

1-1-2014

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Recommended Citation

Thompson, Edward (2014) "Reachiing for the Heavens," *Oz*. Vol. 36. <https://doi.org/10.4148/2378-5853.1529>

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Reaching for the Heavens

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Skidmore, Owings & Merrill*

The Burj Khalifa, located in Dubai, United Arab Emirates, was crowned by the Council of Tall Buildings and Urban Habitat (CTBUH) as the tallest structure built by man. So striking was the achievement that the CTBUH, in their yearly awards ceremony, created a special category titled “Global Icon” to do justice for the achievement. It was envisioned by the awards committee that such an honor might be given only every 10 or 15 years for a project making an impact on a global scale. The awards chairman stated, “This project has redefined a region and a people, created a sense of place for Dubai, advanced technology

of super-tall buildings and established a new benchmark for the integrated practice of architecture and engineering.”

Background

To understand why such a project was undertaken, with its immense design and technical complexities and financial commitment of 1.5 billion dollars, we must examine the circumstances in Dubai that propelled the project and the grand scheme for the city in general.

The driving force for the tower was to establish a world symbol and create

immediate recognition that would call attention to the city and its possibilities. Dubai, mindful that its oil revenues would only support the economy for another 20 years, wanted to diversify its economic base. Authorities wanted to add financial markets, tourism, a transportation hub interchange, and conference and exposition centers just to name a few alternatives. Ultimately Dubai envisioned itself as a new world-class city and an economic generator for the region. A tract of vacant land to the northwest was to become the new centerpiece of Dubai which would encompass hotels, office buildings, condominiums, and the world’s

largest shopping center with the focal point being the Burj (meaning “tower” in Arabic).

Political factors also propelled the emerging housing market. A new law allowing foreign expatriates to acquire residential ownership was in the offering. The population averaged seven expatriates to one local, opening the door to a tremendous pent-up market. The Burj’s owner, Emaar Properties, had also studied the economic potential of the region within a thousand mile radius. They reported that in India alone there were more millionaires than the population of Canada.



Competition

The stage was set for a selected competition to design the commercial park's centerpiece. Three internationally-known firms were selected by Emaar Properties to compete. Skidmore, Owings & Merrill of Chicago, a multidisciplinary firm recognized as the global leader in creating ultra-tall buildings, was selected to design the multi-use tower. In the spring of 2003 the SOM team found itself in the middle of an abandoned and barren army base at the edge of Dubai. This was the site that had been designated as the birth place for the soon-to-be-known tallest building in the world.

At this time it was no secret that other developers were looking to build super-tall projects. The client requested that all participants sign a confidentiality agreement. Especially sensitive was the building's height and the bragging rights it would generate. The race for the world's tallest was underway.

We were entering a race for the heavens which history has recorded across the ages. Examples of man's ambition include the Tower of Babel, the Pyramids, Gothic Cathedrals, Eiffel Tower, and corporate muscle statements such as the Willis Tower (formerly Sears). Advanced technology allowed SOM to take the next step forward for a vertical expression never thought possible, employing international cooperation.

Design Team

Communications is the lifeblood of any complex project and having the base team under one roof was a tremendous asset. SOM had the advantage of a multi-disciplined office comprised of architecture, structural engineering, MEP engineering, interior design, and planning. This allowed one-on-one interaction across the major disciplines. As the project

