MIDDLE EAST TECHNICAL UNIVERSITY
DEPARTMENT OF ARCHITECTURE / BUILDING SCIENCE PROGRAM

BS 536
STUDIES ON TALL BUILDINGS: DESIGN CONSIDERATIONS
Fall 2009-2010

Case Study: **Petronas Towers**
by
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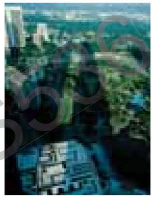
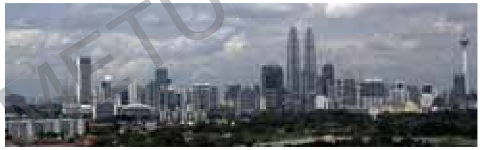
Petronas Towers

Kuala Lumpur City Centre, Malaysia

Outline



P1:Baker, Philippa (ed.). Architecture and Polyphony: Building in the Islamic World Today. Retrieved from http://archnet.org/library/documents/one-document.jsp?document_id=10229



P2:www.wikipedia.com

Petronas Towers

Client
Kuala Lumpur City Centre Holdings Sendirian Berhad
Architect
Cesar Pelli & Associates, US
Engineers
Thornton-Tomasetti Engineers, US, and Ranhill Bersekutu
Contractors
Tower 1 – Mayjus Joint Venture:
MMC Engineering & Construction Co. Ltd, Malaysia
Tower 2 – SKJ Joint Venture:
Samsung Engineering & Construction Co Ltd, S.Korea
(Ref. b)

P3: Abada, Galal. (2004). *Petronas office towers* [On site review report]. Retrieved from http://archnet.org/library/files/one-file.jsp?file_id=1403

The Petronas Towers were designed to be the centrepiece of a larger complex called the Kuala Lumpur City Centre (KLCC), a mixed-use development with a site area of 14.15 acres, which includes the towers, two other office towers, underground parking and service facilities. The project site is well located in the heart of the commercial district of the city, the 'Golden Triangle'. (Ref. c)

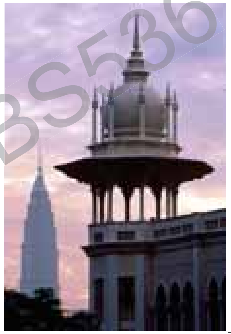
Introduction

Use: Office
Status: Completed
Global ranking: Petronas Twin Towers were the world's tallest buildings from 1998 to 2004.
Preceded by Willis Tower **Surpassed** by Taipei 101
Material: Composite
Height: 1,483 ft (452 meters)
Official Opening: August 28, 1999
Construction April 1993–August 1999
Site area, KLCC 40.5 hectares
Site area, Petronas and retail 5.8 hectares
Built area 218,000m2 each tower 994,000m2
Cost US$ 800,000,000
(Ref. b)

P4: Abada, Galal. (2004). *Petronas office towers* [On site review report]. Retrieved from http://archnet.org/library/files/one-file.jsp?file_id=1403

Architectural Description

This project has received an Aga Khan Award because it represents a new direction in skyscraper design, featuring advanced technology while symbolizing local and national aspirations. The project embodies several innovations, ranging from the use of unusually high-strength concrete to facilitate a soft-tube structural system, to an inventive vertical transportation concept and the integration of cutting-edge energy conservation systems. The success of this project lies in the manner in which it incorporates these technological innovations while generating a slender form that responds poetically to the broader landscape. The simple geometrical pattern that generates the plan not only uses space efficiently to maximize exposure to natural light, but also creates a rich spatial expression. The building has become an icon that expresses the sophistication of contemporary Malaysian society and builds on the country's rich traditions to shape a world city. (Ref. b)

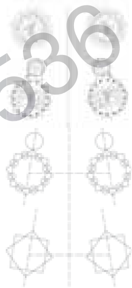


P5: Ref: Pelli, Cesar, & Crosbie, Michael. (2001). *Petronas twin towers: architecture of high-construction*. Great Britain: Wiley-Academy.

