MIDDLE EAST TECHNICAL UNIVERSITY
DEPARTMENT OF ARCHITECTURE / BUILDING SCIENCE PROGRAM

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

Case Study: **The Shard**
by
Nur Özkan

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

Figure 01. A view from the Shard.
Retrieved in 11.05.2015 from http://www.alumascroofing.co.uk/blog/wp-content/uploads/Shard_London_Waterpoofing.jpg

Figure 02. A view from the Shard.
Retrieved from http://www.shangri-la.com/uploadedImages/Shangri-la_Hotels/Shangri-La_-London/Shangri-La-Hotel-At-The-Shard-London-Hero.jpg

Figure 03. A view from the Shard.
Retrieved from: http://ideasgn.com/wp-content/uploads/2013/05/The-Shard-London-Renzo-Piano-012.jpg

Case Study: **The Shard** by Nur Ozkan
Submitted to: Gunel, Ay – Spring 2015

Project Information

Official Name : The Shard (London Bridge Tower) [1]
Architect : Renzo Piano Building Workshop [1]
Location : London, UK [1]
Height : 306 m (Architectural) [1]
244 m (occupied) [1]
Floors Above Ground: 73 [1]
Floors Below Ground: 3 [1]
Gross Floor Area : 127,489 m² [1]
Ground Floor Sizes : 4188 m² [2]
Number of Elevators : 44

Function : Residential / Hotel / Office [1]
Structural System : Shear Walled Frame With Outrigger Hat Truss [1]
Structural Material : Composite [1]
Construction Period : 2009-2013 [1]

[1] The Shard. CTBUH. Retrieved in 06.01.2015. From http://skyscrapercenter.com/building/the-shard/451
[2] Giannini, R. (Structural Engineer-From WS group) [May 5th, 2015] . Personal Communication.

Project Information

Ranking : #1 in London, UK
#2 in Europe
#72 in World
(2015 records) [1]
Cost : £435 million = ~€600 million [1]

Companies Involved
Owner : London Bridge Quarter Ltd [1]
Structural Engineer : WSP Group [1]
MEP Engineer : Arup [1]
Manager : Turner & Townsend [1]

Significant Awards
-World's Best New Skyscraper | Emporis, 2013 [2]
-Best Commercial Building | RIBA, 2014 [3]
-Best Tall Building in Europe | CTBUH, 2013 [1]

[1] The Shard. CTBUH. Retrieved in 03.01.2015. From http://skyscrapercenter.com/building/the-shard/451.
[2] The Shard. EMPORIS. Retrieved in 07.01.2015. From http://www.emporis.com/awards/2013.
[3] Awards. Sellar Property Group. Retrieved 07.01.2015. From http://www.sellarproperty.com/awards/.

Architectural Inspiration

Influence of 17th century cathedral spires (St. Pauls in London) is the main inspiration of architectural form.

8 sided geometry, sharp and translucent form corresponds with the name of shard. Shard also means broken piece of glass. [1]

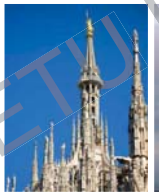


Figure 04 (left).
Cathedral Spires of Milan.

Retrieved in May 25, 2015, from http://www.dudziak.com/picture.php/cathedral_of_milan_spires9452.

Figure 05 (right).
The Shard.

Retrieved May 25,2015, from http://techne.pini.com.br/engenharia-civil/185/piramide-londrina-edificio-mais-alto-da-europa-emprega-estrutura-287980-1.aspx

[1] Shard. (n.d.). In *free dictionary*, retrieved May 25, 2015, from freedictionary.com.

Design Considerations

- One of the most critical point while designing this tall building is historic context of England. Keeping the streetscapes permeable and delicate is key challenge of project [1]
- Effect at street level is equally as important as the impact on skyline. [1]
- Pedestrian flows were studied by engineers at the design stage as it is indicated in Figure 06. [1]

Figure 06. Pedestrian flow at level 03 (concourse level).
Retrieved in May 4th, 2015, from http://ad009cdnb.archdaily.net/wp-content/uploads/2014/11/546160f6e58eccd5400002e_renzo-piano-gains-planning-permission-for-shard-adjacent-residential-tower_plan_concourse_level_1_500.jpg

[1] Moazami, K. (2013). Engineering Tall in Historic Cities: The Shard. CTBUH Journal, International Journal on Tall Buildings and Urban Habitat, 44-49.

