

# Willis tower sears tower construction essay



**ASSIGN  
BUSTER**

Sears Tower, Chicago (442 m) Taipei 101, Taipei (508 m) Burj Khalifa, Dubai (828 m)

Introduction

The construction projects that have been chosen for this assignment are all rated as super-tall buildings in world from different locations; Middle East (Dubai), Far East (Taipei) and Northern America (Chicago). The three structures have been built in various environment and climates, this will mean their design has to be unique to cope with different environmental conditions. When designing a super-tall structure the fundamental aspects that have to be considered are the safety of the habitat around, as sky scraper are built in urban areas, the structure has to be able to support its weight, also to resist the weather condition and earthquake in the area. In 1900 the technology of steel frame developed in various structures in Chicago and New York where advancing to constructing skyscraper from only steel frame. However today reinforced concrete is the main material used for the construction of the sky scraper, damping vibration and giving the structure mass make the reinforced concrete a reliable material to be used. (Daniel Michael Abramson, 2001)

In 1960s, a structural engineer Farzlar Khan designed a structural system that is innovative idea called " tube" which are framed tube, trussed tube and bundle tube. The economic efficient structural system has helped to design variety of shapes and scale for skyscrapers. The method of the " tube" structural was first used on Sears Tower, after a few decades the same method has been used to construction the tallest building in the world standing today Burj Khalifa. (Ali Mir M, 2001)

In 1930 the rivalry was between downtown's Bank of Manhattan Company building and Cities services building as tallest building. In 1973 New York Trade Centre was surpassed by the Sears Tower in Chicago at 442m. A century later other continents were

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changing their new technology and finance to construct the tallest building. Asia was the winner having constructed the Shanghai Financial Centre and Taipei 101 (height of 508m). Today Middle East has the tallest tower by far with Burj kahlifa standing at 828m.

## **Willis Tower (Sears Tower)**

### **Engineering**

The steel structural system used to construct the Willis Tower, 108 stories at height of 442 meter, is bundled tube structure made of 9 tubes each 75 feet by 75feet. On the 50th, 66th, 90th floors the numbers of tubes reduce by two or more. The tubes are connected at different levels with truss belts. This technology reduces the lateral stiffness and avoids gravity settlement on the tower. (Iyengar, 1972)The bundled tube system decreased the shear lag which made the structure lighter, allowing 33 pounds of structural steel per square feet. This made the bundled tube system very efficient (Khan FR and WP Moore, 1980)Willis Tower is made of system of columns that are spaced 15 inch on center with each of nine tubes share two faces columns. As the building is asymmetrical the gravity load is different on each tube. With the belt trusses connected to the tube will allow the gravity load to distribute equally the columns. (Khan FR, 1976)Willis tower experiences lateral wind where the structure acts as a cantilevered tube with various inertia because of column layout. The lower floors have greater moment of inertia also the wind pressure acting on the building depend on area exposed. With the extreme height of the building the Chicago building code was not efficient and reliable enough so wind tunnel testing, computer aided design and statistical analyses was also used to design the structure. (Khan, 1976)

## **Social and Economical**

In 2010, the tower was renamed from Sears tower to Willis Tower after Willis Group Holding is the largest tenant in the tower. The company that commissioned the structure was Roebuck & company, the company used the tower as its new headquarter in the 1970s. In 1969, Sears, Roebuck and company was the largest retailer in the USA. With a net income of \$441million, the company was able to afford an impressive modern building for its new headquarter. (Khan & Yasmin Sabina , 2004)Sears, Roebuck & company had the support of the Richard Daley (Chicago's Mayor), for the company to construct in the city center at South Wacker. The mayor was enthusiastic that the Sears's headquarter will help Chicago economically to bring the headquarters of other large businesses in to the city. Daley also increased the height restriction on the building height. (Willis C, 1995)Sears did studies on the company's growth and current business, with that their result showed that in the future they company will need 2 and 4 million square feet with each department having an area of 110, 000 square feet. Sears also looking at constructing a 40 story cube as a cost effective solution. A structural engineering and architecture firm based in Chicago called Skidmore, Owings and Merrill (SOM) was hired to design the structure. SOM did their own studies and concluded to have 55, 000 square feet stories on top of one another making a 80 story tower but if the SOM was able to make it cost effective. (Adams N & Skidmore, O&M, 2007)Structural engineer hired for the project was Fazlur Khan, who came up with the structural tower the Sears Tower. Sears tower was designed with a bundled tube system, the system provided strength for the structure and saving Sears \$10million. Also another innovative structural system was used " braced tube"( Khan FR, <https://assignbuster.com/willis-tower-sears-tower-construction-essay/>