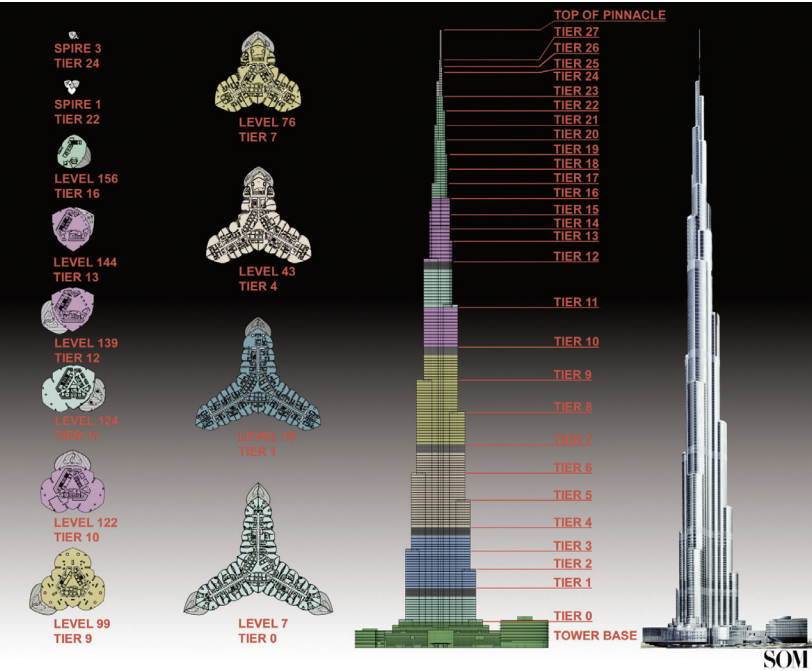
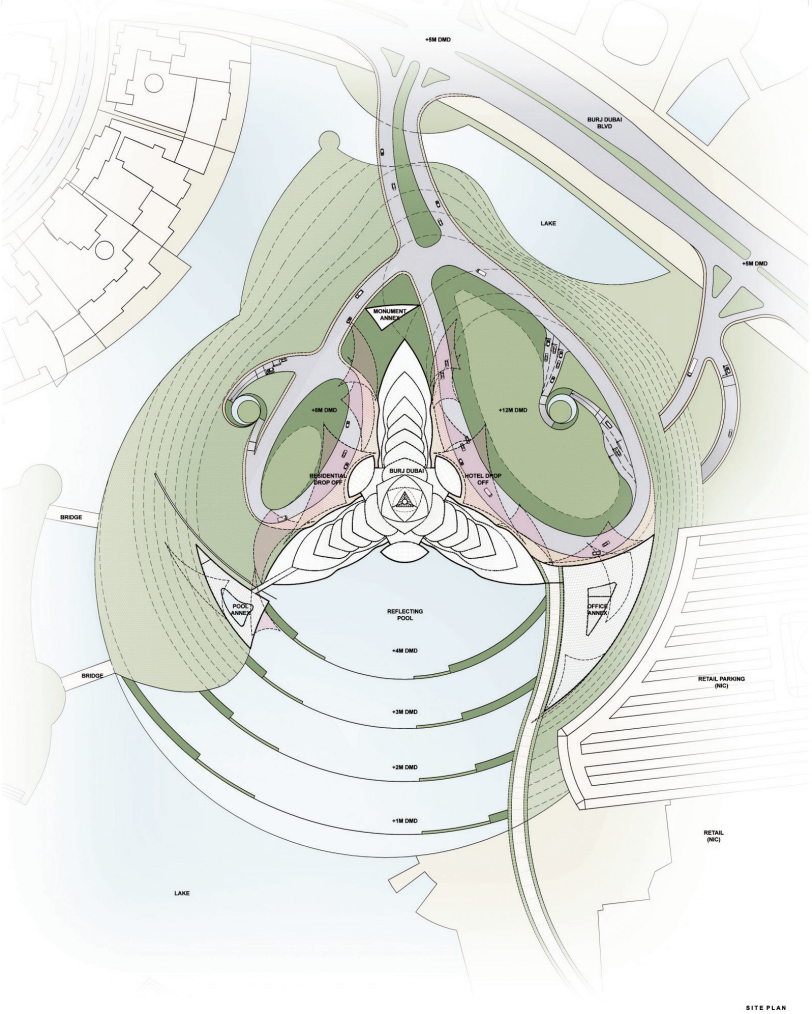
developed, 40 specialty consultants in 11 different countries joined the base team. The world's intelligence was being channeled into SOM for conformation and implementation. At the peak of the design effort SOM had a team of 90 professionals engaged in the design and construction documents. The project was literally being worked on 24 hours a day somewhere in the world.

