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Review on Structural Study of Burj Khalifa

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Abstract: **The world's tallest building Burj Khalifa, which was under construction for six years, was inaugurated on 4th Jan 2010.The construction of this 828m tall, reinforced concrete tower structure, broke several records during its construction. As it is the first time a tower of this height is attempted, a combination of several important technological concepts and innovative structural design methods were utilized in its construction. The Burj Dubai project is the tallest structure ever built by man. The early integration of aerodynamic shaping and wind engineering considerations played a major role in the architectural massing and design of the residential tower, where mitigating and taming the dynamic wind effects was one of the most important design criteria. Designers purposely shaped structural concrete Burj Dubai"Y"shapein plan to reduce the wind force so the tower, as well as to keep the structure simple and foster constructability. tower's design and construction, which are integrated from thee early design period. Access for the tower's exterior for both window washing and facade maintenance is provided by 18 permanently installed track and fixed telescopic, cradle equipped, building maintenance units. The track mounted units are stored in garages, within the structure, and are not visible when not in use. The manned cradles are capable of accessing the entire facade from tower top down to level seven. The building maintenance units jib arms, when fully extended will have a maximum reach of 36 meters with an overall length of approximately 45 meters. When fully retracted, to parked position, the jib arm length will measure approximately 15 meters.**

Keywords:Centrifuge,BurjKhalifa,Structure,Construction, Planning, Stiff, Aerodynamic

I. INTRODUCTION

BurjKhalifa, known as Burj Dubai prior to its inauguration, is a skyscraper in Dubai, United Arab Emirates, and is the tallest man made structure in the world, at 829.8 m (2,722 ft).

Construction of BurjKhalifa 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) 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 as chief architect, and Bill Baker as chief structural engineer. The primary contractor was Samsung C&T of South Korea.

A building with "no peer" and an "incomparable feat of engineering" (Emaar, 2009) is how Burj Khalifa is described on its website. Situated in the urban hub of Dubai, U.A.E, and standing tall and proud at 828 metres, BurjKhalifa, as shown in Figure 2, is currently the world's tallest building. The skyscraper has been designed to be "the Arab world's tribute to the art and science of modern engineering and design" (Emaar, 2009). BurjKhalifa was inaugurated on 4th

January 2010, at a cost of $1.5 billion. It serves as a mixed-use building, including 30,000 apartments and 9 hotels. It currently

holds 17 World Records, most of which are linked to the height of the building.

The design architect for this super skyscraper is Adrian Smith of Skidmore, Owings and
Merrill (SOM). The inspiration for this building comes from the regional desert 'Hymenocallis' flower. Just like the petals stretch outwards from the stem, the wings ofBurjKhalifapull out from the central core, giving an abstract —"Y" form to the building. The designs also imitate the patterning principles found in Islamic Architecture.

BurjKhalifa has a "triple-lobed footprint. The modular, Y-shaped structure, with setbacks along each of its three wings provides an inherently stable configuration for the structure",.The mixed-use tower features luxury residence, with fitness facilities, swimming pools, recreational rooms, a library for residents, a gourmet market and restaurants. Floor 124 is used as the public observatory deck, drawing in a global audience. To ease the flow of inhabitants, BurjKhalifa has been designed with three Sky Lobbies, offering their own "unparalleled experience". There are also 57 elevators and 8 escalators. The form ofBurjKhalifa reflects Islamic Architecture through the use of onion domes when the building is viewed from the sky, or the base. Even the interiors have been decorated with artwork that is a"tribute to the spirit of global harmony symbolic of BurjKhalifa being an international collaboration".

One of the most challenging issues that face BurjKhalifa is the effects of wind, especially due to its height. To counter this matter, "over 40 wind tunnel tests" (Emaar, 2009) were carried out, before a satisfied and safe design could be raised from the ground. The tests initiated from collecting data regarding Dubai's wind climate and ran through to testing wind conditions on site even as late as the construction stage, with the use of tower cranes. Ahmad K.

Abdelrazaq, the senior project structural engineer of BurjKhalifa recalls how he climbed to the top of BurjKhalifa where "we installed accelerometers to measure the building acceleration, and sonimometers to measure wind speed and direction and atmospheric conditions. This has allowed us to check the actual building movements continuously every tenth of a second". All this useful information is "likely to influence the design and engineering of the next generation of super-tall towers".

