Scientific Advancements in Design & Construction of Tall Buildings in the World.

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Buildings all over the world have remained examples of exclusive beauty and grace, strength and as examples of grandeur, leaving behind interesting facts of site selection, study of types of soil, construction innovation and design, exclusive workmanship to leave behind a legacy .

Taj Mahal is one of the seventh wonders of the world built by Moughal King Shah Jahan; on the banks of river Yamuna in Agra in memory of the late queen of Mumtaz Mahal.

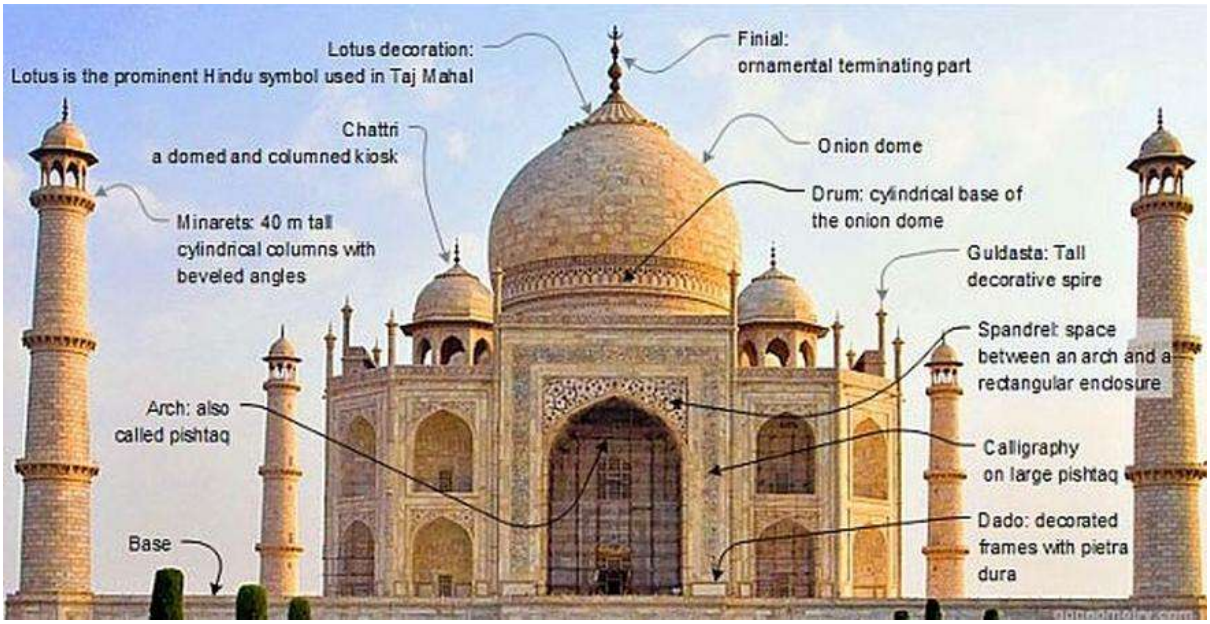
The Taj Mahal, a World Heritage Site was built between 1630–49 by the emperor Shah Jahan in memory of his wife Mumtaz Mahal .[1] Its construction took 22 years and required 22,000 laborers and 1,000 elephants, at a cost of 32 million rupees. (corresponding to US$ 827 million in 2015) It is a large, white marble structure standing on a square plinth and consists of a symmetrical building with an *iwan* (an arch-shaped doorway) topped by a large dome and finial. However, it is believed that Shah Jahan had all the labors' hands severed brutually so that such a marvel would never be constructed again for any other ruler or empire.