1976). The main construction challenge was to meet the 15 months construction programme to complete the structure and reducing the construction cost, prefabrication was one of the most important principles employed during the building of the Sears Tower. Structural units called 'Christmas trees' allowed for a 95% reduction in welding on the job site. The units were welded offsite and consisted of a two-story column with half-length beams welded to either side of the column. On site, the units only needed bolted splice plate connections between beams and web bolted connections for the column splices. As welding on site is one of the most costly and time consuming aspects of steel construction, this process saved a great deal of money and time for Sears. This use of prefabrication of the Sears Tower project significantly streamlined the construction process. (Ali. Mir M, Kyoung Sun Moon, 2007)

## **Sustainability**

At the time of the construction of the Sear Tower in 1970's sustainability was not an important consideration for developers, as result the designers did not take in to account any criteria for designing green building. In the past decade due to the green house effect the energy efficiency of building design and sustainability is important factor in the building design. In 2009 Willis Tower (Sears Tower) revealed sustainability plans estimated to be \$ 350 million. The plan is to have energy saving, reduce carbon dioxide emissions and encourage economic development in Chicago by produces more than 3600 jobs. (Jennifer Brenner, 2009)The tower will be following the Leadership in Energy and Environmental Design (LEED) criteria, it will be designed by Chicago-based Adrian Smith + Gordon Gill Architecture

(AS+GG). The sustainability plans were: Efficiency Improvements to façade and windows. The plans are to replacement the 16000 single-panel windows, with new windows that have glazing. New Mechanical system, new gas boilers that use fuel cell technologies. Also new high efficiency chillers and upgrade distribution system were installed To reduce 40% of the energy consumption in the tower, 104 high speed elevators and 15 escalators with newest technology were installed. Restroom fixtures, condensation recovery system and was efficient landscaping were upgraded, had will save 24million gallons of water each year. With new lighting technology that has light control and daylight harvesting. The light will be automatically dim in spaces depending on the amount sunlight entering through windows with light control system. Solar hot-water panels have been fixed on the building to produce heated water for the building. Green roofs on the tower will be tested to improve insulation, improve mitigate the urban heat island effect and to reduce storm water runoff. Wind turbine will be tested as the towers height can be used to create electricity for the tower.(Jennifer Brenner, 2009)

## **Taipei 101**

### **Engineering**

The Taipei tower 101 was the world's tallest building (height of 508m) from 2004 to 2010 designed by C. Y Lee & partners (Architect) and Thornton Tomasetti (Structural engineer). The tower is located in area where it experience earthquakes and typhoons, the main challenge for the architects and structural engineers was designing a tower that could withstand earthquake and typhoons. The towers structure has been inspired by the baboon plant where the plant is very light and flexible but also very strong.

