

ONE WORLD TRADE CENTER

Other Name: Freedom Tower¹
Country, State, City: U.S.A., New York, New York City¹
Building Type: Skyscraper²
Building Status: Completed¹
Structural Material: Composite¹
Structural System: Hybrid System³
Building Function: Commercial Office¹
Architectural Style: Modernism²
Energy Label: LEED Gold¹
Construction Dates: 2006-2014⁴
Global Ranking: #3 Tallest in the World⁵
National Ranking: #1 Tallest in United States⁶



[1] Council on Tall Buildings and Urban Habitat One World Trade Center Fact Sheet. <http://skyscrapercenter.com/building/one-world-trade-center>
[2] Emporis One World Trade Center Building Directory. <http://www.emporis.com/building/one-world-trade-center-new-york-city-ny-usa>
[3] Ahmad Bahmani, Yoram Eilon (2012). The Rise of One World Trade Center. Structure Magazine November 2012, p.22-24.
[4] SOM Publishing (2005). World Trade Center Tower One. Freedom Tower. Architectural Fact Sheet, June 2005.
[5] Kenneth Lewis, Nicholas Holt (2011). Case Study: One World Trade Center. New York, CTBUH Journal, Issue 11, p.14-19.
[6] M. Halis Günel, H. Emre Işın (2014). Tall Buildings: Structural Systems and Aerodynamic Form.

BUILDING FACTS & SPECS

Companies Involved ¹
Owner: One World Trade Center LLC(current)
Silverstein Properties (Past)
Architect: Skidmore, Owings & Merrill – David Childs
Structural Engineer ² : MEP Engineer: Jaros Baum & Bolles ³
Design: WSP Cantor Seink
Peer Review: Leslie E. Robertson Associates
Cost: AECOM
Facade: Permatseisa Group
Wind: RWDI
Technical Data ⁴ :
Tower GFA(Gross Floor Area): 325,279 m2
Height Architectural: 541.33 m (1,776') ⁵
Floors: 104
Elevator/ Escalator: 73/11
Top Elevator Speed: 37.30 km/h (540 m/min in Emporis)
Building Cost: \$3,900,000,000 (world's most expensive building)

Figure4. Photo of 1 WTC © John W. Cahill / CTBUH

[1] Council on Tall Buildings and Urban Habitat One World Trade Center Fact Sheet. <http://skyscrapercenter.com/building/one-world-trade-center/98>
[2] Emporis One World Trade Center Building Directory. <http://www.emporis.com/building/one-world-trade-center-new-york-city-ny-usa>

BUILDING FACTS & SPECS

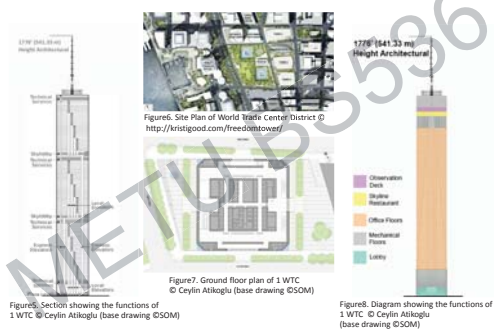


Figure6. Section showing the functions of 1 WTC © Ceylan Atikoglu (base drawing ©SOM)

ARCHITECTURAL DESIGN

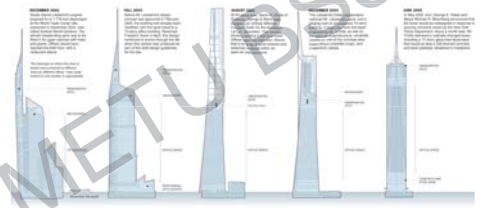
- Height of spire: 1776 feet (541m) for Declaration of Independence³
- Height of roof: 1368 feet (417m) same as Twin Towers³
- Landmark with simplicity and clarity of form⁴
- Business center of Lower Manhattan besides commercial spaces⁵
- The tower filled with crystalline form and reflecting light as its future concept.⁶
- Changing light and weather conditions makes surfaces like kaleidoscope.⁷
- The tower's structure allows for flexible interior spans which are column-free.⁸
- High public lobby (24.3' with mechanical floors in blast resistance cubic base of 61 m tall.²