The building's longest plane of symmetry runs through the entire complex except for the sarcophagus of Shah Jahan, which is placed off centre in the

crypt room below the main floor. This symmetry is extended to the building of an entire mirror mosque in red sandstone, to complement the Mecca-facing mosque placed to the west of the main structure. *Parchin kari*, a method of decoration on a large scale-inlaid work of jewels and *Jali* work has been used to decorate the structure.

https://en.wikipedia.org/wiki/Mughal_architecture

https://www.tutorialspoint.com/taj_mahal/taj_mahal_architecture_and_design.htm

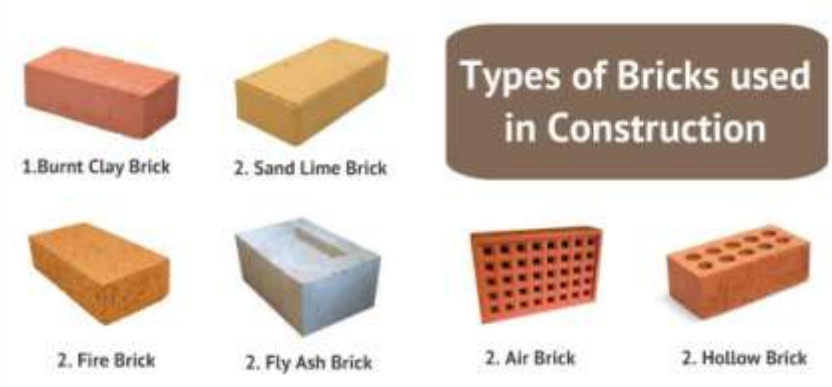


Structural Details of Taj Mahal

1. On a platform 22' high and 313' square. Each tower is 133 feet tall Building is 186 feet high and 70 wide.
2. Corner minarets are 137' tall. Main structure 186' on a side, dome to 187'.
3. The mausoleum is 57 m (190 ft) square in plan.
4. "The central inner dome is 24.5 m (81 ft) high and 17.7 m (58 ft) in diameter, but is surmounted by an outer shell nearly 61 m (200).
5. The Taj stands on a raised, square platform (186 x 186 feet) with its four corners truncated, forming an unequal octagon.
6. The architectural design uses the interlocking arabesque concept, in which each element stands on its own and perfectly integrates with the main structure. It uses the principles of self-replicating geometry and symmetry of architectural elements.
7. Its central dome is fifty-eight feet in diameter and rises to a height of 213 feet.
8. It is flanked by four subsidiary domed chambers.
9. The four graceful, slender minarets are 162.5 feet each.

10. The entire mausoleum (inside as well as outside) is decorated with inlaid design of flowers and calligraphy using precious gems such as agate and jasper.
11. The main archways, chiselled with passages from the Holy Qur'an and the bold scroll work of flowery pattern, give a captivating charm to its beauty.
12. The central domed chamber and four adjoining chambers include many walls and panels of Islamic decoration.

Building constructions research and development has advanced over the hundreds of years of human civilisation, with constant innovations in building durable structures with strong foundations. The building materials



In India the most beautiful and Qutub Minar was buile in 1199, by Qutubudhin Aibak in Delhi. We look at the structure, built in bricks and covered with decorated stone slabs. While we see five stories of the structure today, it is said the top one was damaged and has been removed.

If we look at the structure carefully, we see its a conical at the top and is weight heavy at the bottom with a wide circumference.

The Qutb Minar, also spelled as Qutub Minar and Qutab Minar, Originally known as Rao Petarah's Temple is a minaret and "victory tower" that forms part of the Qutb complex, a **UNESCO World Heritage Site**

in the Mehrauli area of New Delhi, India. The height of Qutub Minar is 72.5 meters, making it the tallest minaret in the world built of bricks. The tower tapers, and has a 14.3 metres (47 feet) base diameter, reducing to 2.7 metres (9 feet) at the top of the peak.

