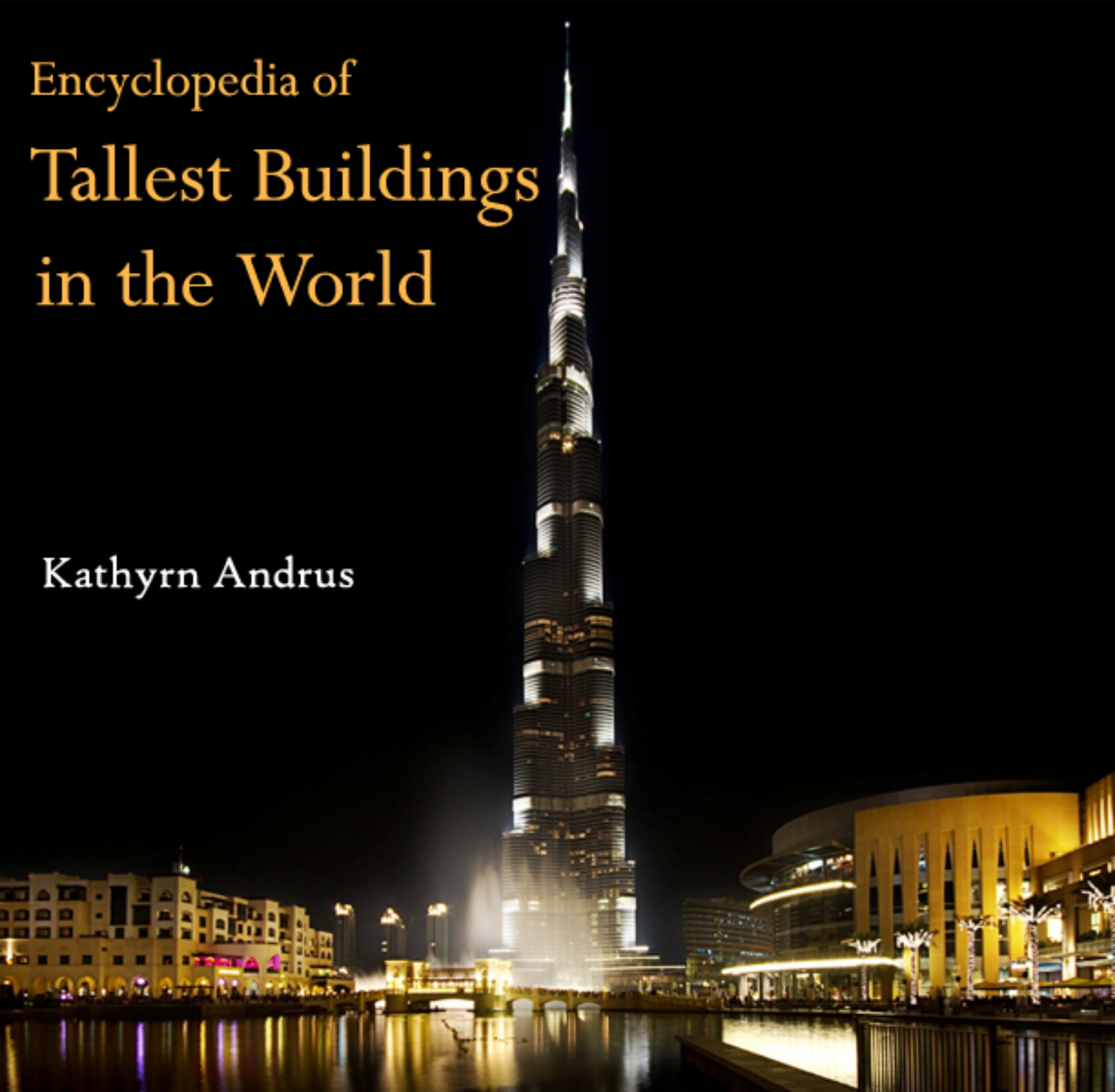
Encyclopedia of Tallest Buildings in the World

Kathyrn Andrus



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Burj Khalifa

Burj Khalifa

برج خليفة

Burj Khalifa on 23 December 2009

Burj Khalifa has been the world's tallest building since 2010.

