Burj Khalifa

Carolina Berkheimer-Lubeck, Michael Clariday, Sarah Lawley, Chloe Mengers, Cristina Robalino
Overview

Main Structural System

Foundation

Lateral Resisting System

Loads
Overview

Structural System      Foundation      Lateral Resisting System      Loads

Architect –
Adrian Smith at SOM

Structural Engineer –
Bill Baker at SOM

Developer –
Emaar Properties

“Test the limits of reinforced concrete”
“A tall tower would not only give the master plan an identity, but would also become the identity for EMAAR and the Country of Dubai”

- Adrian Smith
Location – 1 Sheikh Mohammed bin Rashid Boulevard, Dubai, United Arab Emirates

Construction Started – January 6th, 2004

Completed – December 31st, 2009

Cost - $1.5 Billion in USD
Architectural Height – 828 m (2717 ft)

Tip Height – 829.8 m (2722 ft)

Top Floor – 584.5 m (1918 ft) (Level 154)

Observatory – 555.7 m (1823 ft) (Level 148)
Overview  Structural System  Foundation  Lateral Resisting System  Loads

**Program** - hotels, commercial space, entertainment space, offices, and residential spaces

**Material** – Glass, steel, aluminum, and reinforced concrete

**Floor Count** – 163 above ground, 154 usable floors plus 9 maintenance levels, 46 spire levels, 2 below ground parking levels

**Floor Area** – 309,473 m2 (3,331,100 ft²)

**Elevators** – 57 (55 single deck and 2 double deck) by Otis Elevator Company
The initial concept for the design of the Burj Khalifa originated from the *hymenocallis flower*, and *spiral minarets* that are an important part of Islamic architecture.
The form was designed based on how to address the effect of the wind on the structure. The wind force increases as the height of the building increases. How did they solve this?
Design a system that is strong, stiff, and effective

To achieve this, they used the latest technology in materials available locally, latest innovation in analysis, design, materials, and construction methods.
The main structural system for this megastructure has been named a “buttressed core”. This new structural system allows for a dramatic increase in height.

The structural system consists of a three-winged structure anchored to a strong hexagonal central core, each wing is buttressed to the other to provide a highly stable system.

The central core provides the torsional resistance for the building, while the wings provide the shear resistance and increased moment of inertia.
The three wings attached to the central core have four bays each, forming a Y-shaped plan. At every seventh level one outer bay is removed from one of the wings as the tower spirals up. The Y-shaped plan is ideal for residential and hotel usage, with the wings allowing maximum outward views and inward natural light.
Within the wings, corridor walls extend from the hexagonal core to almost the end of the wing and end on thick walls named hammerhead walls.

With the addition of flat plate floor construction and perimeter columns, the entire structural system of the Burj Khalifa acts like a single unit creating a tower that acts as one giant concrete beam cantilevering from the ground.
High performance concrete with high compressive strength
Structural steel with a diagonally braced lateral system for the spire
Special exterior cladding specifically designed to withstand the temperature changes and wind forces
Geotechnical investigation: by Grahame Bunce of Hyder Consulting, the geotechnical engineer for the project and Harry G. Poulos of Coffey Geotechnics who is a technical reviewer for the geological aspects.

Geotechnical investigations used various techniques using boreholes (roughly 30 boreholes were drilled).

Located on the Arabian Gulf = marine sediments

Low-lying land where sea level has changed throughout the periods

Located on the edge of the Arabian plate and close to Iranian Fold Belt = seismic area
Reinforced concrete raft that is 3.7 meter thick and made of High Performance Self Compacting Concrete

Cathodic Protection System that creates a barrier to keep “eroding chemicals” from ground water affecting the concrete

Low permeability and high density = greater protection from ground water

12500 cubic meters poured in four pours for raft foundation

192 piles that are 47 meters in length.

1.5 meters in diameter (piles) and placed 3.75 meters apart from center-to-center
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Structural Overview

Allows entrance from on-grade to the first set of levels

Varying heights and entrances, allows for a transition between the three sides of the building

Entrances have glazing and allow for separate points of entry for the various levels including corporate levels, the Armani Hotel, and the private personal residences within the building.

Structure of Podium: suspended cable net
The winding tiers begin from this staggered base.
Determining the affect of wind on a building

Over 40 studies done in wind tunnel

Design Models

Construction Models
Y-shape helps control wind pressure

6 wind directions

Building responds better to major wind impact on wings

Heavy wind directions in Dubai: Northwest and South
Overview

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Core and Spire

Hexagonal Concrete Core
Resists torsion
Walls up to 1300mm (50 inches) thick

700 feet tall
Over 400 tons of structural steel
Structural pipes up to 1200 mm (47 inches) in diameter
‘Confuses the wind’ to prevent vortex shedding

Rotating Steps Backward
Dubai is classified as a UBC97 Zone 2 seismic region with a seismic zone factor of Z=0.15 and the soil profile is Sc.

It is a ‘bundled tube with various heights combined in a three wing shape.’

Does not govern the design of the reinforced concrete structure.

Was recognized in the design of the reinforced concrete Podium buildings and the spire composed of structural steel.
Over 58,900 cubic yards of concrete was used to construct the concrete and steel foundation.

The concrete core walls used 80 MPa of concrete from ground level to a vertical height of 601 meters.

The perimeter columns are sized to match the same stress on the interior corridor walls.

Outriggers at the mechanical floors allow the columns to participate in lateral load resistance.

All of the vertical concrete is utilized to support both gravity and lateral loads.
Part of the load in a reinforced concrete column is transferred from the concrete to rebar. This reduces creep.

Rebar in the columns and walls at Level 135 support about 15% of the load and the concrete supports 85%.

After 30 years, rebar will support 30% and concrete supports 80%.

The force in rebar increases as the steel ratio is increased and/or as the total load decreases.

Figure 20 – Exchange of Gravity Axial Force between Concrete and Rebar vs. Time
In Conclusion

Latest modern Marvel

Tallest Man-made structure in the world

Race for the next Tallest building is on
Sources

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