Qutub Minar

Qutub Minar, Delhi

Description

The Qutb Minar, also spelled as Qutub Minar and Qutab Minar, Originally known as Rao Petarah's Temple is a minaret and "victory tower" that forms part of the Qutb complex, a UNESCO World Heritage Site in the Mehrauli area of New Delhi, India. Wikipedia

Address: Seth Sarai, Mehrauli, New Delhi, Delhi 110030

Height: 73 m

Hours:

Closed · Opens 7AM Fri

Construction: Started in 1199 by Qutb-ud-din Aibak / completed in ~ 1220 by his son-in-law Iltutmish

Coordinates: Coordinates: 28°31′28″N 77°11′07″E / 28.524355°N 77.185248°E

The design of the structure clearly indicates that the Architect had an understanding of the strong wind creating problems at the top with a possibility of gradually swinging the structure if it was top heavy. So we see it as a top light structure. This concept is reflected even today when we see the tallest structures of the world, creating adequate space for air to pass through or pliability.

Look at the **Eifel Tower of Paris**, carefully, the steel structure is wide at the bottom and has air pockets for the air to pass through. You notice a big square design in the lower portion which is hollow and allows air to pass through. Also the design in the entire structure allows air to pass through gently. This is called **Air Engineering**.

Eiffel Tower, Paris, France

The Eiffel Tower is a wrought-iron lattice tower on the Champ de Mars in Paris, France. It is named after the engineer Gustave Eiffel, whose company designed and built the tower. Wikipedia

Located in: Champ de Mars

Address: Champ de Mars, 5 Avenue Anatole France, 75007 Paris, France

Height: 300 m, 324 m to tip

Construction started: 28 January 1887

Hours:

Open · Closes 12:45AM

Top floor: 276 m (906 ft)

This velocity of air, the nature of strong winds and its seasonal directions need to be closely studied and documented for deliberations and planning prior to designing the high rise building.

Burj Al Arab

Bruj Al Arab

Burj al Arab, Dubai

The Burj al Arab (translation: Arabian Tower), is a luxury hotel that stands on an artificial island nearly 300 m from the Jumeirah Beach in Dubai, UAE. Standing at 321 m, it is the third tallest hotel in the world and one of the most expensive, costing an estimated 7.8bn dollars.

Dubai had enjoyed economic prosperity in the 1990s due to oil revenues, but officials decided declining reserves would require a shift in the economy and so they moved into luxury tourism and real estate development. In 1993, the Sheikh ruler of Dubai commissioned the British consultancy Atkins to design a building that would become synonymous with Dubai and the United Arab Emirates.

Led by the architect Tom Wright, Atkins designed a high-tech building to resemble the billowing sail of a traditional Arab 'dhow' or yacht.

Despite its height, 39% is made up of non-occupyable space, and the building has faced criticism because of its ostentatious levels of opulence and a favouring of style over function. Notwithstanding this however, since officially opening in December 1999, the Burj al Arab has succeeded in its aim of becoming an iconic symbol of Dubai.

Design and construction

The building is notable for a number of complex engineering and construction feats. The artificial island that was constructed needed to be built low enough to give the impression that the building was floating on water. The reclamation of the land from the sea took 3 years, as engineers created a ground/surface layer of large rocks. To avoid the risk of flooding, perforated concrete blocks were mounted on the bedrock in a honeycomb pattern designed to act as a giant artificial 'sponge' and reduce the wave impact.