[2] Emporis One World Trade Center Building Directory. <http://www.emporis.com/building/one-world-trade-center-new-york-city-ny-usa>
[3] Ahmad Bahmani, Yoram Eilon (2012). The Rise of One World Trade Center. Structure Magazine November 2012, p.22-24.
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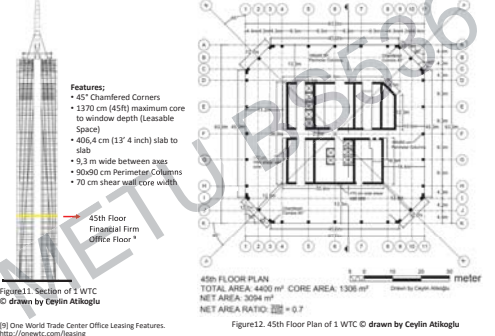
ONE WORLD TRADE CENTER EVOLUTION

- The Evolution Designs from December 2002 to June 2005¹
- First design called Vertical World Gardens by Studio Daniel Libeskind on December 2002.
- Second design modified by 70th floor and called Freedom Tower on February 2003.
- Third one is designed by David Childs of SOM entirely different twisting tower.
- Fourth design is collaborated by Libeskind and Childs and kept tapered form.
- Last design has radically changed to have security precautions by Childs.



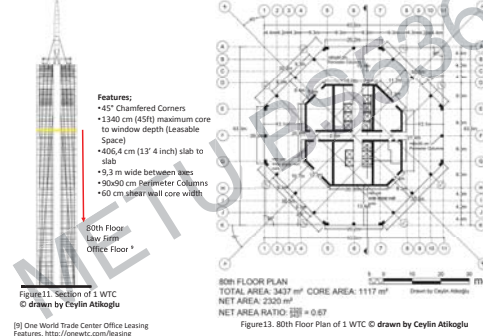
[1] World Trade Sustainability. <http://kristigood.com/freedomtower/>. Retrieved on 5th January 2014.

ARCHITECTURAL DESIGN



[8] One World Trade Center Office Leasing Features. <http://onewtc.com/leasing>

ARCHITECTURAL DESIGN



[9] One World Trade Center Office Leasing Features. <http://onewtc.com/leasing>

ARCHITECTURAL DESIGN

- Entrance on four sides of building connecting and activating street level. (while considering security requirements)⁴
- Chamfered edges with tower's cubic base transforms into eight tall triangles in elevation. (Square Antiprism Frustum)⁵
- Rotated plan 45 degrees from base quadrangle.⁶
- Tapering of building geometry reduces wind effect.⁷
- 63 m x 63 m (same size with Twin Towers) footprints.⁴
- Aspect Ratio= Height/Dimension 541/63=8.5 (while Twin Towers 420/63=6.6)
- The spire hybrid structure (137 m spire and 3 level platform ring) with steel mast.⁸
- The "twisting" of the floor plates produces a tapering tower with a complex geometry.⁷



[3] Ahmad Bahmani, Yoram Eilon (2012). The Rise of One World Trade Center. Structure Magazine November 2012, p.22-24.
[4] SOM Publishing (2005). World Trade Center Tower One. Freedom Tower. Architectural Fact Sheet, June 2005.
[5] Kenneth Lewis, Nicholas Holt (2011). Case Study: One World Trade Center. New York, CTBUH Journal, Issue 11, p.14-19.
[7] A controversial tower rise at ground zero. <http://enr.com/construction/projects/port/11/11/09/One-World-Trade-Center-rap>. Retrieved on 5th January 2015.