Project Program

The Burj Khalifa is a large-scale, mixed-use project of luxury condominiums, and a five-star hotel consisting of hotel units and hotel residences. The tower's gross area is over 275,000 square meters (3,000,000 square feet) above grade with a total of 450,000 square meters (5,000,000 square feet) including below grade levels. The project comprises 900 residences, 37 office floors, the 160 room-and-suite Armani hotel, 144 private Armani-designed residences, a four story fitness center and recreational facility, restaurants, service shops, observation deck on level 124, and parking for 3,000 cars below grade.

Architectural Design

The design of the Burj is derived from the geometries of the regional desert flower Hymenocallis and the patterning system of Islamic architecture. The tower is composed of three "wing" elements arranged around a central core. The "Y"-shape plan provides the maximum amount of perimeter area for windows and views in the living space. As the tower rises, setbacks occur at the end bay of each "wing" in an upward spiraling pattern diminishing the mass of the tower as it rises upward. The setbacks were extensively modeled in the wind tunnel to minimize the wind forces on the structure. A high-performance exterior cladding system was employed to withstand the extreme temperatures. The primary material includes reflect-



tive low-emissivity glazing, aluminum and stainless steel insulated spandrel panels, and vertical, polished stainless steel tubular fins to accent the height and slenderness of the tower. The surface area of the cladding is equal to 27.5 acres or about 25 American football fields. The top of the spire measures 828 meters in height or 2,717 feet or approximately one half of a mile.

Structural Design

The structural system of the Burj Khalifa, termed a “buttressed core,” utilizes high-performance concrete as its primary material. The tower’s lateral load system provides resistance to wind and seismic forces. It is comprised of high-performance reinforced-concrete core walls linked to the exterior columns through a series of reinforced-concrete shear-wall panels located on the mechanical levels. The typical floor system consists of a reinforced-concrete flat plate. The design of the tower was significantly influenced by its performance with respect to the wind forces. About 40 wind tunnel tests were preformed, including different design iterations, to develop the optimal building geometry.

The building’s foundation system is a 12-foot thick high-performance reinforced-concrete mat supported on piles. Over 190 piles 5 feet in diameter were driven 140 feet deep below the mat. The amount of concrete used is equal to a solid cube 207 feet on a side along with 35,700 metric tons of steel.

At the top of the tower is a structural steel spire. The lateral load-resisting system consists of a structural-steel, mega-bracing system that is founded on top of the reinforced concrete core wall. The spire is approximately 200 meters in height. It was constructed inside the building and jacked into place.





Mechanical, Electrical, Plumbing, and Vertical Transportation Systems

Due to its height the tower uses “sky sourced” fresh air. Air is drawn in at the top where it is reduced in density and temperature, thus saving energy. At peak cooling times, the tower requires approximately 12,500 tons of cooling per hour which is equivalent to the capacity provided by 28 million pounds of melted ice in one day. The tower’s water system supplies an average of 946,000 liters or 250,000 gallons of water per day. The building also generates a substantial “reverse” stack affect. The Burj was designed to passively control the forces reducing the demand for mechanical pressuration.

Hot and humid outside air, combined with the cooling requirements of the building, results in a significant amount of condensation of moisture from the tempered air. This condensate water is collected and drained in a separate piping system down to a holding tank located in the basement of the car park. This water is pumped into the site irrigation system for use on the tower’s landscaping. The system produces about 15 million gallons of supplemental water per year. This is equivalent to 20 Olympic swimming pools. The system is one of the largest condensate recovery systems in the world.