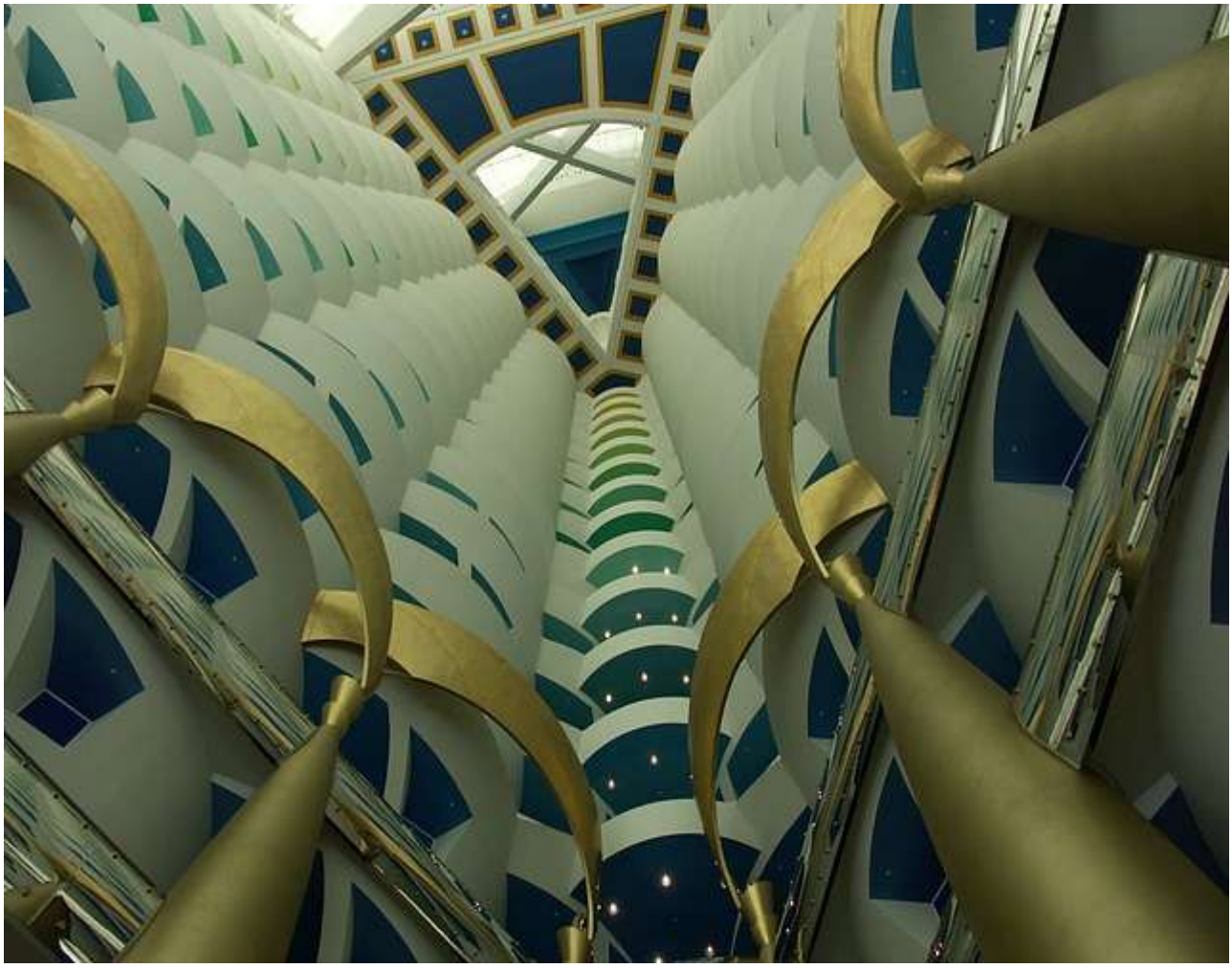
To secure the building to the artificial island, 230 concrete piles measuring 40 m (130 ft) had to be driven into the sand. In total, the building contains more than 70,000 m3 of concrete and 9,000 tons of steel. At peak, 2,000 construction workers were involved in the project.

The building's layout is in the form of two wings spread in a V-shape, creating a 'mast' and enclosing a massive atrium. The façade is covered with two layers of architectural fabric, separated by 60 cm, in order to filter out excessive heat and sunlight.

Each of the 202 hotel suites consists of two levels, with a curved façade and balcony on the upper floor. These were prefabricated and installed on site into the concrete structure. To achieve adequate stiffness, giant metal trusses with a triangular section, each measuring 85 m long, were used on the exterior side walls. These have the effect of diagonally bracing the two side trusses and the large concrete 'mast'. These trusses can expand and contract by up to 5 cm in a day, and to accommodate this a special steering linkage rod had to be designed.