ARCHITECTURAL DESIGN

- Sustainable Design
 - The tower is designed to have a high degree of environmental sustainability by incorporating building tenants to the strategies.⁵
 - Using new technologies maximize efficiency, minimize waste and pollution.⁶
 - Cutting edge innovation in air quality, energy efficiency, daylighting, water conservation, materials conservation, clean production.⁴
 - Much of the materials used in its construction come from postindustrial recycled materials, and more than three-quarters of its waste will be recycled.⁴
 - Reuse of rainwater for water conservation.⁴
 - The tower makes use of off-site hydroelectric and windpower.⁷
 - Curtain wall designed for maximum daylight, while reinforcing the tower's monumentality.⁸
 - City's first carbon neutral building as an ambitious goal.⁹



[4] SOM Publishing (2005). World Trade Center Tower One. Freedom Tower. Architectural Fact Sheet, June 2005.
[5] Kenneth Lewis, Nicholas Holt (2011). Case Study: One World Trade Center. New York, CTBUH Journal, Issue 11, p.14-19.
[6] A look at the new One World Trade Center. <http://www.architecturaldigest.com/architecture/2012/09/one-world-trade-center-new-york-david-childs-articles-retrieved-on-28th-November-2014>
[11] World Trade Sustainability. <http://kristigood.com/freedomtower/>. Retrieved on 5th January 2014.

SAFETY DESIGN

- The building setback distance increased to 27 m for security.²
- Advanced life safety systems exceed New York City Building Codes.⁴
- The tower has extra strong fireproofing whilst the air supply system incorporates chemical and biological filters; emergency stairs are extra-wide and pressurized.⁴
- Cubic base mixture of stainless steel/titanium; light-reflective and blast-resistant. (Inflax dregli)⁴
- Extra-wide pressurized stairs (¾20 wider than code), low level emergency lighting and concrete protection for air sprinklers and emergency risers.⁴
- "Areas of refuge" are located on each floor.⁴
- Enhanced elevators are housed in a protected central building core (90 cm) which serves all of the tower's floors.⁴
- Tower stair exit locations at all adjacent streets.⁴
- According to design consultant of Port Authority Del Valle, "it may not be the tallest building in the world, but it is certainly the safest".⁴



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STRUCTURAL DESIGN

- Lateral Load Resisting System
 - Redundant steel moment frame consists of columns and beams (linked by bolting and welding) resists lateral loads for bending.³
 - Tower Structure: Hybrid System (Concrete Core with Perimeter Steel Frame)⁴
 - According to Günel the structure: Outriggered Frame System.⁵
 - Günel states that the structure as itself consist of Rigid Frame System with Shear Wall/Framed System in its Core. Moreover with Braced Frame on perimeter columns, the structure behaves like a tube.⁶
 - Reinforced concrete core resist gravitational loads, lateral loads (wind and seismic loads).⁷
 - Concrete Strength: 14,000 psi (96.528kpa), 4,000 psi (55.158 kpa) base to top.⁸
 - Perimeter moment frame system wraps around vertical and sloped forming as a tube system.⁹
 - Outriggered trusses connect concrete core and perimeter columns at upper mechanical levels.¹⁰
 - Steel framing system erected before embedding concrete.⁹

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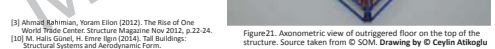
- 1WTC is the first project using 14,000 psi (96.526 kpa) concrete in New York City.³
- Tower tapers rises with the chamfered corners on the floor's footprint forms an aerodynamic and structurally efficient shape.³
- "The geometrical shape of the tower reduces exposed wind loads, as well as the amount of structural steel needed and the demand on the lateral system of the tower" written by Ahmad Bahmani (project structural engineer and CEO of WSP Cantor Seink).⁴
- Adding outriggers decreases "Top Deflection" (which is height³ / 5000 * 541³ / 5000 * 1.08) effectively in the middle.⁵ In 1 WTC it is located on the top.
- The acceleration of highest occupied level meets the criteria of human comfort and the structure is designed for wind storms with a 1000 year return period.⁶



[3] Ahmad Bahmani, Yoram Eilon (2012). The Rise of One World Trade Center. Structure Magazine November 2012, p.22-24.
[4] Kenneth Lewis, Nicholas Holt (2011). Case Study: One World Trade Center. New York, CTBUH Journal, Issue 11, p.14-19.
[10] M. Halis Günel, H. Emre Işın (2014). Tall Buildings: Structural Systems and Aerodynamic Form.