Former/other name(s)	Burj Dubai
Record height	
Preceded by	Taipei 101
General information	

Location	Dubai, United Arab Emirates
Status	Complete
Groundbreaking	January 2004
Constructed	2004–2010
Opening	4 January 2010
Use	Mixed-use
Height	
Roof	828 m (2,717 ft)
Top floor	621.3 m (2,038 ft)
Technical details	
Floor count	163 habitable floors plus 46 maintenance levels in the spire and 2 parking levels in the basement
Floor area	309,473 m^2 (3,331,100 sq ft)
Cost	$1.5 billion
Companies involved	
Architect(s)	Adrian Smith at SOM
Structural engineer	Bill Baker at SOM
Contractor	Samsung C&T, Besix and Arabtec Supervision Consultant Engineer & Architect of Record Hyder Consulting Construction Project Manager Turner Construction Grocon Planning Bauer AG and Middle East Foundations Lift contractor Otis VT consultant Lerch Bates
Developer	Emaar Properties

Burj Khalifa (Arabic: **برج خليفة** "Khalifa Tower"), known as **Burj Dubai** prior to its inauguration, is a skyscraper in Dubai, United Arab Emirates, and the tallest man-made structure ever built, at 828 m (2,717 ft). Construction began on 21 September 2004, with the exterior of the structure completed on 1 October 2009. The building officially opened on 4 January 2010, and is part of the new 2 km^2 (490-acre) flagship development called

Downtown Dubai at the 'First Interchange' along Sheikh Zayed Road, near Dubai's main business district.

The tower's architecture and engineering were performed by Skidmore, Owings, and Merrill of Chicago, with Adrian Smith (now at his own firm) as chief architect, and Bill Baker as chief structural engineer. The primary contractor was Samsung C&T of South Korea.

The total cost for the project was about US$1.5 billion; and for the entire "Downtown Dubai" development, US$20 billion. In March 2009, Mohamed Ali Alabbar, chairman of the project's developer, Emaar Properties, said office space pricing at Burj Khalifa reached US$4,000 per sq ft (over US$43,000 per m^2) and the Armani Residences, also in Burj Khalifa, sold for US$3,500 per sq ft (over US$37,500 per m^2).

The project's completion coincided with the global financial crisis of 2007–2010, and with vast overbuilding in the country, led to high vacancies and foreclosures. With Dubai mired in debt from its huge ambitions, the government was forced to seek multibillion dollar bailouts from its oil rich neighbor Abu Dhabi. Subsequently, in a surprise move at its opening ceremony, the tower was renamed **Burj Khalifa**, said to honour the UAE President, Khalifa bin Zayed Al Nahyan for his crucial support.

Due to the slumping demand in Dubai's property market, the rents in the Burj Khalifa plummeted 40% some ten months after its opening. Out of 900 apartments in the tower around 825 were still empty at that time.

Conception

Burj Khalifa has been designed to be the centrepiece of a large-scale, mixed-use development that would include 30,000 homes, nine hotels such as The Address Downtown Dubai, 3 hectares (7.4 acres) of parkland, at least 19 residential towers, the Dubai Mall, and the 12-hectare (30-acre) man-made Burj Khalifa Lake.

The building has returned the location of Earth's tallest freestanding structure to the Middle East where the Great Pyramid of Giza claimed this achievement for almost four millennia before being surpassed in 1311 by Lincoln Cathedral in England.