The building also features an inverted steel cone suspended near the roof at a height of 210 m (689 ft). This is primarily used as a helipad but has also been used for several PR events, most famously an exhibition tennis match between Roger Federer and Andre Agassi in 2005.

Interior



The atrium is 180 m (590 ft) tall.

As one of the most luxurious hotels in the world (the only one to have been given the unofficial commendation of '7 stars' by the media), the interior was designed to be palatial, eclectic and baroque.

Having decorated many high-profile hotels around the world, the Chinese designer Khuan Chew was commissioned to design the interior based on the four elements of the ancient world – water, fire, wind and earth. Water is present throughout the hotel in aquariums and fountains, while fire is included in an entrance fountain, together with steam representing air. Earth is symbolised by the 24,000 m2 of marble and precious stones used throughout the hotel, as well as 2,000 m2 of gold foil.

The hotel is also notable for its two distinctive restaurants. Al Muntaha (The Ultimate) is 200 m (660 ft) above the Persian Gulf, a C-

section design that projects out at 30 m from each side of the central 'mast' column. This is supported by a cantilever extending 27 m (89 ft) from either side of the mast, and a series of 1.6 m thick steel beams that fan out from the column towards the restaurant edges.

The Al Mahara (Oyster) features a large seawater aquarium and is accessed via a simulation of a submarine voyage. The wall of the acrylic glass tank is 18 cm (7.1 in) thick to withstand the water pressure.

Project data

- Location: Jumeirah Beach Road, Dubai, United Arab Emirates.
- Height: 321 m (1,053 ft).
- Architect: Atkins.
- Owner: Jumeirah Group.
- Construction began: 1994.
- Construction completed: 1999.
- Number of room: 202.
- Construction cost: $7.8 billion.

World's one of the most Luxurious Hotels

Luxurious Bathroom **Lavish Bed rooms**

Helipad

Exteriors

Luxurious & lavish Dining Areas

Burj Khalifa, Dubai, World's Tallest Building:

Burj Kalifa Dubai, World's Tallest Building

Burj Khalifa was designed by Adrian Smith, of Skidmore, Owings & Merrill, whose firm designed the Willis Tower and One World Trade Center. Hyder Consulting was chosen to be the supervising engineer with NORR Group Consultants International Limited chosen to supervise the architecture of the project. The design is derived from the Islamic architecture of the region, such as in the Great Mosque of Samarra. The Y-shaped tripartite floor geometry is designed to optimize residential and hotel space. A buttressed central core and wings are used to support the

height of the building. Although this design was derived from Tower Palace III, the Burj Khalifa's central core houses all vertical transportation with the exception of egress stairs within each of the wings.[6] The structure also features a cladding system which is designed to withstand Dubai's hot summer temperatures. It contains a total of 57 elevators and 8 escalators.

The Burj Khalifa, known as the Burj Dubai prior to its inauguration in 2010, is a skyscraper in Dubai, United Arab Emirates. With a total height of 829.8 m and a roof height of 828 m, the Burj Khalifa has been the tallest structure and building in the world since its topping out in 2009. Wikipedia

Located in: Burj Park by Emaar

Address: 1 Sheikh Mohammed bin Rashid Blvd - Downtown Dubai - Dubai - United Arab Emirates