STRUCTURAL DESIGN

- Axonometric View of Tower Top
- Structure System:
 - According to Mehmet Halis Günel; Outriggered Frame Systems¹⁰
 - According to Oral Büyükkızılcı; Outrigger Braced Structure System¹¹
 - According to Smith; Outrigger-Braced Structures¹²
 - According to Taranath; Outrigger and Belt Truss Systems¹³
- Bahmani (Structural designer of 1WTC) states that to resist lateral loads the concrete core at the upper mechanical levels connected to perimeter columns via series of multilevel outrigger trusses.¹⁴



[3] Ahmad Bahmani, Yoram Eilon (2012). The Rise of One World Trade Center. Structure Magazine November 2012, p.22-24.
[10] M. Halis Günel, H. Emre Işın (2014). Tall Buildings: Structural Systems and Aerodynamic Form.

STRUCTURAL DESIGN

- 90% of Occupied Spaces Used Natural Light
- High Quality Filtered Air
- Reinforced Concrete Core
- Perimeter Steel Frame
- Outriggered Frame
- Made from recycled materials (80% of waste products)
- 90 cm thick reinforced concrete core walls for safety



[11] World Trade Sustainability. <http://kristigood.com/freedomtower/>. Retrieved on 5th January 2014.

STRUCTURAL DESIGN

- Axonometric View of Tower Base (podium)
- Base structure system showing both concrete core and perimeter steel frame; framed structure, shear walled structure and without curtain wall structure view.
- The composite type of the structure can be defined with materials. Here concrete is embedded after steel frame.
- The podium has some hefty blast-resistant walls at the base," says del Valle.⁸



[8] Kenneth Lewis, Nicholas Holt (2011). Case Study: One World Trade Center. New York, CTBUH Journal, Issue 11, p.14-19.

REFERENCES

- [1] Council on Tall Buildings and Urban Habitat One World Trade Center Fact Sheet. <http://skyscrapercenter.com/building/one-world-trade-center/98>
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 - [3] Ahmad Rahimian, Yoram Eilon (2012), The Rise of One World Trade Center. Structure Magazine Nov 2012, p.22-24.
 - [4] SOM publishing (2005). World Trade Center, Tower One, Freedom Tower. Architectural Fact Sheet, June 2005.
 - [5] Kenneth Lewis, Nicholas Holt (2011). Case Study: One World Trade Center, New York, CTBUH Journal Issue III
 - [6] 1 World Trade Center by SOM. <http://architectcorner.blogspot.com.tr/2013/03/1-world-trade-center-by-skidmore-owings.html> Retrieved on 25th December 2014.
 - [7] A controversial tower rises at ground zero. <http://architecturaldigest.com/projects/portfolio/2011/09/One-World-Trade-Center.asp> Retrieved on 5th January 2015.
 - [8] A look at the new One World Trade Center. <http://www.architecturaldigest.com/architecture/2012-09/one-world-trade-center-new-york-david-childs-article> Retrieved on 28th November 2014.
 - [9] One World Trade Center Office Leasing Features. <http://onevtc.com/leasing> Retrieved on 7th January 2015.
 - [10] M. Halis Günel, H. Emre Işın (2014). Tall Buildings: Structural Systems and Aerodynamic Form, Routledge – Taylor and Francis Group.
 - [11] World Trade Sustainability. <http://kristapood.com/freedomtower/> Retrieved on 5th January 2014.
- Links for Videos
- <http://www.youtube.com/watch?v=w5AbwXtg&list=WL&index=2>
 - <http://www.youtube.com/watch?v=7aWQ2V0uM&list=WL&index=11>
 - <http://www.youtube.com/watch?v=3DWR5IatHQ&list=WL&index=4>
 - <http://www.youtube.com/watch?v=00maLWlOw&list=WL&index=5>
 - http://www.youtube.com/watch?v=_Uxngw-d0d&list=WL&index=6
 - <http://www.youtube.com/watch?v=q84uMzGw70&list=WL&index=7>
 - <http://www.youtube.com/watch?v=5u6Q2m18EY&list=WL&index=8>
 - http://www.youtube.com/watch?v=4VTen_juS&list=WL&index=9
 - http://www.youtube.com/watch?v=Nn11DWH_LEA&list=WL&index=3
- Drawings by Ceylan Atikoglu based on SOM drawing images and renders.