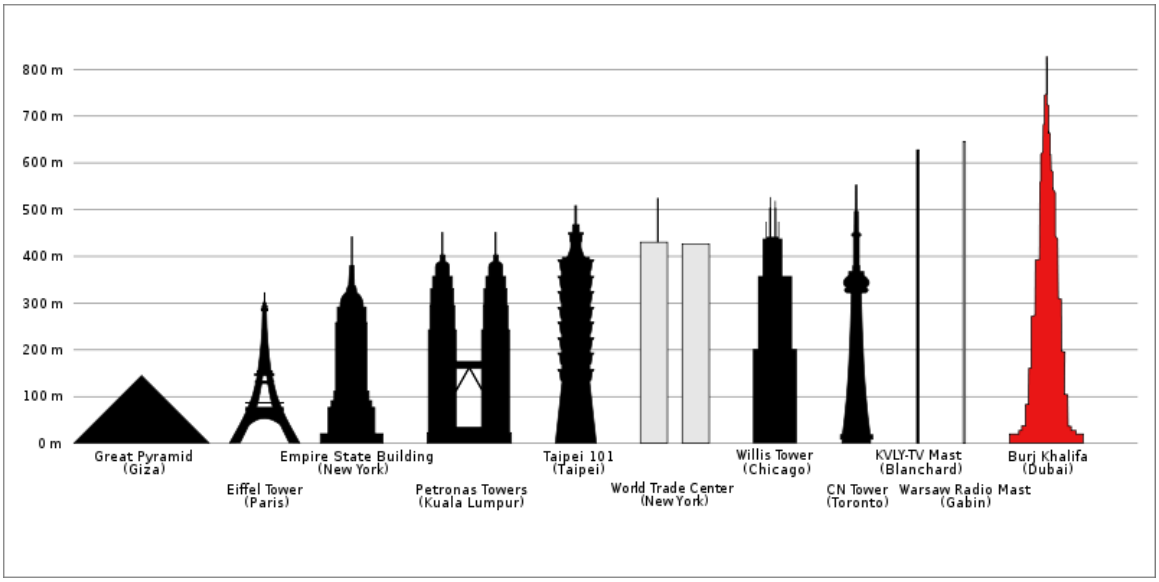
The decision to build Burj Khalifa is reportedly based on the government's decision to diversify from an oil based economy to one that is service and tourism oriented. According to officials, it is necessary for projects like Burj Khalifa to be built in the city to garner more international recognition, and hence investment. "He (Sheikh Mohammed bin Rashid Al Maktoum) wanted to put Dubai on the map with something really sensational," said Jacqui Josephson, a tourism and VIP delegations executive at Nakheel Properties.

Height

Current records

- Tallest skyscraper to top of spire: 828 m (2,717 ft) (previously Taipei 101 – 509.2 m/1,671 ft)
- Tallest structure ever built: 828 m (2,717 ft) (previously Warsaw radio mast – 646.38 m/2,121 ft)
- Tallest extant structure: 828 m (2,717 ft) (previously KVLY-TV mast – 628.8 m/2,063 ft)
- Tallest freestanding structure: 828 m (2,717 ft) (previously CN Tower – 553.3 m/1,815 ft)
- Building with most floors: 160 (previously Willis Tower – 108)
- Building with highest occupied floor in the world: 160th floor
- World's highest elevator installation, situated inside a rod at the very top of the building
- World's fastest elevators at speed of 64 km/h (40 mph) or 18 m/s (59 ft/s) (previously Taipei 101 – 16.83 m/s)
- Highest vertical concrete pumping (for a building): 606 m (1,988 ft) (previously Taipei 101 – 449.2 m/1,474 ft)
- The first world's tallest structure in history to include residential space
- Highest outdoor observation deck in the world (124th floor) at 452 m (1,483 ft)
- World's highest mosque (located on the 158th floor)
- World's highest installation of an aluminium and glass facade, at a height of 512 m (1,680 ft)
- World's highest swimming pool (76th floor)
- World's highest nightclub (144th floor).
- World's highest restaurant called At.mosphere located on 122nd floor at the height of 442 m (1,450 ft). (Previously the world's highest restaurant was 360, at a height of 350 m (1,148 ft) in CN Tower).
- World's highest New Year fireworks display in the world.