Departments: Burj Khalifa Pool Annex

Height: 828 m, 830 m to tip CTBUH

Floors: 163

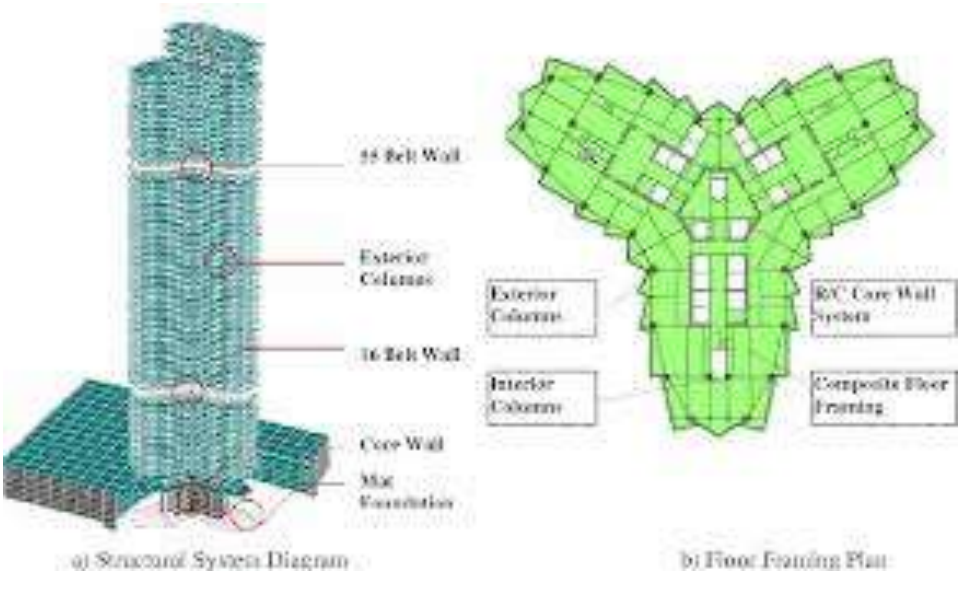
Hours:

Open 24 hours

Top floor: 585.4 m (1,921 ft)

Tower Palace Three, Tower G, or simply **Tower Palace Three, is a73-floor luxury residential skyscraper in Seoul, South Korea :**

The structure was originally designed to be 93 stories high, but was later scaled down due to zoning rights imposed by city regulations.



A notable feature of this structure is the implementation of the Y-shaped tripartite floor geometry which maximizes views and floor space. This innovation pioneered the way for the development of the buttressed core, which is used in the floor plan of the Burj Khalifa as a result of its potential application in mega tall skyscrapers. It was the tallest building in the country in 2004 but was surpassed in height by the Northeast Asia Trade Tower in Incheon , South Korea.

Northeast Asia Trade Tower

Skyscraper in Incheon, South Korea

Description

The Posco Tower-Songdo or Northeast Asia Trade Tower is a skyscraper in Songdo International City, the world's most expensive private real estate project in the Incheon Free Economic Zone, South Korea. The 305-metre building is currently South Korea's fourth tallest, and has 68 floors. Wikipedia

Height: 305 m

Floors: 68

Opened: 10 July 2014

Top floor: 276.7 m (908 ft)

Observatory: 276.7 m (908 ft)

Architect: Kohn Pedersen Fox/Heerim Architects & Engineers

Construction started: July 2006

North Asia Trade Tower, Incheon , South Korea

Northeast Asia Trade Tower in Incheon when it was topped out in 2009. It was designed by United States-based architectural firm Skidmore, Owings and Merrill.

The building is 263.7 m (865 ft) high.[2] Its shape is formed by three oval lobes joined together. It is the eighth-tallest all-residential building in the world.