The Site

- 26-storey-high Southwark tower (Constructed at 1970s) was located on the site before The Shard was erected. Piles of old building remained at site and this is one of the major challenges of construction. [1]
- The building has no significant basement; however, it was supported on under-reamed piles (Figure 07). It could not be used in Shard's construction and also it costs too much to remove them. That's the piles were designed considering settlement of old ones. [1]

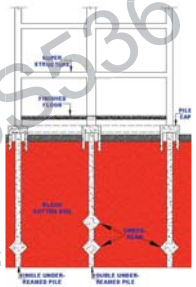
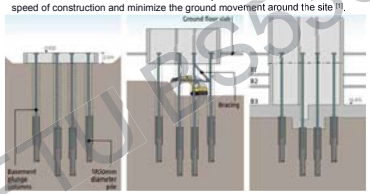


Figure 07. Under-reamed piles.
Retrieved in May 4th, 2015, from http://civil-engg-world.blogspot.com.tr/2011/05/under-reamed-piles-safest-foundation.html

[1] Moazami, K. (2013). Engineering Tall in Historic Cities: The Shard. CTBUH Journal, International Journal on Tall Buildings and Urban Habitat, 44-49
Ream: The act of enlarging a drilled hole. Ream [Def. 2.1.a]. (n.d.). *Merriam-Webster Online*. Retrieved June 7, 2015, from http://www.merriam-webster.com/dictionary/ream.

Top-Down Construction

- All of these factors lead construction firm to top-down construction to increase the speed of construction and minimize the ground movement around the site [1].



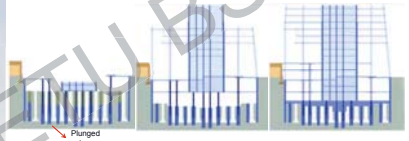
1. Initial section of the core constructed, which restrains the head of the basement plunge columns.
2. Basement excavation progresses around plunge columns. Slip forming of core commences.
3. Once excavation is complete, the raft and walls are cast and the bracing removed.

Figure 08. Top-Down Construction process.
Retrieved in May 4th, 2015, from http://www.skyscrapercity.com/showthread.php?t=407549&page=256

[1] Moazami, K. Parker, J. Gianini, R. (2008). Steel-Concrete-Steel: Unique Hybridsat LondonTallest. CTBUH Journal, International Journal on Tall Buildings and Urban Habitat, 44-49.

Top-Down Construction

- Top down construction of the building consists of basically 3 main steps.
  - Constructing the perimeter walls (actually very dense piles) and also the *plunged columns*.
  - Excavation of the site.
  - Construction of basement slabs. (B3, B2 and B1 respectively)

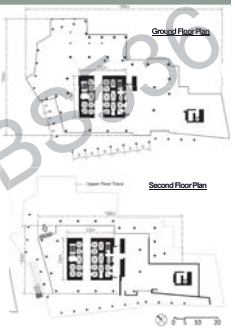


1. Central core is supported by plunged columns (24 of them.)
2. Construction of the concrete core at the levels above grade.
3. Construction of B1 basement.

Figure 09. Top-Down Construction process.
NBS TV. (2013, March). *Building the shard* [Video file]. Retrieved from http://www.thenbs.com/nbsTV/DesignSpecification/programme.asp?refCode=313331&title=Engineering+the+shard.

Architectural Drawings

- Ground floor area of the building is 4822 m². [1]
- Central core is concrete at all levels.
- There is a setback at ground floor level and traces of upper level can be identified from the drawing.
- There is a setback at ground floor level.
- Perimeter taking columns are composite. It is box section steel profiles with concrete fill.
- Dimensions of the central core are 22x20 at the bottom and it narrows down to 7,5 x 11 meters at the very top as the building tapers.



[1] Giannini, Rodolfo (From WS group-Structural Engineer). Personal Communication. May 5th, 2015

Figure 10. Ground and 2nd Floor Plan.
GFA | 4822 m² [1], ~1790 m² **Drawn by Nur Özkan.**

Architectural Drawings

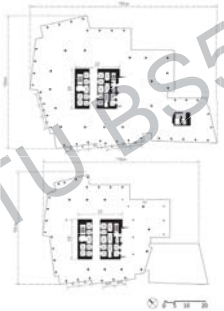


Figure 11. 9th and 18th Floor Plan (Office Type). GFA | 4042, 2584 m2 **Drawn by Nur Özkan**

Architectural Drawings

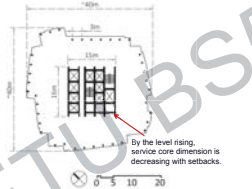


Figure 12. 39th Floor Plan (Hotel Type)
GFA | 1218 m²
Drawn by Nur Özkan.

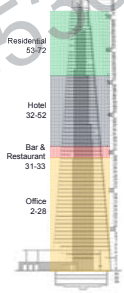


Figure 13. Section of the building.
Drawn by Nur Özkan.