Architectural Description

Pelli's design answered the developer's call to express the 'culture and heritage of Malaysia' by evoking Islamic arabesques and employing repetitive geometries characteristic of Muslim architecture. In plan, an 8-point star formed by intersecting squares is an obvious reference to Islamic design; curved and pointed bays create a scalloped facade that suggests temple towers. The identical towers are linked by a bridge at the 41st floor, creating a dramatic gateway to the city. (Ref. e)

www.archnet.org/library



Conceptual Plan diagrams

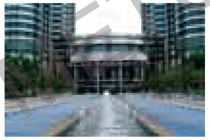
(Ref: Pelli, Cesar, & Crosbie, Michael. (2001). *Petronas twin towers: architecture of high-construction.* Great Britain: Wiley-Academy.)

Architectural Description

- The structure is high-strength concrete, a material familiar to Asian contractors and twice as effective as steel in sway reduction. Supported by approximately 23x23m concrete cores and an outer ring of widely-spaced super columns, the towers showcase a sophisticated structural system that accommodates its slender profile and provides from 1300 to 2050 square meters of column-free office space per floor. (Ref. c)
- Other features include a curtain wall of glass and stainless steel sun shades to diffuse the intense equatorial light; a double-decker elevator system with a sky lobby transfer point on the 41st floor to accommodate the thousands of people who use the complex daily. (Ref. d)

The identical towers are linked by a bridge at the 41st floor, creating a dramatic gateway to the city.

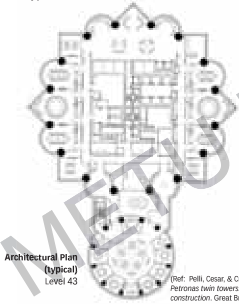
Abada, Galal. (2004). *Petronas office towers* [On site review report]. Retrieved from http://archnet.org/library/files/one-file.jsp?file_id=1403



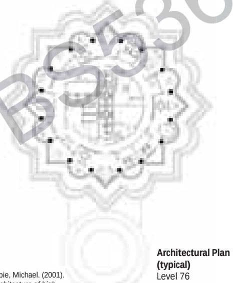
Abada, Galal. (2004). *Petronas office towers* [On site review report]. Retrieved from http://archnet.org/library/files/one-file.jsp?file_id=1403

Architectural Description

Typical Floor Plans



Architectural Plan (typical) Level 43



Architectural Plan (typical) Level 76

(Ref: Pelli, Cesar, & Crosbie, Michael. (2001). *Petronas twin towers: architecture of high-construction.* Great Britain: Wiley-Academy.)

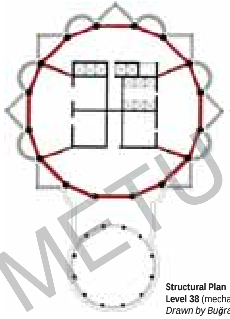
Architectural Description

- Tower One: Petronas Headquarters' offices.
- Tower Two: Mostly private tenants, KLCC Holdings' offices, some vacant areas for rent.
- Total gross floor area: 218,000 square metres in each tower, eighty-eight storeys.
- Total net floor area: 119,300 square metres in each tower, height: 452 metres.
- Typical floor-to-floor height: 4.0 metres.
- Finished ceiling height: 2.65 metres.
- Raised floor: 125 millimetres, levels eight–seventy-two.
- Sky bridge: centre-line span, 58.44 metres; width, 5.29 metres; height, 9.45 metres; 170 metres above street level.
- Height of pinnacles: 73.5 - 75 metres.

(Ref. c)

Baker, Philippa (ed.). Architecture and Polyphony: Building in the Islamic World Today. Retrieved from http://archnet.org/library/documents/one-document.jsp?document_id=10229

Structural Description

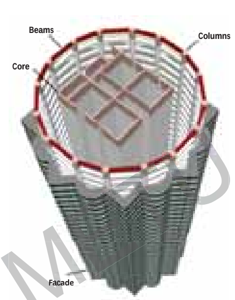


Structural Plan
Level 38 (mechanical floor)
Drawn by Buğra Tetik

The structure of the building consists of a dual system consisting of reinforced concrete core wall system, and exterior reinforced concrete columns. The floor framing system consists of composite steel framing system. A composite metal deck frames between the steel beams, and acts compositely with them. Reinforced concrete was selected as the primary structural material for the lateral resisting system as used extensively in the tower because of its availability and availability of skilled labor in Malaysia in particular and South-east Asia in general. (Ref. i)