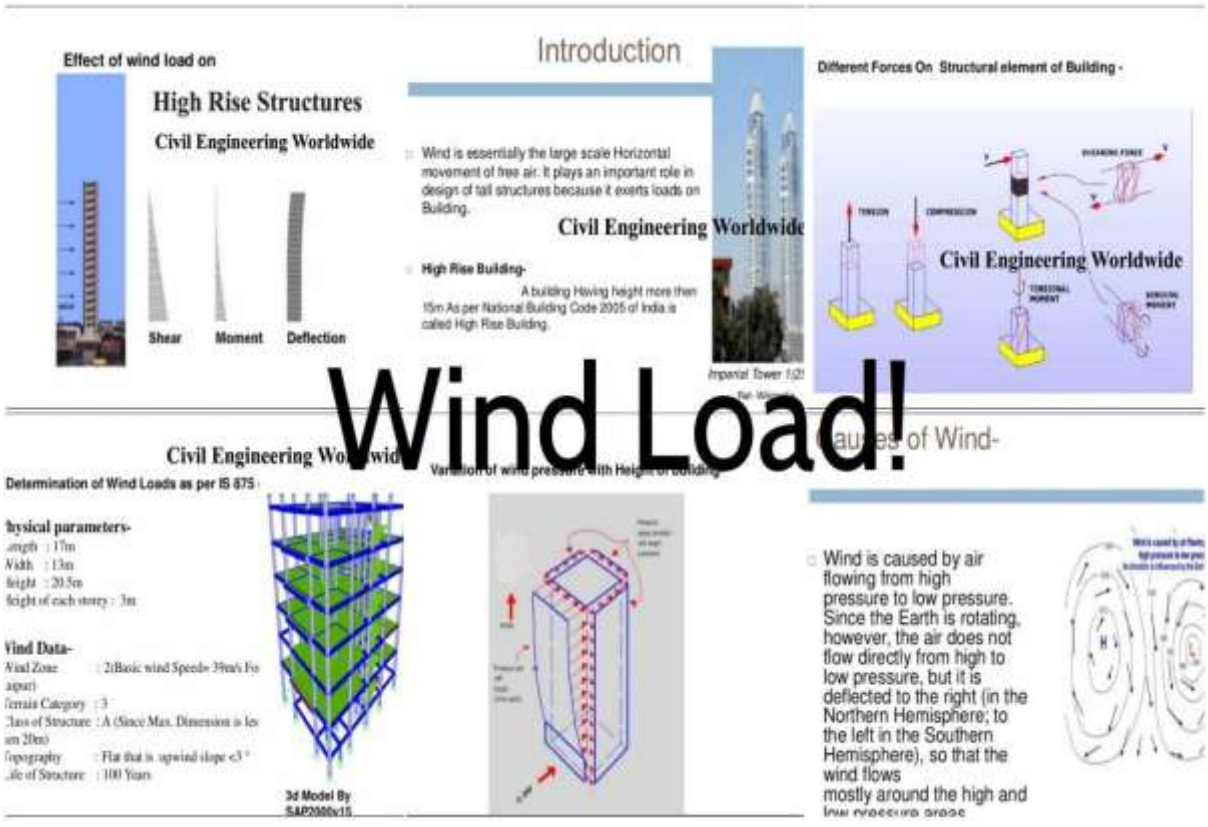
The tapered portion of the building has been designed keeping the wind velocity, its strength and the impact of strong winds if allowed to hit directly. The tapered portion is designed to let the wind pass off smoothly, ensuring that the building does not swing or shaky.

Great Mosque of Samara

Burj Al Arab in Dubai

https://global.ctbuh.org/resources/papers/download/2287-aerodynamic-and-flow-characteristics-of-tall-buildings-with-various-unconventional-configurations.pdf

Wind Engineering for Tall buildings



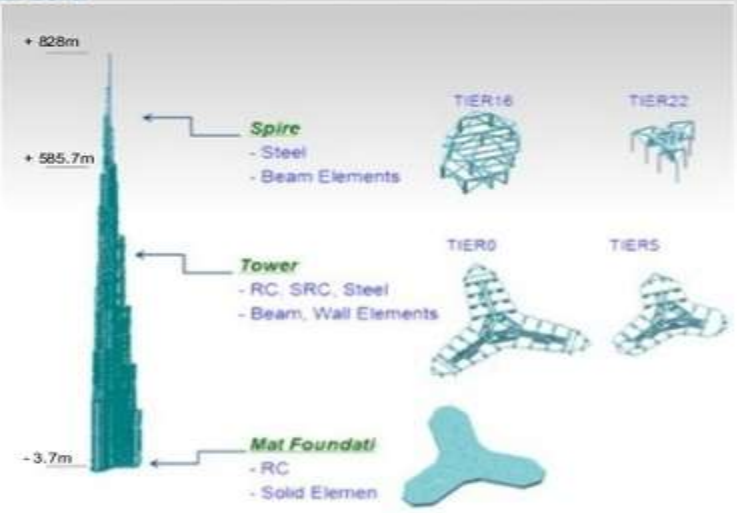
https://www.quora.com/How-engineers-balance-the-Burj-ul-Khalifa-against-wind