The innovative design that was used on the tower had given the structure strength and flexibility. (Leonard M. Joseph , 2006)The technology used to give the structure balance and stability was from the idea of outrigger used on sailing boats to sail fast but also keep its balance. The Taipei tower has a central core, in every 8th floor horizontal trusses outrigger are connected to the central core. There are 8 external column surround the central cores the outrigger trusses are also attached to the external columns. The foundation is reinforced by 380 piles, drilled down to 80m in the ground. The piles are 1.5m in diameter, they can withstand load of 1000 tonnes. (Shaw-song Sheih, Jiun-Hong Jong, 2001)Screen shot 2011-12-18 at 15. 47. 20. png Screen shot 2011-12-18 at 15. 46. 51. pngThe Taipei has an innovative damper design made by Thornton-Tormastti Engineers. On the 87th to 92th floor there is a suspended pendulum weighing 660 tons with a diameter of 18 feet. As the tower experiences gust of wind, the damper acts like a tuned mass damper. The damper uses inertia, when the tower sways the damper swing like a giant pendulum then it pushes on to the oil shock absorbers, which reduces the sway. (Ray Clancy, 2009)

## **Economical, Political and Social**

Taipei 101 not only has incredible technology but the construction of the 101 storey tower to represent growth and economical achievement in Taiwan, with breaking the record for the world tallest in which it is located in environment that experience typhoon and earthquakes. In the 1990's Taiwan become one of few countries to construct super-tall building, with the buildings such as Shin Kong Life Tower and T&C Tower. (Georges Binder, 2008)In 1997, when the property market was in decline, the mayor of Taipei

organized to meet up with the developers such as Harrace Lin, that they will on a large site. Xin Yi planned District was a vacated site to become multifunctional area in the capital of Taiwan. For Herace Lin to win the bid, they organized a team supported by China Development Industrial Bank, Cathay Insurance, Shin Kong Insurance and China Insurance. There was major problem with the insurance companies investing on the project as their companies would not invest more than 5% of the asset. To resolve the issue Harace Lin built a larger financial, eleven companied joined with the Taiwan Stock Exchange that they will become 5% shareholders, needed by the Taipei City Government tender document. This meant Taipei 101 was the first project to have private sector and Taipei City Government work as a team. Initially there were seven teams of developers, Harace Lin's team was the winner of the bid, which had the highest cost NT\$20 billion with the design looked by a committee from the Taipei City Government. After many designs on the building they came up with a 101 storey tower that was named TAIPEI 101, symbolizing today's digital world and 101 levels. Taipei 101 was designed to give tenants the highest standard multifunctional environment, with the companies ABN AMRO, ING Insurance, KPMG and The Taiwan Stock Exchange use the tower as their headquarters. The TAIPEI 101 also has the largest shopping mall in the Taipei; with well known brands should Cartier, Dior, Prada, Tiffany & Co and ect. Vertical malls work well in Asia but will not work in other countries; the structure is designed to have people move efficiently within the retails and entertainments venue. The shopping mall exit is on the level 4 and 5, making the crowd control efficient which is a major factor of the urban life created in Taipei101. Curve structure



of the mall making the crowd walk round will make shoppers see more which means buy more.

## **Sustainability**

In 2009, Taipei Financial Center Corporation planned to make Taipei101 the tallest green building in the world by 2011 summer, overviewed by LEED standard. Currently the structure is energy efficient with double panel windows that blocks external heat by 50% and recycle water that produces the 30% of the buildings demands. In July 2011 Taipei 2011 achieved LEED platinum Certification with the project costing NT\$60million, the plans are that the new development will save \$1. 2million in costs each year. (Wu Li-sha, 2011)Working with Eco Tech International and Steven Leach Associates have helped Taipei 101 to produce its green features. The building's cooling system had algorithms placed for the chiller plant and changing sequence of operation making the system efficient. (Leanne Toblas, 2011)

## **Burj khalifa**

### **Engineering**

The Burj Khalifa tower currently the world's tallest building, 162 stories at height of 828m. Important technological concept and innovative structural design method have been used on the reinforced concrete tower structure. The architectural and structural design was by the Skidmore, Owings and Merrill (SOM). The architect, Adrian smith designed the Burj Khalifa to resemble the bundled tube where the structural system was used in Willis Tower, but it is not a tube structure. (Dr. N. Subramanian, 2010)The tower lateral load resisting system which is of high performance, this is due to reinforced concrete ductile core walls vary in thickness from 1300mm to <https://assignbuster.com/willis-tower-sears-tower-construction-essay/>