The final "spiraling 'Y' shaped plan…helps to reduce the wind forces on the tower", as shown in Figure 5. This allows the building to "confuse the wind", and therefore "wind vortices never get organized over the height of the building because at each new tier the wind encounters a different building shape". Having said this, the top of the tower still "sways 1.5 meters", though this movement is not of any concern or danger. All these considerations are put in place to priorities safety of the tower and its inhabitants at all timessummers. This had to be taken into account when choosing the right cladding for the building to prevent overheating. Therefore, the exterior cladding "is comprised of reflective glazing with aluminum and textured stainless steel spandrel panels and stainless steel vertical tubular fins". There are an estimated "26,000 glass panels, each individually hand-cut" on the outside of BurjKhalifa.

It is an understatement to say that BurjKhalifa represents the state-of-the-art in building design. From initial concept through completion, a combination of several important technological innovations

and innovation structural design methods have resulted in a superstructure that is both efficient and robust.

The various structure elements are as follows:

The **superstructure** is supported by a large reinforced concrete mat, which is in turn supported by bored reinforced concrete piles. The design was based on extensive geotechnical and seismic studies. The mat is 3.7 meters thick, and was constructed in four separate pours totaling 12,500 cubic meters of concrete. The 1.5 meter diameter x 43 meter long piles represent the largest and longest piles conventionally available in the region. A high density, low permeability concrete was used in the foundations, as well as a cathodic protection system under the mat, to minimize any detrimental effects form corrosive chemicals in local ground water.

The **podium** provides a base anchoring the tower to the ground, allowing on grade access
from three different sides to three different levels of the building. Fully glazed entry pavilions constructed with a suspended cable-net structure provide separate entries for the Corporate Suites at B1 and Concourse Levels, the BurjKhalifa residences at Ground Level and the Armani Hotel at Level 1.

The **exterior cladding** is comprised of reflective glazing with aluminum and textured stainless steel spandrel panels and stainless steel vertical tubular fins. Close to 26,000 glass panels, each individually hand-cut, were used in the exterior cladding of BurjKhalifa. Over 300 cladding specialists from China were brought in for the cladding work on the tower. The cladding system is designed to withstand Dubai's extreme summer heat, and to further ensure its integrity, a World War II airplane engine was used for dynamic wind and water testing. The curtain wall of BurjKhalifa is equivalent to 17 football (soccer) fields or 25 American football fields.

In addition to its aesthetic and functional advantages, the spiraling “Y” shaped plan was utilized to shape the structural core of BurjKhalifa. This design helps to reduce the wind forces on the tower, as well as to keep the structure simple and foster constructability. The structural system can be described as a “buttressed core”, and consists of high performance concrete wall construction. Each of the wings buttress the others via a six-sided central core, or hexagonal hub. This central core provides the torsional resistance of the structure, similar to a closed pipe or axle. Corridor walls extend from the central core to near the end of each wing, terminating in thickened hammer head walls. These corridor walls and hammerhead walls behave similar to the webs and flanges of a beam to resist the wind shears and moments. Perimeter columns and flat plate floor construction complete the system. At mechanical floors, outrigger walls are provided to link the perimeter columns to the interior wall system, allowing the perimeter columns to participate in the lateral load resistance of the structure; hence, all of the vertical concrete is utilized to support both gravity and lateral loads. The result is a tower that is extremely stiff laterally and torsionally. It is also a very efficient structure in that the gravity load resisting system has been utilized so as to maximize its use in resisting lateral loads.

As the building spirals in height, the wings setback to provide many different floor plates.

The setbacks are organized with the tower's grid, such that the building stepping is accomplished by aligning columns above with walls below to provide a smooth load path. As such, the tower does not contain any structural transfers. These setbacks also have the advantage of providing a different width to the tower for each differing floor plate. This stepping and shaping of the tower has the effect of "confusing the wind": wind vortices never get organized over the height of the building because at each new tier the wind encounters a different building shape.

II. ADVANTAGES OF BURJ KHALIFA

1. It is an understatement to say that BurjKhalifa represents the state-of-the-art in building design.

2. This design helps to reduce the wind forces on the tower, as well as to keep the structure simple and foster constructability.

3. The cladding system is designed to withstand Dubai's extreme summer heat, and to further ensure its integrity, a World War II airplane engine was used for dynamic wind and water testing.

4. Tallest free-standing structure in the world.

5. The result is a tower that is extremely stiff laterally and torsion ally.

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