History of height increases



Burj Khalifa compared to some other well known tall structures

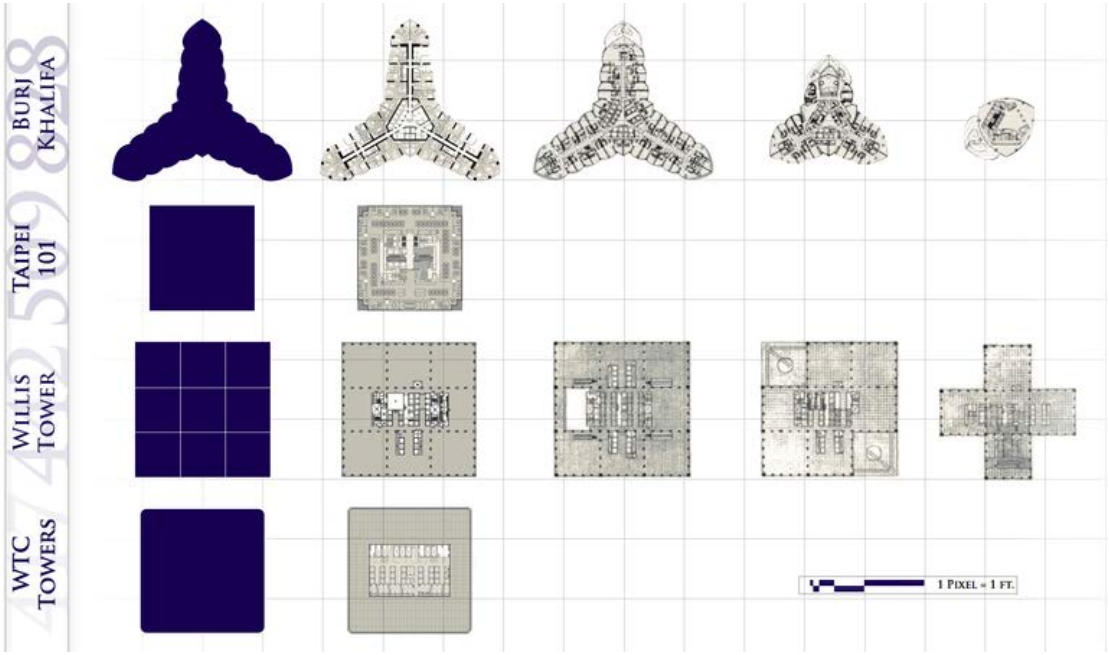
There are unconfirmed reports of several planned height increases since its inception. Originally proposed as a virtual clone of the 560 m (1,837 ft) Grollo Tower proposal for Melbourne, Australia's Docklands waterfront development, the tower was redesigned by Skidmore, Owings and Merrill (SOM). Marshall Strabala, an SOM architect who worked on the project until 2006, late 2008 said that Burj Khalifa was designed to be 808 m (2,651 ft) tall.

The design architect, Adrian Smith, felt that the uppermost section of the building did not culminate elegantly with the rest of the structure, so he sought and received approval to increase it to the current height. It has been explicitly stated that this change did not include any added floors, which is fitting with Smith's attempts to make the crown more slender.

Delay

Emaar Properties announced on 9 June 2008 that construction of Burj Khalifa was delayed by upgraded finishes and would be completed only in September 2009. An Emaar spokesperson said "The luxury finishes that were decided on in 2004, when the tower was initially conceptualized, is now being replaced by upgraded finishes. The design of the apartments has also been enhanced to make them more aesthetically attarctive and functionally superior." A revised completion date of 2 December 2009 was then announced. However, Burj Khalifa was opened on 4 January 2010.

Architecture and design



Cross-section comparisons

A *Hymenocallis* flower showing six spokes, as pattern for the three-lobed design

The tower is designed by Skidmore, Owings and Merrill, which also designed the Willis Tower (formerly the Sears Tower) in Chicago and the new One World Trade Center in New York City among numerous other famous high-rises. The building resembles the bundled tube form of the Willis Tower, but is not a bundle tube structure. Its design is reminiscent of Frank Lloyd Wright's vision for The Illinois, a mile high skyscraper designed for Chicago. According to Marshall Strabala, an SOM architect who worked on the building's design team, Burj Khalifa was designed based on the 73 floor Tower Palace Three, an all residential building in Seoul. In its early planning, Burj Khalifa was intended to be entirely residential.

Subsequent to the original design by Skidmore, Owings and Merrill, Emaar Properties chose Hyder Consulting to be the supervising engineer. Hyder was selected for its expertise in structural and MEP (mechanical, electrical and plumbing) engineering. Hyder Consulting's role was to supervise construction, certify SOM's design, and be the engineer and architect of record to the UAE authorities. Emaar Properties also engaged GHD, an international multidisciplinary consulting firm, to act as an independent verification and testing authority for concrete and steelwork.