Architectural Drawings

Figure 14. Decreasing service core setbacks at section view. **Drawn by Nur ÖZKAN.**

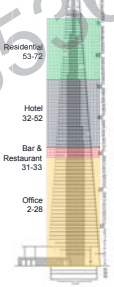
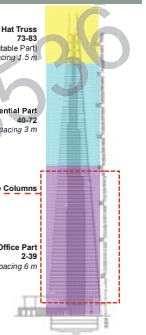


Figure 15. Section of the building.
Drawn by Nur Özkan.

Structural System

- Structural framing system is both concrete and steel (composite).
- Column spacing is 6 m at the office level, 3 m at hotel & apartment levels and 1.5 m at the top (outrigger hat truss) in general. Perimeter columns up to level 40 is steel and composite, and then it continues with concrete depending on mass damping effect. Last usable floor is 73rd and then it turns into steel framing, once again. [1]
- Representation of column spacing are indicated in Figure 16.
- "At lower retail and office levels above ground, composite steel framing (level 3 to 39) provides spans up to 15 meter from perimeter to concrete core." [1]



[1] Moazami, K. Parker, J. Gianini, R. (2008). Steel-Concrete-Steel: Unique Hybridsat LondonTallest. CTBUH Journal, International Journal on Tall Buildings and Urban Habitat, 44-49.

Figure 16. Section of the building.
Drawn by Nur Özkan.

Structural System

- Blue columns represents the rectangular ones which continues upon the facade. Green ones represents the circular columns which end at middle levels (18-22) of the building. Orange ones locates only at the first 3 levels.

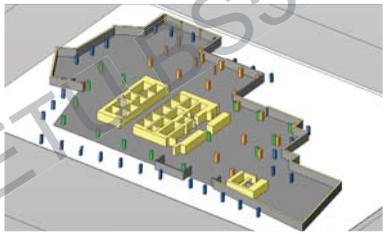


Figure 17. Axonometric plan of Ground Floor level of the building. **Drawn by Nur Özkan**

Structural System

- Blue columns represents the rectangular ones which continues upon the facade. Green ones represents the circular columns which end middle levels of the building.

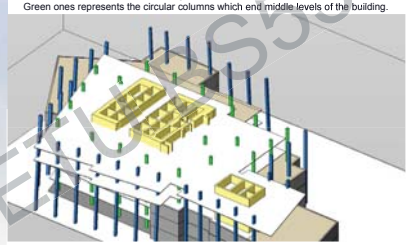


Figure 18. Axonometric plan of the building. **Drawn by Nur Özkan**

Structural System

- Blue columns represents the rectangular ones which continues upon the facade. Green ones represents the circular columns which end middle levels of the building. Yellow parts indicate structural core.

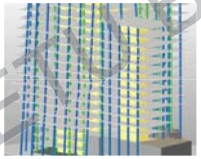


Figure 19 and 20. Structural Axonometric drawing. **Drawn by Nur Özkan.**

Structural System

- A view of the main structure during construction.

Figure 21. A photograph representing the structural system of the building during construction.
NBS TV. (2013, March). *Building the shard* [Video file]. Retrieved from http://www.thenbs.com/nbsTV/DesignSpecification/programme.asp?refCode=313331&title=Engineering+the+shard.

Structural System

- Non linear structural axis at vertical dimension.

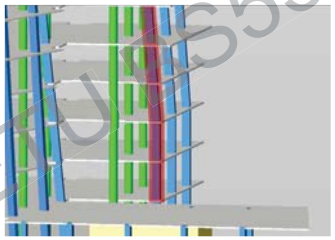


Figure 22. Structural Axon | Non-linear structural axis. **Drawn by Nur Özkan**.

Structural System

- Non linear structural axis at facade.

Figure 23. Non-linear structure at facade. Photo was shot at 17th May, by Güray Tekin.

Structural System | Outrigger Hat Truss

- Parker (2012) states that during the wind tunnel tests, the top deflection arrives 300 - 400 mm. This was too much for such kind of a building and they've designed a outrigger hat truss. [1]
- Outrigger hat truss locates at the very top of the building, inhabitable space due to the tapering shape. [2]
- This outrigger part also named as «Radiator» because it contains the heating plants of the building. [1]

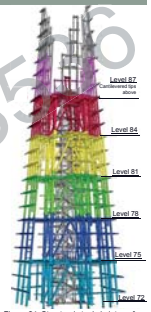


Figure 24. Structural steel skeleton of the spire.
Retrieved 21st April 2015 From http://www.bdonline.co.uk/Pictures/web/d/e/r/shard_WSP_web__599.jpg

[1] Parker, J. (2012). Building the Shard. INGENIA, 24-30.
[2] Moazami, K. Parker, J. Gianni, R. (2008). Steel-Concrete-Steel: Unique Hybridsat LondonTallest. CTBUH Journal, International Journal on Tall Buildings and Urban Habitat, 44-49.