The structural frame for each of the main towers consists of sixteen cylindrical high-strength concrete perimeter columns connected by a haunched ring beam at each level. This haunching allows for the passage of mechanical systems at the center span of the beam. This frame is tied back to the structural elevator core at the thirty-eighth and fortieth floors by concrete outrigger beams. (Ref. a)

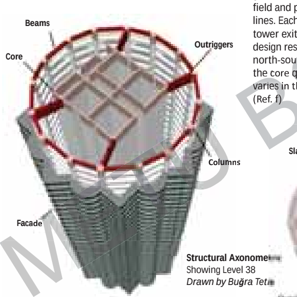
Structural Description



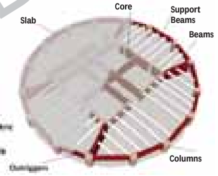
Structural Axonometric Showing Typical Level
Drawn by Buğra Tetik

- The core is constructed with added strength at the corners to help resist the moment created by lateral wind forces. Two essentially solid shear walls cross within the core to further increase its stiffness. The grade of concrete is consistent between the perimeter columns and structural core and ranges from 80 MPa at the base to 40 MPa at the top. (Ref. a)
- Various approaches were explored in developing the overall structural system of the Petronas Towers. The scheme being implemented consists of cast in-place perimeter frame with sixteen columns and cast in-place concrete core. (Ref. f)
- Outrigger beams at mid-height of the structure provides additional stiffness to the structure. The concrete used varies in three steps from grade 80 at the lower floors to grade 40 at the upper floors. Grade 80 is specified up to level 22 for the 2.4m diameter reinforced concrete columns. The floor system consists of cast in-place concrete slab on ribbed metal deck to act compositely with filled concrete, supported on steel beams. (Ref. f)

Structural Description



Concrete grades for the ring beams follow the grades in the columns to avoid confusion in the field and possible waste in the concrete pump lines. Each Tower has one central core for all lifts, tower exit stairs and mechanical services. Core design resulted in two virtually solid walls running north-south and one running east- west making the core quite stiff and efficient. Concrete grade varies in three steps from 80 Mpa to 40 Mpa. (Ref. f)



Structural Axonometric
Showing Level 38
Drawn by Buğra Tetik

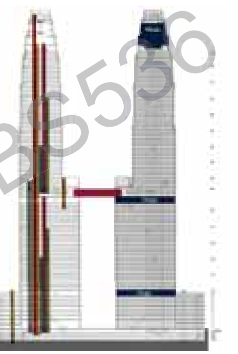
Structural Description

What is Outrigger System?

According to Taranath:

The core-outrigger system also known as the belt truss system which the axial stiffness of the perimeter columns is invoked for increasing the resistance to overturning moments.

This efficient structural form consists of a core, comprising either braced frames of shear walls, with horizontal cantilever outrigger trusses or girders connecting the core to the outer columns. The core may be centrally located with outriggers extending on both sides or it may be located on one side of the building with outriggers extending to the building columns on one side.

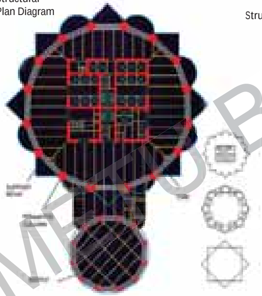


Section of Towers
Drawn by Buğra Tetik in the light of ref:d

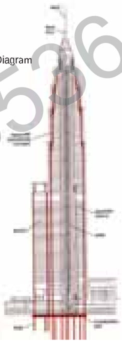
Section shows vertical circulation shafts by colored vertical bars and also shows hvac floors. Outriggers located on mid-hvac floor between level 38-40. That location approximately equals to 0,455H as appropriate to Taranath.

Structural Description

Structural Plan Diagram



Structural Section Diagram



Abada, Galal. (2004). *Petronas office towers* [On site review report]. Retrieved from http://archnet.org/library/files/one-file.jsp?file_id=1403

Section area is getting thiner while the building is rising. It is about aerodynamic concerns.