The design of Burj Khalifa is derived from patterning systems embodied in Islamic architecture. According to the structural engineer, Bill Baker of SOM, the building's design incorporates cultural and historical elements particular to the region. The Y-shaped plan is ideal for residential and hotel usage, with the wings allowing maximum outward views and inward natural light. The design architect, Adrian Smith, has said the triple lobed footprint of the building was inspired by the flower *Hymenocallis*. The tower is composed of three elements arranged around a central core. As the tower rises from the flat desert base, setbacks occur at each element in an upward spiralling pattern, decreasing the cross section of the tower as it reaches toward the sky. There are 27 terraces in Burj Khalifa. At the top, the central core emerges and is sculpted to form a finishing spire. A Y-shaped floor plan maximizes views of the Persian Gulf. Viewed from above or from the base, the form also evokes the onion domes of Islamic architecture. During the design process, engineers rotated the building 120 degrees from its original layout to reduce stress from prevailing winds. At its tallest point, the tower sways a total of 1.5 m (4.9 ft).

To support the unprecedented height of the building, the engineers developed a new structural system called the buttressed core, which consists of a hexagonal core reinforced by three buttresses that form the ‘Y' shape. This structural system enables the building to support itself laterally and keeps it from twisting.

The spire of Burj Khalifa is composed of more than 4,000 tonnes (4,400 ST; 3,900 LT) of structural steel. The central pinnacle pipe weighing 350 tonnes (390 ST; 340 LT) was constructed from inside the building and jacked to its full height of over 200 m (660 ft) using a strand jack system. The spire also houses communications equipment.

More than 1,000 pieces of art will adorn the interiors of Burj Khalifa, while the residential lobby of Burj Khalifa will display the work of Jaume Plensa, featuring 196

bronze and brass alloy cymbals representing the 196 countries of the world. The visitors in this lobby will be able to hear a distinct timbre as the cymbals, plated with 18-carat gold, are struck by dripping water, intended to mimic the sound of water falling on leaves.

The exterior cladding of Burj Khalifa consists of 142,000 m^2 (1,528,000 sq ft) of reflective glazing, and aluminium and textured stainless steel spandrel panels with vertical tubular fins. The cladding system is designed to withstand Dubai's extreme summer temperatures. Additionally, the exterior temperature at the top of the building is thought to be 6°C (11°F) cooler than at its base. Over 26,000 glass panels were used in the exterior cladding of Burj Khalifa. Over 300 cladding specialists from China were brought in for the cladding work on the tower.

A 304 room Armani Hotel, the first of four by Armani, occupies 15 of the lower 39 floors. The hotel was supposed to open on 18 March 2010 but after several delays the hotel finally opened the public on 27 April 2010. The corporate suites and offices were also supposed to open from March onwards but the hotel and observation deck remain the only parts of the building which are open.

The sky lobbies on the 43rd and 76th floors will house swimming pools. Floors through to 108 will have 900 private residential apartments (which, according to the developer, sold out within eight hours of being on the market). An outdoor zero-entry swimming pool will be located on the 76th floor of the tower. Corporate offices and suites fill most of the remaining floors, except for a 122nd, 123rd and 124th floor where the *At.mosphere* restaurant, sky lobby and an indoor and outdoor observation deck is located respectively. Burj Khalifa will receive its first residents from February 2010. They will be among the first of 25,000 people who will live there.

Burj Khalifa is expected to hold up to 35,000 people at any one time. A total of 57 elevators and 8 escalators are installed. The elevators have a capacity of 12 to 14 people per cabin, the fastest rising and descending at up to 18 m/s (59 ft/s). Engineers had considered installing the world's first triple-deck elevators, but the final design calls for double-deck elevators. The double-deck elevators are equipped with entertainment features such as LCD displays to serve visitors during their travel to the observation deck. The building has 2,909 stairs from the ground floor to the 160th floor.

The graphic design identity work for Burj Khalifa is the responsibility of Brash Brands, who are based in Dubai. Design of the global launch events, communications, and visitors centers for Burj Khalifa have also been created by Brash Brands as well as the roadshow exhibition for the Armani Residences, which are part of the Armani Hotel within Burj Khalifa, which toured Milan, London, Jeddah, Moscow and Delhi.