Structural System | Outrigger Hat Truss

Figure 25. Structural steel skeleton of the spire.
NBS TV. (2013, March). *Building the shard* [Video file]. Retrieved from http://www.thenbs.com/nbsTV/DesignSpecification/programme.asp?refCode=313331&title=Engineering+the+shard.

Structural System | Outrigger Hat Truss

Figure 26 and 27. Structural steel skeleton of the spire.
NBS TV. (2013, March). *Building the shard* [Video file]. Retrieved from http://www.thenbs.com/nbsTV/DesignSpecification/programme.asp?refCode=313331&title=Engineering+the+shard.

Structural System | Column Transfer

- The levels where the columns were 6 m span composite / steel and turn into 3 m span concrete, specialists find necessary to create transfer points against the creep.

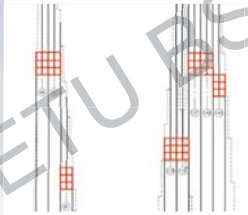


Figure 28 (left). Knik point where the column transfer happens. [1]

Figure 29 (above). Column Transfer at Backpack [1]

[1] Stålbyggnadsdagen(2012). The Shard: structural engineering. SBI: Swedish Institute of Steel Construction. Retrieved in June 1st 2015 from http://sbi.se/uploads/source/files/SBD/presentationer-12/1530.pdf

Structural System | Column Transfer

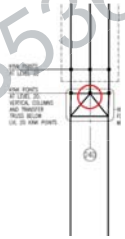


Figure 30. An image representing the Knik points. [1]

[1] Stålbyggnadsdagen(2012). The Shard: structural engineering. SBI: Swedish Institute of Steel Construction. Retrieved in June 1st 2015 from http://sbi.se/uploads/source/files/SBD/presentationer-12/1530.pdf

Structural System | Beam Types

- At the left hand side, 50 cm deep steel beams were suitable for office spaces which can accommodate large services. At the right hand side, 20 cm thick post tensioned concrete slab was used at hotel and residential parts.

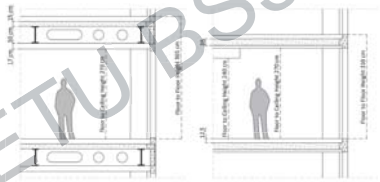


Figure 31. Beam types of the building. **Drawn by Nur ÖZKAN**.

Facade System | Sun Control

- Fully glazed outer shell of the building was designed as double skin curtain wall. It reduces the heat coming into the building.
- Besides double glazed facade, there is another element that provides sun control. Intelligent sun curtain is indicated in Figure 32.
- It opens when its sensors detects excessive sun light.
- Architects were able to use a lighter, more translucent looking glazing by the help of this component. It makes stronger the fading away impression at the top that architect wanted.

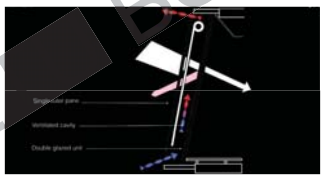


Figure 32. Sun control at the Shard. From presentation of Arup.
Healy, D. (2013, July 29). *The shard's unsung heroes*. The Shard's Unsung Heroes [Video file]. Retrieved from https://www.youtube.com/watch?v=_UhclKwbCik.

References

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Healy, D. (2013, July 29). *The shard's unsung heroes* [Video file]. Retrieved from https://www.youtube.com/watch?v=_UhclKwbCik.

NBS TV. (2013, March). *Building the shard* [Video file]. Retrieved from http://www.thenbs.com/nbsTV/DesignSpecification/programme.asp?refCode=313331&title=Engineering+the+shard.

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Moazami, K. Parker, J. Gianni, R. (2008). Steel-Concrete-Steel: Unique Hybridsat London Tallest. CTBUH Journal, International Journal on Tall Buildings and Urban Habitat.

Parker, J. (2012). Building the Shard. INGENIA, 24-30.

Stålbyggnadsdagen (2012). *The shard: structural engineering. SBI: Swedish institute of steel construction*. Retrieved in June 1st 2015 from http://sbi.se/uploads/source/files/SBD/presentationer-12/1530.pdf

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Gunel, M. H., and H. E. Ilgin. *Tall Buildings: Structural Systems and Aerodynamic Form*, Routledge – Taylor and Francis Group Book Company, 2014.