The tower’s MEP management system utilizes “smart” lighting and mechanical controls to lower operational and energy costs. Individual electrical energy monitoring systems enable optimization of energy. The tower’s peak electrical demand is estimated at 50 mega volt amperes (MVAs). This would be equivalent to 500,000 100-watt light bulbs operating at the same time. Other features include solar panels, ice storage systems, gray-water systems, demand-based controls, and natural ventilation in

minimally-occupied areas such as the car parking garage.

The vertical transportation systems consist of 57 elevators, including double-deck arrangements. The double-deck cabs have a capacity of 21 persons per deck. The main service elevator rises 504 meters which is the world’s longest above-grade elevator. (South African gold mines such as Mponeng’s travel farther with a triple-deck configuration) The Burj elevators are among the world’s fastest traveling at nine meters per second.

The services are distributed from a central utility plant on site which also provides services to other buildings in the park. This leads to economies of scale.

Interior Design

SOM’s interior design was inspired by the local culture but also mindful of the buildings status as an international residential destination. SOM’s interiors stresses that “the built environment is all about the life within.”

These qualities embody humanity, beauty, and function. The signature design of the Burj Khalifa features scholarly inspiration of Arabic calligraphic script abstractions. The curvilinear, upward-rising, organic geometry of the building is reminiscent of Arabic letters. These two geometries were abstracted into an interior design vocabulary of softly-shaped spaces that flow through the building in a continuous curvilinear, similar to shapes of the building and the calligraphy of Arabic letters. The vision for the interiors is one of simplicity, clarity, and timelessness. This was achieved through a careful definition of spaces and a highly-edited palette of materials and colors. Only a handful of materials were used throughout, which were inspired by the character of the land:

- Silver travertine floors and pale Venetian stucco on walls and ceilings for their resemblance to the colors of the pearl harvesting tradition of the region.
- Richly-hued and figured Brazilian Santos rosewood for its resemblance to the wood used in local merchant and fishermen's boats for centuries.
- Stainless steel and glass are homage to the building architecture and present day technology.

All this was orchestrated into a progression of public spaces, using play of shadow and light, high and low ceilings, strategically-located lighting, softly-sounding water fountains and

pools, oasis-like, sparse-but-intense greenery and comfortably-tradition-inspired seating.

Interior and Exterior Art Work

Fine art is always the last touch of elegance on a project. It shows the attention to detail that sets the project apart from the ordinary. Emaar Properties embraced the arts and encouraged SOM's recommendations for locations and suggestions of contemporary art work as well as antique artifacts. Over 500 individual pieces of art were placed in the tower. The interior's primary art investment is displayed in the residential entrance pavilion. A large sculpture by

Jaume Plense titled "World Voices," comprising 196 stainless steel rods and gold-plated symbols seated in a peaceful pool of water representing the number of countries in the world. This symbolized the collaboration of many people from around the world on the project. More public art adorns the Mohammed Bin Rashid Boulevard. Emaar Properties stated that this was a "tribute to the spirit of global harmony."

Project Schedule Milestones

The project was fast-tracked, so construction was started while the design documents were being completed. This was about a two-year process including program and scope changes. The following milestone schedule relates to the physical construction and the significance at that stage of development:

- April 2003—Design kickoff meeting
- January 2004—Excavation started
- June 2006—Level 50 reached
- January 2007—Level 100 reached
- July 2007—Level 141 reached, becomes world's tallest building

- September 2007—Level 150 reached, becomes world's tallest freestanding structure
- April 2008—Level 160 reached, becomes world's tallest man-made structure
- January 2010—Official opening ceremony

It should be noted that at the height of construction approximately 6,800 workers were employed on the site representing a multitude of different nationalities.