Water supply system

The Burj Khalifa's water system supplies an average of 946,000 l (250,000 USgal) of water per day.

At the peak cooling times, the tower requires cooling equivalent to that provided by 10,000 t (22,000,000 lb) of melting ice in one day. The building has a condensate collection system, which uses the hot and humid outside air, combined with the cooling requirements of the building and results in a significant amount of condensation of moisture from the air. The condensed water is collected and drained into a holding tank located in the basement car park, this water is then pumped into the site irrigation system for use on the Burj Khalifa park.

Maintenance

To wash the 24,348 windows, a horizontal track has been installed on the exterior of Burj Khalifa at levels 40, 73 and 109. Each track holds a 1,500 kg (3,300 lb) bucket machine which moves horizontally and then vertically using heavy cables. Above level 109, up to tier 27 traditional cradles from davits are used. The top of the spire, however, is reserved for specialist window cleaners, who brave the heights and high winds dangling by ropes to clean and inspect the top of the pinnacle. Under normal conditions, when all building maintenance units will be operational, it will take 36 workers three to four months to clean the entire exterior facade.

Unmanned machines will clean the top 27 additional tiers and the glass spire. The cleaning system was developed in Melbourne, Australia at a cost of A$8 million.

Features

The Dubai Fountain

The Dubai Fountain

View from Palace Hotel

Outside, and at a cost of Dh 800 million (US$217 million), a record setting fountain system was designed by WET Design, the California based company responsible for the fountains at the Bellagio Hotel Lake in Las Vegas. Illuminated by 6,600 lights and 50 coloured projectors, it is 275 m (902 ft) long and shoots water 150 m (490 ft) into the air, accompanied by a range of classical to contemporary Arabic and world music. On 26 October 2008 Emaar announced that based on results of a naming contest the fountain would be called the Dubai Fountain.

Observation deck

An outdoor observation deck, named *At the Top*, opened on 5 January 2010 on the 124th floor. It is the second highest observation deck in the world and the highest outdoor observation deck in the world, at 452 m (1,483 ft). The observation deck also features the Behold Telescope, an augmented reality device developed by gsmprjct° of Montréal, which allows visitors to view the surrounding landscape in real-time, and to view previously saved images such as those taken at different times of day or under different weather conditions. To manage the daily rush of sightseers, visitors are able to purchase tickets in advance for a specific date and time and at a 75% discount over tickets purchased on the spot.

On 8 February 2010, the observation deck was closed to the public after power supply problems caused an elevator to become stuck between floors, trapping a group of tourists for 45 minutes. Despite rumours of the observation deck reopening for St. Valentines Day (14 February), it remained closed until 4 April 2010.

Burj Khalifa park

Burj Khalifa is surrounded by an 11 ha (27-acre) park designed by landscape architects SWA Group. The design of the park is also inspired by the core design concepts of Burj Khalifa which is based on the symmetries of the desert flower, *Hymenocallis*. The park has six water features, gardens, palm lined walkways, and flowering trees. At the centre of the park and the base of Burj Khalifa is the water room, which is a series of pools and water jet fountains. In addition the railing, benches and signs incorporate images of Burj Khalifa and the *Hymenocallis* flower.

The plants and the shrubbery will be watered by the buildings's condensation collection system that uses water from the cooling system. The system will provide 68,000,000 L (15,000,000 imp gal) annually. WET designers, who also developed the Dubai Fountain, developed the park's six water features.

Floor plans

The following is a breakdown of floors.

Floors	Use
160 and above	Mechanical
156–159	Communication and broadcast
155	Mechanical
139–154	Corporate suites
136–138	Mechanical
125–135	Corporate suites
124	*At the Top* observatory

123	Sky lobby
122	*At.mosphere* restaurant
111–121	Corporate suites
109–110	Mechanical
77–108	Residential
76	Sky lobby
73–75	Mechanical
44–72	Residential
43	Sky lobby
40–42	Mechanical
38–39	Armani Hotel suites
19–37	Armani Residences
17–18	Mechanical
9–16	Armani Residences
1–8	Armani Hotel
Ground	Armani Hotel
Concourse	Armani Hotel
B1–B2	Parking, mechanical

Construction

Aerial closeup of Burj Khalifa under construction in March 2008

The tower was constructed by South Korean company, Samsung Engineering & Construction, which also did work on the Petronas Twin Towers and Taipei 101. Samsung Engineering & Construction built the tower in a joint venture with Besix from Belgium and Arabtec from UAE. Turner is the Project Manager on the main construction contract.