Structural System Material

- **Structural material :** concrete , steel
- **Structural System:** Buttressed Core

Dimensional finite element structural analysis model

- The tower superstructure of Burj Khalifa is designed as an all reinforced concrete building with high performance concrete from the foundation level to level 156, and is topped with a structural steel braced frame from level 156 to the highest point of the tower.
- The structure of Burj Khalifa was designed to behave like a giant column with cross sectional shape that is a reflection of the building massing and profile.



The consideration loads on the tower:

3) Wind Load

Wind Engineering in general

- Several wind engineering techniques were employed into the design of the tower to control the dynamic response of the tower under wind loading by disorganizing the vortex shedding formation (frequency and direction) along the building height and tuning the dynamic characteristics of the building to improve its dynamic behavior and to prevent lock-in vibration.

❑ Shape strategies to reduce excitation :

- Softened corners
- Varying cross-section shape

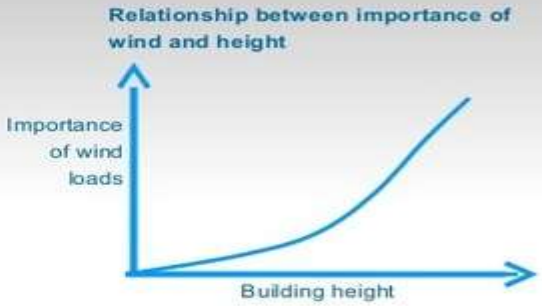
- Porosity or openings
- Tapering and setbacks

- Spoilers

The consideration loads on the tower

Wind Engineering Management

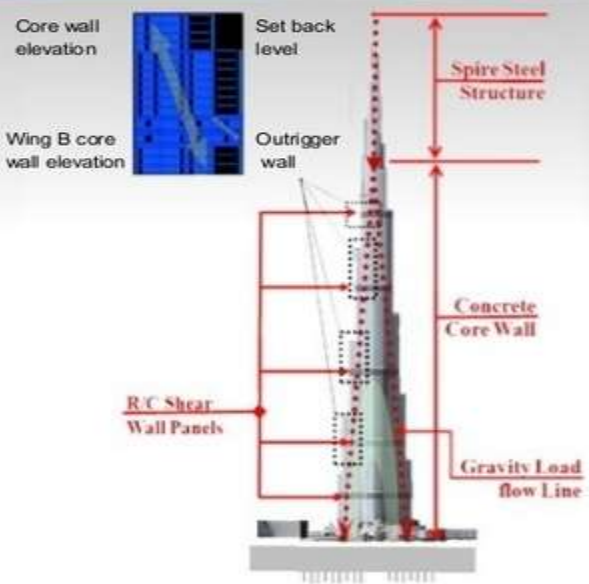
- The wind engineering management of Burj Khalifa was achieved by :
  - Varying the building shape along the height while continuing, without interruption, the building gravity and lateral load resisting system.
  - reducing the floor plan along the height, thus effectively tapering the building profile.
  - Using the building shapes to introduce spoiler type of effects along the entire height of the tower, including the pinnacle, to reduce the dynamic wind excitations.
  - Change the orientation of the tower in response to wind directionality, thus stiffening the structure normal to the worst wind direction.



The consideration loads on the tower:

2) Gravity Load Management :

- **Gravity load management** is also critical as it has direct impact on the overall efficiency and performance of the tower and it should be addressed at the early design stage, during the development and integration of the architectural and structural design concept.
- The limitations on the wall thicknesses (500-600mm) of the center core and the wing walls thickness (600mm) allowed, art of working with concrete, the gravity load to flow freely into the center corridor Spine web walls (650mm) to the hammer head walls and nose columns for maximum resistance to lateral loads.



Best Regards

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