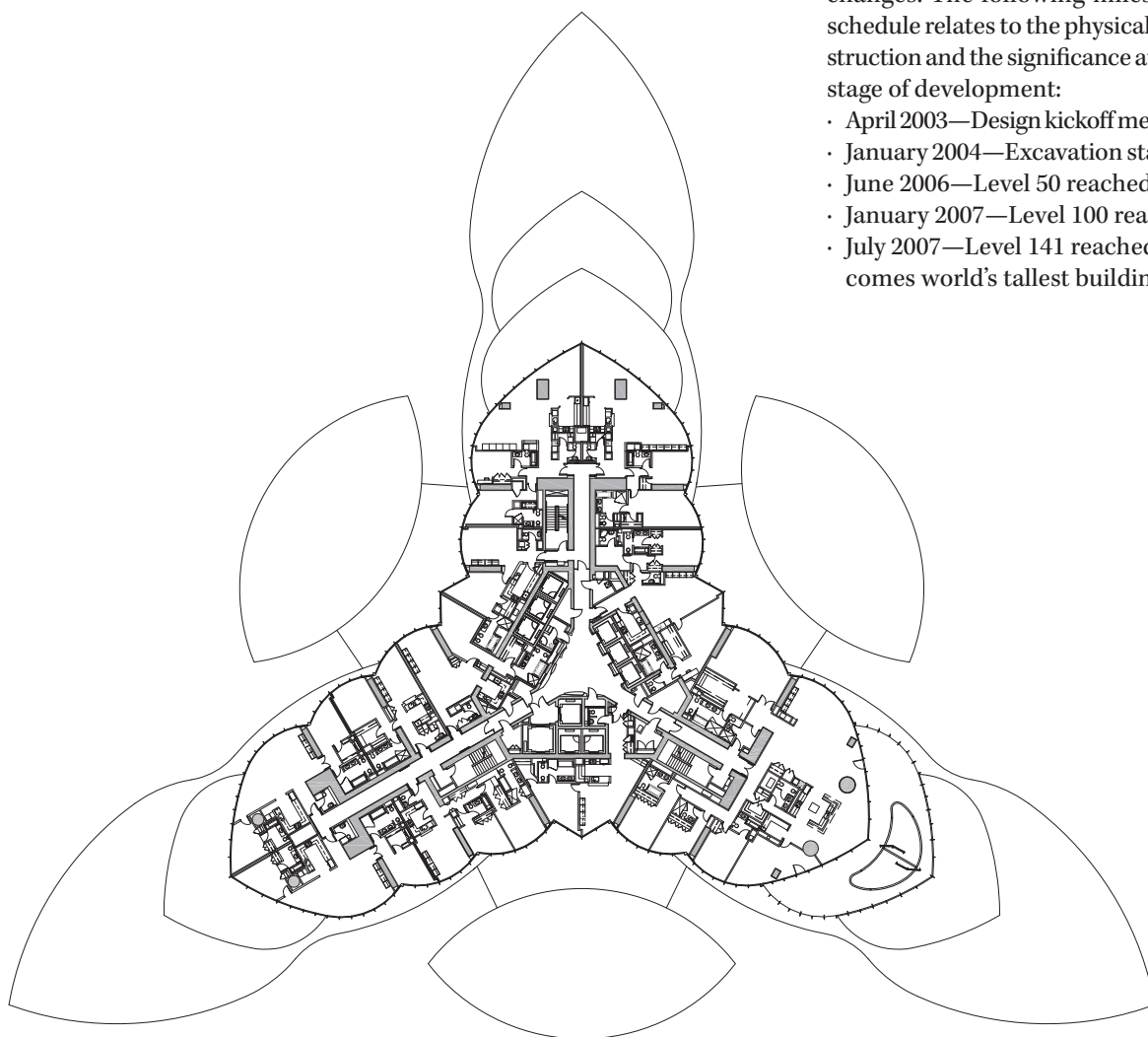
Project Changes / Team Flexibility

Market conditions dictated the initial program for the Burj. Since the design and construction period was lengthy the project needed to react to the shifts in the economy. During the Burj design, an office element was added to the top of the structure. This was a major change and two new elevators had to be added to the core to accommodate the use change. Another major change of a technical nature took place during the design. Wind tunnel testing by RWDI indicated the point of the building needed to be faced into the prevailing wind to reduce the excitation effects of the wind on the structure. The building was rotated 120 degrees to accommodate the findings.