Under UAE law, the Contractor and the Engineer of Record, Hyder Consulting, is jointly and severally liable for the performance of Burj Khalifa.

The primary structural system of Burj Khalifa is reinforced concrete. Over 45,000 m^3 (58,900 cu yd) of concrete, weighing more than 110,000 tonnes (120,000 ST; 110,000 LT) were used to construct the concrete and steel foundation, which features 192 piles, with each pile is 1.5 metre diameter x 43 metre long buried more than 50 m (164 ft) deep. Burj Khalifa's construction used 330,000 m^3 (431,600 cu yd) of concrete and 55,000 tonnes of steel rebar, and construction took 22 million man-hours. A high density, low permeability concrete was used in the foundations of Burj Khalifa. A cathodic protection system under the mat is used to minimize any detrimental effects from corrosive chemicals in local ground water. In May 2008 concrete was pumped to a then world record delivery height of 606 m (1,988 ft), the 156th floor. The remaining structure above is built of lighter steel.

Burj Khalifa is highly compartmentalised. Pressurized, air-conditioned refuge floors are located approximately every 35 floors where people can shelter on their long walk down to safety in case of an emergency or fire.

Special mixes of concrete are made to withstand the extreme pressures of the massive building weight; as is typical with reinforced concrete construction, each batch of concrete used was tested to ensure it could withstand certain pressures.

The consistency of the concrete used in the project was essential. It was difficult to create a concrete that could withstand both the thousands of tonnes bearing down on it and Persian Gulf temperatures that can reach 50 °C (122 °F). To combat this problem, the concrete was not poured during the day. Instead, during the summer months ice was added to the mixture and it was poured at night when the air is cooler and the humidity is higher. A cooler concrete mixture cures evenly throughout and is therefore less likely to set too quickly and crack. Any significant cracks could have put the entire project in jeopardy.

The unique design and engineering challenges of building Burj Khalifa have been featured in a number of television documentaries, including the *Big, Bigger, Biggest* series on the National Geographic and Five channels, and the *Mega Builders* series on the Discovery Channel.

Milestones

- January 2004: Excavation commences.
- February 2004: Piling starts.
- 21 September 2004: Emaar contractors begin construction.
- March 2005: Structure of Burj Khalifa starts rising.
- June 2006: Level 50 is reached.
- February 2007: Surpasses the Sears Tower as the building with the most floors.
- 13 May 2007: Sets record for vertical concrete pumping on any building at 452 m (1,483 ft), surpassing the 449.2 m (1,474 ft) to which concrete was pumped during the construction of Taipei 101, while Burj Khalifa reached 130 floor.

- 21 July 2007: Surpasses Taipei 101, whose height of 509.2 m (1,671 ft) made it the world's tallest building, and level 141 reached.
- 12 August 2007: Surpasses the Sears Tower antenna, which stands 527.3 m (1,730 ft).
- 12 September 2007: At 555.3 m (1,822 ft), becomes the world's tallest freestanding structure, surpassing the CN Tower in Toronto, and level 150 reached.
- 7 April 2008: At 629 m (2,064 ft), surpasses the KVLY-TV Mast to become the tallest man-made structure, level 160 reached.
- 17 June 2008: Emaar announces that Burj Khalifa's height is over 636 m (2,087 ft) and that its final height will not be given until it is completed in September 2009.
- 1 September 2008: Height tops 688 m (2,257 ft), making it the tallest man-made structure ever built, surpassing the previous record-holder, the Warsaw Radio Mast in Konstantynów, Poland.
- 17 January 2009: Topped out at 828 m (2,717 ft).
- 1 October 2009: Emaar announces that the exterior of the building is completed.
- 4 January 2010: Burj Khalifa's official launch ceremony is held and Burj Khalifa is opened. Burj Dubai renamed Burj Khalifa in honour of the current President of the UAE and ruler of Abu Dhabi, Sheikh Khalifa bin Zayed al Nahyan.