500m is connected to series deep reinforced concrete beams at each level. Steel shear plates are placed on the beam to create I-shapes beams, with shear studs attached in concrete section. High-performance concrete is a crucial part of the viability of super-tall buildings, both structurally and economically. The stiffness provided by high-modulus concrete has significant benefits in terms of limiting movement, and high strength is necessary to reduce the cross-section of vertical elements. The lateral load resisting system on the top of the center reinforced concrete wall is made of a very tall spire consists of a diagonal structural steel bracing system from level 156 to the top which 750 m above the ground. The Burj Khalifa tower is crowned with a 4, 000 tonnes structural steel telescopic spire, which houses communications equipment. The spire was constructed from inside the building and jacked to its full height of over 200 metres using a hydraulic pump. Wind engineering is one the most important concerns in the design for constructing tall building. Early integration of aerodynamic shaping and wind engineering played a major role in the architectural massing and design of this multi-use tower, where mitigating and taming the dynamic wind effects was one of the most important design criteria set forth at the onset of the project design. The Burj Khalifa is designed to minimizing the wind force acting on the tower. The change in tower shape, this makes the wind vortices around the tower that acts differently for different shapes at different frequencies. Before the construction the tower, extensive wind tunnel studies and testing regimes took place to achieve a full understanding of the building wind behavior and reaction. The utilization of high strength concrete and concrete pumping technologies was critical in the construction of the project. C60 and C80 grade concrete was used for vertical members,

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and C50 grade concrete was used for horizontal members. (Ahmad Abdelrazag 2010) Direct concrete pumping and delivery methods required considerations for the following: selection of optimum concrete mix design with excellent flow characteristics to minimize/avoid blockages; selection of equipment that has enough capacity to deliver concrete to the highest level, more than 160 floors up; design of a pipe line that can be installed with maximum construction efficiency; selection of equipment and pipe line system that work well with the site's overall logistics and planning; maintenance of quality control of the pumping system and placement method by monitoring all components of the system and ensuring the concrete properties required.

### **Economical, Political and social**

The Burj Khalifa is location in Dubai, the cost of constructing the Burj Khalifa was \$1.5 billion. After the construction the price of the office spaces reached \$4000 per square feet and residential spaces as high as \$3,500 per square feet. Dubai's economy was built on the oil and natural gas. March 2000, Dubai Financial Market (DFM) was established, its trading volume was at about 400 billion shares worth total of \$95 billion in total. The sheikhs are inspired by ultra-modern architecture and engineering, where well known inland and offshore structures have been built for example palms island, Burj-al-Arab, emirate tower and ect. The structures are built to encourage business to make the flagship office in Dubai. Therefore the Burj khalifa was built as an icon structure and to create more office space for businesses to move into Dubai. The Dubai's government ambition was to create the

financial center in Middle East to be half way in time zone between Tokyo and London.

## **Sustainability**

Burj Khalifa has placed solar power panels on the building top heat up 140,000 liter of water every day that will be spared to apartments and offices within the tower. The solar power is planned to save 3,200 kilo-watts per day. (Khaleej Times, 2010)The Burj kahalifa has a system which collects moisture from the building's air conditioning units and the water is reused to water the surrounding landscaping. This system will provide 15 million gallons of water every year. (Orlando Crowcroft, 2010)With the height of the building and high temperature during the day, the pumping and pouring for 110,000 tones concrete flooring was done during the night where the concrete can cure and this will avoid cracking, it save on the energy to cool the concrete during construction of the structure.