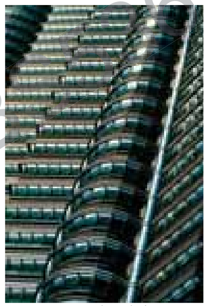
Special Description

Climatic Performance

The Petronas Towers respond remarkably well to the tropical climate of Kuala Lumpur using several techniques. The glass curtain walls have stainless-steel sunshades to diffuse the intense equatorial light. These 'tropical walls, minimize the heat and glare entering the building but at the same time they reflect the play of light and shadow, expressing the tropical environment.

The use of tinted laminated glass also helps to reduce heat gain from the sunlight and ultraviolet (UV) transmission. However, it was noticed that in some offices natural light is not sufficient to light the spaces and occupants have to use artificial lighting.

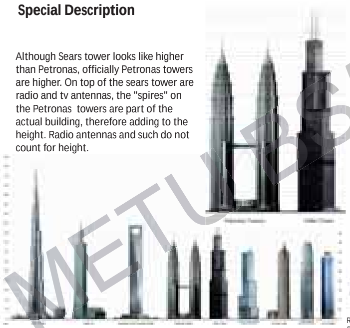
The use of exhaust air to pre-cool and dehumidify fresh, warm air, has proved to be highly cost effective as it reduces the amount of energy required to air condition the building by 50 per cent.



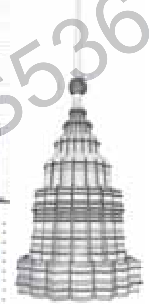
Photographs of Petronas Towers
http://archnet.org/library/files/one-file.jsp?file_id=1283

Special Description

Although Sears tower looks like higher than Petronas, officially Petronas towers are higher. On top of the sears tower are radio and tv antennas, the "spires" on the Petronas towers are part of the actual building, therefore adding to the height. Radio antennas and such do not count for height.



http://skyscraperpage.com/cities/?buildingID=22



Ref: Pelli, Cesar, & Crosbie, Michael. (2001). *Petronas twin towers: architecture of high-construction.* Great Britain: Wiley-Academy.

References

(a) Pollalis, Spiro. (2002). *International cooperation and information transfer in the realization of the world's tallest buildings*. Retrieved from http://www.cdi.gsd.harvard.edu/

(b) Baker, Philippa (ed.). Architecture and Polyphony: Building in the Islamic World Today. The Aga Khan Award for Architecture, The Ninth Award Cycle. London: Thames and Hudson; Geneva: The Aga Khan Award for Architecture, 2004. Retrieved from http://archnet.org/library/documents/one-document.jsp?document_id=10229

(c) Abada, Galal. (2004). *Petronas office towers* [On site review report]. Retrieved from http://archnet.org/library/files/one-file.jsp?file_id=1403

(d) Pelli, Cesar, & Crosbie, Michael. (2001). *Petronas twin towers: architecture of high-construction*. Great Britain: Wiley-Academy.

(e) Willis, Carol. (2004). *The Petronas towers*. Retrieved from http://www.skyscraper.org/TALLEST_TOWERS/t_petronas.htm

(f) Naidu, Kribanandan Gurusamy. (1995). The Petronas tower: the world's tallest building. *CPAC SEMINAR 95*

(g) Pelli, Cesar. http://www.pcparch.com/#/projects/headquarters/petronas-towers/description/

(h)Taranath, Bungale S. (2005). *Structural analysis and design*. Newyork: dekker.

(i) Kim, Jae-Ho, & Lee, Seung-Hoon. (2004). Application of high performance concrete in petronas twin tower, klcc. *CTBUH Seoul, Korea*, 10. Retrieved from http://www.ctbuh.org/Publications/TechnicalPapers/tabid/71/language/en-US/Default.aspx

(j) www.citationmachine.net

(k) wikipedia.com

Ref: Pelli, Cesar, & Crosbie, Michael. (2001). *Petronas twin towers: architecture of high-construction*. Great Britain: Wiley-Academy.