade inlets will accelerate wind velocity by a factor of 2.5, resulting in more than 8 times the power generation when compared to a turbine located in an open field. [6]

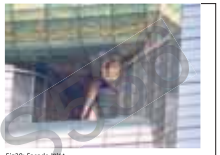


Fig28: Façade inlet

Fig29: Vertical axis wind turbine

[7] Tomlinson, R.,Baker, W., Leung, L.,Chien, S. & Zhu, Y.(2014).Case Study: Pearl River Tower, Guangzhou, China.*CTBUH Journal* ,14(2), p.15.
Fig28 retrieved from http://i1.ytimg.photobucket.com/albums/r5/z0rgg/PearlRiverTower5_t1kHw1YNNVCM.jpg
Fig29 retrieved from http://www.som.com/FILE/17811/pearlriver_mep_700x800_som_06.jpg?h=800&s=1

HIGH PERFORMANCE FEATURES/FAÇADE DESIGN

- The façade system is oriented to optimize the use of daylight while controlling solar loads. [8]
- Photovoltaics (pvs) are integrated with the building envelope, serving the dual function of building skin and power generator. [7]
- They are asymmetrically located on the building's vaulted roof glass and incorporated into the sunshade devices on the east and west façades where they yield maximum results.[7]

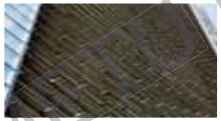


Fig30: Photovoltaics panel from west façade

Fig31: Vaulted roof with solar panels

[8] Tomlinson, R.,Baker, W., Leung, L.,Chien, S. & Zhu, Y.(2014).Case Study: Pearl River Tower, Guangzhou, China.*CTBUH Journal* ,14(2),p.14.
Fig30 retrieved from http://wntiepass.com/journal/wp-content/uploads/media/the_pearl_river_tower_partial_report/image5.png
Fig31 retrieved from: http://assets.inhabitat.com/wp-content/blogs.dir/1/files/2010/03/Pearl-River-Tower-Green.jpg

HIGH PERFORMANCE FEATURES/BUILDING ENVELOPE

- The building envelope's cavity is mechanically ventilated from the occupied space via low-level inlets under the inner monolithic glass. A ducted return air connection at the top of the cavity pulls warmed air through their space and returns it to the air handling unit.[8]
- The movement of room air through the ventilated cavity is critical to limiting solar gain, especially on the south elevation. once the hot return air is delivered back to the air handling system, the building automation system (bas) control sequences decide whether to exhaust this air or use some to mix with the ventilation air for heat exchange. [9]

Fig32: Double skin façade

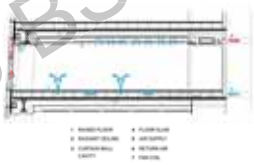


Fig33: Climate control diagram

[8] Tomlinson, R.,Baker, W., Leung, L.,Chien, S. & Zhu, Y.(2014).Case Study: Pearl River Tower, Guangzhou, China.*CTBUH Journal* ,14(2),p.14.
[9] Epstein, K.(2015,June 2). *How Far Can You Go?: Case Study: Pearl River Tower.* p24.
Fig32 retrieved from http://cdn.greendiary.com/wp-content/uploads/2012/07/pearl-river-tower4_TD7He_24429.jpg
Fig33 retrieved from http://archrecord.construction.com/projects/portfolio/2014/03/images/Pearl-River-Tower-Skidmore-Owings-and-Merrill-14Spx8.jpg

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