## **Conclusion**

### **Engineering**

Willis tower (Chicago) and Burj Khalifa (Dubai) have both been inspired by the tube structure system designed by Farzlar Khan, with the towers located in different environment and weather conditions the structural system has work on both towers. Tube structural system is when the structural is made tubes and number of tubes reduce in selective floor for example in willis tower on the 50th, 66th, 90th the number of tubes reduce by two or more. However, the Taipei Tower 101 has been designed by C. Y Lee & partners with the innovative design to be the second tallest tower in the world and also to be able to withstand typhoon and earthquake. The structure of the <https://assignbuster.com/willis-tower-sears-tower-construction-essay/>

tower is inspired by the Baboo plant for strength and flexibility, the technology used to keep the structure stable is the design of outrigger on sailor boats. The engineering design used for the towers to resist the wind is diverse in each tower. Burj Khalifa's structure has a design to minimizing the wind force acting on it " confuse the wind", the shape of the tower changes force acting on the tower changes. The Taipei 101 will not be able to use Burj Khalifa's design for withstanding wind forces, the structural engineers of Thomton-tornastti Engineers has made an innovative damper design. A suspended pendulum on the 87th to 92th floor acts a dampers absorbing the energy to reduce the sway of the tower to withstand typhoon and earthquake . The Willis tower has the same engineering used as in the Burj Khalifa to withstand the wind forces acting on the tower, the shape changing of the tower reduces the wind force acting on to the tower. The Burj Khalifa project demonstrates that tall building system developmentis always directly related to the latest developments in material technologies, structuralengineering theories, wind engineering, seismic engineering, computer technologies, andconstruction methods. The Burj Khalifa project capitalizes on the advancements in thesetechnologies, and in advancing the development of super-tall buildings and the art of structural engineering. As of today, the Burj Khalifa is the tallest man made structure in the world in all categories, and it has become a catalyst for further development in high rise construction in the Middle East and throughout the world. The Burj Khalifa project is another step forward in meeting thetechnological challenges of future construction and it set a new stage for the future generation of super-tall buildings. (Ahmad Abdelrazag 2010)

## **Economical, Political and social**

The development and construction of super-tall buildings represents growth and economical achievement of a city or a region. In case of Willis Tower (Sear tower), Roebuck & company as result of business expansion commissioned the construction of the tower for its new headquarter in the 1970s. The Chicago mayor was enthusiastic that the Sear's headquarter will be help Chicago economically to bring the headquarters of other large businesses in to the city. 101 Taipei project was initiated at different stage of Taiwan's development. In 1997, when the property market was in decline, the mayor of Taipei organized to meet up with the developers and set up a consortium of companies to build the Taipei 101 Tower. It was the first project to have private sector and Taipei City Government work as a team to develop the project. The Taipei tower 101 was the world's tallest building from 2004 to 2010 giving Taiwan symbolic status of one of leading economies in Asia. Politically the rivalry with main land china was the driving factor to have the tallest building in Taiwan to be higher than all skyscraper built in Shanghai. In contrast to the other two projects, the Burj khalifa was built as an iconic structure, by far the tallest structure or super tall building in the world. The Dubai's government ambition was to create a new financial center in Middle East to be half way in time zone between Tokyo and London. The development of Dubai happened during short period of 2000 to 2010, it was not driven by a market demand but by an ambitious governmental programme to create vibrant economical zone in the region based on service industry and tourism. Burji Khalifa currently 70% unoccupied is reflection of political and economical failure of ambitious development in Dubai.

## **Sustainability**

Burji Khalifa and 101 Tapie used the latest technology to maximize the energy efficiency and sustainability. The used of double panel cladding and recycling of water is a future used in both projects. Also utilizing solar panel system and energy efficient mechanical and ventilation equipment saves great deal of energy during the operation of the towers. In contrast at the time of the construction of the Willis Tower (Sear Tower) in 1970's sustainability was not an important consideration for developers, as result the designers did not take in to account any criteria for designing green building. It is encouraging that the owners are considering to comply to LEEDS standard criteria during the refurbishment of the Tower. To replace the façade and windows with more energy efficient system, using more efficient mechanical, lighting, lifts and ventilation systems.