The interior design and construction documents were another late-add to the SOM scope of work. The scope-change integrated into the team well, because SOM was able to cross-pollinate the architects and the interior designers so that the learning curve of the building was minimized. This also allowed communications and coordination to proceed rapidly to meet the given schedules.

Codes

One of the first meetings SOM had in Dubai was with the building de-



partment. Partnering with the local building authorities has the advantage of opening the door for two-way communications. This helps to eliminate any technical surprises as the design develops and it recognizes their authority and influence over the project. We also wanted their buy-in on SOM's recommendation to using international codes. SOM proposed this exception primarily because Dubai's own code did not address tall buildings to the degree that was needed. This was not an unusual condition because most local codes do not address super-tall buildings. We came to an agreement that for this exceptional project the team would use the International Building Code. The exception was that the British standards were to be used for the electrical design. Also 9/11 had caused the world to reexamine their respective building codes. In response, and independently, SOM developed a list of enhancements that were incorporated into the Burj's fire and life safety systems. One such first was a "lifeboat" approach to the elevators in order to evacuate the building quicker. Under certain situations the lifeboats would decrease the total evacuation time by 45% over the stairs alone. Refuge areas were also provided every 25 floors.

Communications

Communication was essential for this international effort. SOM developed a discipline that was strictly adhered to, both in house and out of house. Every team member received memos and copies of the agreement and a specific team library was established. The first order of business was establishing the computer systems, video conferencing, email, express mail and points of contact for each party involved. SOM set up structured meetings with:

- Client and construction manager weekly video conferencing.

- Working meetings with disciplines.
- Weekly discipline management reviews of budgets, progress, problems and man power.
- Every three weeks SOM would hold a meeting in Dubai with the client, construction manager, and the prime contractor. In addition to presenting design updates, from these meetings the team developed an understanding of the client's needs and collaboration on such items as erection strategy and sequencing, material availability, labor skills, crane lifting capacities, maximum panel sizing, and concrete pumping.

Reflections

Why push the limits? The Burj Khalifa pushed the envelope on almost every design and technical front. As a consequence it helped open the door to the proliferation of tall buildings currently being announced. Note that the CTBUH is keeping track of the projects on the global stage. In some respects we all push limits on our projects. These experiences form the building blocks of our creative and technical knowledge. As a profession architects are subjected to constant change, both in design inspiration and developments in physical materials and their application. As the "state of the art" changes and influences our designs, we can produce environments that are more desirable, economic, viable, and safe. If we stop pushing the limits of our knowledge our creative soul will wither. Professional vitality is held in our ability to embrace these new changes, which are fit for purpose, and apply them to the built environment in order to enhance our existence.

If we look at the broader thought of Burj Khalifa, it is more philosophical. We dare to dream and bring that inspiration into reality. Such visionaries were the Sheik of Dubai, Mohammed bin Rashid Maktoum, and Moham-



med Alabar of Emaar Properties. They challenged a team of international consultants and contractors, inspired by SOM's design, to bring reality to that vision. A challenging and remarkable journey for all ensued with spectacular results. Visionaries and professionals coming after us will draw from our experience and knowledge and will be instilled with confidence to ascend to the plateau of "Global Icon."

Notes

Owner/Developer: Emaar Properties PJSC
Design Architect, Structural Engineer, MEP Engineer, and Interior Designer: Skidmore, Owings & Merrill LLP Chicago
Construction Manager: Turner International
Main Contractor: Samsung; Besix Group; Arabtec
Associate Architect: Hyder Consulting
Drawings: © SOM
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