

Burj khalifa: the world's tallest building



**ASSIGN
BUSTER**

On 4th of January, 2010, Dubai, where there was only wind-blown litter a generation ago, witnessed the opening ceremony of the world's tallest building," Burj Khalifa".

A brilliant work of art with difficult structural problems took 1, 325 days to completion since the start of the excavation work in January, 2004.

" Burj Khalifa" has returned the name of the " World's Tallest Structure" back to the Middle-Eastern structures where the Great Pyramid of Giza claimed that honor for millions of years before the construction of Lincoln Cathedral in England in 1311.

It is amazing to know that the triple-lobed foot print is inspired from the desert flower " Hymenocallis" which is common in Dubai.

Being located in Dubai, UAE, the tower was influenced by Islamic and middle-eastern architecture. This influence resulted in the tri-axial geometry of Burj Khalifa.

The tower consists of three wings arranged around the a central core in the shape of Y. As the tower rises from the flat desert ground, setbacks occur through the 26 helical levels decreasing the cross-section of the tower as it spirals skywards.

The Y-shape plan is ideal for residential and hotel usage maximizing outwards view and inward natural light. Plus, it allows maximum view of the Arabic Gulf.

As a super-tall structure, there were many difficult structural problems. To ensure safety and effectiveness of the selected design, a model of the building was subjected to extensive peer program.

Designers used the “ buttressed core” in “ Burj Khalifa” consisting of a hexagonal hub buttressed by three wings bracing each other forming the Y-shape. Not only bracing each other but acting as a tripod base which is more stable than a four-cornered base. The corridor walls of the wings extending from the central core to the end of each wing terminate in a thickened hammer head walls.

The main purpose of the Y-shape is to reduce the wind effects as well as keeping the structure simple, safe and foster constructability. The result is a stiff tower that can support itself laterally and overcomes twisting.

Setbacks in each tier occur in a spiral stepping pattern up the building. These setbacks confuse the wind as the wind vortices never get organized because at each tier the building has different shape.

The hexagonal core provides the essential torsional resistance like a closed tube. The wing walls and hammer head walls behave as webs and flanges of a beam resisting wind shears and moments. Specific strength of concrete walls ranges from C60 to C80 cube strength using Portland cement and fly ash.

The C80 concrete used in the lower portion of the building has a specified Young’s Elastic Modulus (E) of 43, 800 N/mm² after 90 days.

Wall and column sizes were determined using Virtual work/LaGrange multiplier methodology which results in very efficient structure.

Wall thickness and column sizes are adjusted to reduce the effect of concrete creep and shrinkage. To reduce the effect of differential column shortening between perimeter columns and interior walls, the size of perimeter columns were adjusted such that the self-weight gravity stress acting on it is equal to that stress on the interior walls.

As shrinkage in concrete occurs faster in thinner elements , the perimeter columns had the same thickness of interior corridor walls(600 mm)to ensure that both columns and walls will shorten by the same rate due to concrete shrinkage.

That super-structure had foundations consisting of a reinforced concrete raft of thickness 3. 7 meters supported by 194 piles. Pouring the raft was divided into four separate pours. Self consolidated concrete (SCC)of C50 cube strength was used.

Each pile is 1. 5 meters diameter; 43 meter long buried more than 50 meters deep.

Piles were designed to support 3, 000 tons each and while load tests, they supported over 6, 000 tons.

Unfortunately, the tower's substructure is constructed in a groundwater having chloride and sulfate concentrations higher than those in sea water!

Having these aggressive conditions, a strict program of measures was required to ensure the durability of the foundations. Measures applied specialized waterproof covers, increasing concrete thickness, addition of corrosion inhibitors to the concrete mix and a cathodic protection system using titanium mesh.

To get higher strength and lower permeable concrete cover to the steel bars, a controlled permeability formwork was used. Besides, a special concrete mix was designed to resist the attack from the groundwater.

The concrete mix for piles having 25% fly ash, 7% silica fume and a water to cement ratio of 0.32, was designed to be fully self consolidating concrete having slump of 675 ± 75 mm to avoid defects during construction.

For that unprecedented height of the building, it was essential to compute wind forces and resulting motions in the upper levels as they became dominant factors in the structural design.

Wind tunnel tests were undertaken under the direction of Rowan Williams Davies and Irwin Inc'.

The wind tunnel program included rigid-model force balance test, a full multi-degree of freedom aeroelastic model studies, measurements of localized pressures, pedestrian wind environment studies and climatic studies. Models used was of scale 1: 500.

The wind tunnel data was then combined with the dynamic property of the tower to get the full tower's dynamic response to wind and the overall effective wind force distributions.

The tower has six important wind directions. The principal three wind directions are when the wind is blowing into the nose of each of the three wings. The other three directions when the wind is blowing between the wings. The orientation and setbacks of the tower were selected relative to the most frequent strong wind direction for Dubai.

A several round of wind tunnel tests were undertaken during the construction of the tower. After each round of tests, the geometry of the tower as well as the number and spacing of setbacks changed to minimize the effect of the wind forces on the tower by confusing the wind.

As the design reached its end, a more accurate aeroelastic model was made. The aeroelastic model is as elastic as the building. The results of testing the aeroelastic model showed that the predicted tower's motion was within the ISO standard recommended values without the need of any auxiliary damping.

At the tallest point of the tower, it sways a total of 1. 5 meters.

Special concrete mix design having compressive strength of 10 MPa at 10 hours for the vertical elements to permit the continuity of construction cycle and a design strength/modulus of 80 MPa/44GPa.

The concrete tests indicated that the compressive strength of used concrete used was much higher than the required one.

One of the most difficult issues in concrete design is to ensure pumpability of concrete to reach world record heights especially in high summer

temperatures. Four basic separate mixes were developed to enable reduced pressure pumpability when the building gets higher.

A horizontal pumping trial was conducted in February 2005 having the same pressure losses equivalent to height of 600 meters to determine the pumpability of these mixes . The concrete mix used contained 13% fly ash and 10% silica fume with maximum aggregate size of 20 mm. The mix is virtually self consolidating concrete having slump of 600 mm and used for pumping pressure exceeding 200 bars.

After the level 127, a less strength concrete is required(60 MPa compressive strength) having maximum aggregate size of 10 mm. High quality control was required to ensure pumpability to the highest concrete floor considering the severe conditions of weather which vary from a very cool winter to a very hot summer with temperature exceeding 50°C.

Pumping concrete was executed using Putzmeister pumps which are capable to pump concrete up to 350 bars through high pressure 150 mm pipeline.

To convert the dream of Burj Khalifa to reality, the latest advancements in construction techniques and material technology were used.

The walls' forms were made using Doka's SKE 100 automatic self-climbing formwork system. Steel forms were used in the circular nose. Columns and the floor slabs are poured on MevaDec formwork.

The construction sequence for the structure began with the central core and slabs being cast in the three sections, followed by the wings walls and slabs and then the nose columns and slabs.

To ensure the verticality of the structure, a special GPS monitoring system was developed to monitor the verticality of the building as it gets higher. This was due to the limited conventional surveying techniques in the site.

When completed, Burj Khalifa has become the world's tallest structure. Being a magnificent achievement in using the latest technologies and materials, able to integrate the architectural design concept with the structural design, Burj Khalifa will always be a special case to study.

N. B: Highlighted sentences are from (Engineering the World's Tallest – Burj Dubai)