WEBINAR Talk on "The Structural Engineering Design and Construction of The Tallest Building in Europe Lakhta Center, St. Peterburg, Russia"

by Ir. Lo Seng Ling

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A Webinar talk entitle of "The Structural Engineering Design and Construction of The Tallest Building in Europe Lakhata Center, St. Peterburg, Russia" was organised by the Civil and Structural Engineering Technical Division (CSETD) of IEM on 12th July 2021. Total of 264 participants attended this online talk.

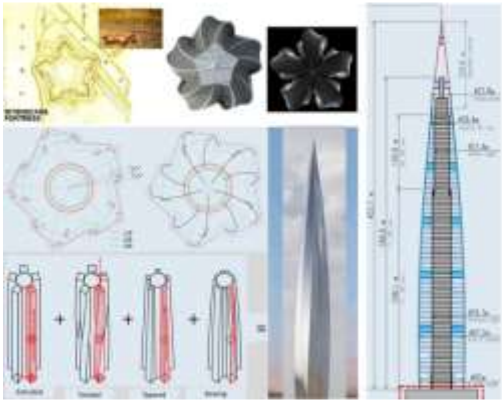
The online talk was presented by Mr Ahmad Abdelrazaq, an Executive Vice President in Samsung C&T Corporation in South Korea. Mr. Ahmad Abdelrazaq graduated from University of Texas with Bachelor of science in Civil Engineering in 1984 and Master of Science in Civil Engineering in 1986. While working in Samsung C&T Corporation, he was involved in design and construction planning of several projects in South Korea and international projects including Burj Khalifa, Samsung HQ Office, 151-storey Ichon Tower at Seoul, 260 Tower at Mumbai, UIC and Tanjung Pagar at Singapore. Mr Ahmad Abdelrazaq also held several positions, such as Head of High-rise & Complex Building, Head of Building Business Development (marketing & sale/technical proposal division). He is also an Executive Project Direction of Merdeka PN118 in Kuala Lumpur and Lakhta Center in St. Peterburg.

Mr Ahmad served in SOM as Associate Partner. His responsibilities includes design of complex buildings, long-span structures and ultra highrise towers, such as Burj Kahlifa, Tower palace III in South Korea, Jin Mao Tower in Shanghai, Hotel De Artes in Spain and Millennium Park in Chicago.

Lakhta Center is situated in Primorsky District at the outskirts of Saint Peterburg and developed as a business center. It is a new landmark and iconic business center to expand and complement the existing historical and world heritage Central Business District (CBD). It is also planned to connect all the access to public infrastructure. The Lakhta Center is a Multifunction Complex Development (MFCD) consists of 86 storey of office floors for Gazprom Neft and Gazprom Grop affiliates, scientific/educational center, a sport center, a children's technopark, a planetarium, a multi function hall, an exhibition center, shop, restaurants and cafe, parking facilities, public plaza and other public facilities. There is also a 'Stylobate' and 'The Arch' to form as the main entrance of the center.

The geometry of the tower was influenced by the Swedish town of Niyen and Niyenscans Fortress. The height of the tower is 462m above the ground. The exterior geometry of the tower is sculpted around a central circular core wall with 5 equal petals that rotate 90 degree from the base to the top of the tower.

The center core wall is optimised to house the vertical transportation system, staircase, mechanical shafts, elevator lobbies and other technical facilities. The core wall is 26.1m diameter from Level 1 to 58, 21.4m diameter from Level 59 to 80 and 16m diameter from Level 81 to 88. The exterior composite steel columns follow the exterior geometry of the tower by twisting at 0.89 per floor, tapering and bowing from Level 1 to the top of the pinnacle. The structural steel braced frame provides stability and lateral load resistance to the spire. The main steel pipe columns of the spire are founded at the exterior composite columns at Level 83 and then taper to a single central ting to support the single pipe pinnacle a 462m height.



Tower geometry (extruded, twisted, tapered and bowed)

The crystalline and complex geometry of the tower resulted in significant changes to the floor plate shape and floor area. This also resulted structural challenges that required simplifications and innovations in selecting structural systems. A robust and redundant Mega Frame system was selected as the primary lateral load resisting and stability frame for the tower superstructure.

The center core wall was designed as reinforced concrete wall connected to ten composite steel reinforced concrete columns at the perimeter of the tower and added a series of two-story equally spaced composite outrigger trusses for 5 layers. The center reinforced concrete core wall is rigidly connected to the composite outrigger through an externally stiffened reinforced floor ring plate that transfer the top and bottom outrigger horizontal forces to the core wall. This new and innovative core wall-outrigger connection very efficient and significantly improved the constructability aspects without complex detailing.

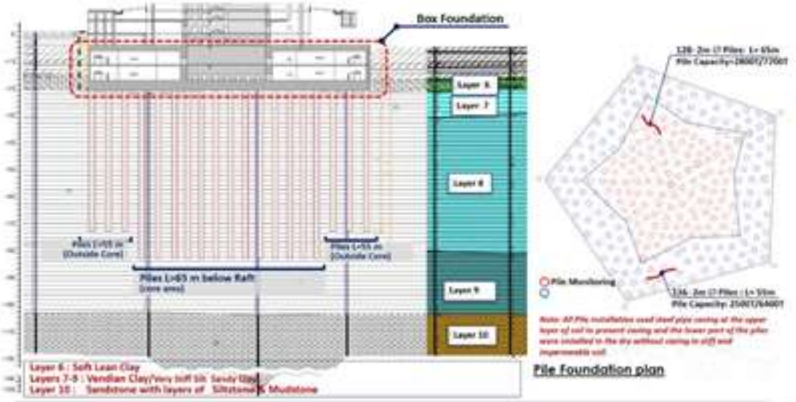
To simplify the framing concept, composite steel framing for a typical odd and even floor was selected as primary structural material. The composite steel framing is not only flexible but also increase in speed of construction. The advantages of composite steel framing are can accommodate significant changes in building geometry for every floor, long span between the core wall and the exterior columns, long span between the exterior columns. The typical floor framing comprising of 60mm thick deck with 90mm reinforced concrete topping, spanning between 400mm composite steel beams supported by 750mm depth steel girders.

The foundation for the tower is comprising of 264mm to 2000mm diameter of bored piles that extended 65m under the core footprint and 55m outside the core footprint. These piles are used to reinforce the soil rigid mass block and redistribute the 670000 megatonnes load evenly to the effective pile-reinforced-soil-mass under the box foundation area. The 28m diameter core wall received approximately 70% of the vertical gravity load of the tower over a relatively small area. This is not sufficient to transfer loads from the heavily loaded core wall and to manage the differential settlement between the core wall and the exterior columns of the tower.

Therefore, a stiff reinforced concrete box foundation consists of the entire subgrade structure is utilised to transfer the loads of tower evenly and to control the differential settlement within the tolerance. The average bearing pressure at the bottom of the box foundation is estimated at approximately 900kPa. This pressure is significantly reduced to approximately 200 kPa at 60m below the base of the box foundation.

The reinforced concrete box foundation system consists of 3.6m bottom raft plate (bottom flange) and 2m top plate (top flange), that are connected by ten 16.6m deep high-performance reinforced concrete with fin-web wall. The 16.6m deep web walls, spanning from the center core wall to the edge of the bottom raft slab, create a highly stiff and efficient two-way reinforced concrete box foundation system that allows for uniform distribution of the tower load to the piles-soil block mass.

A 3-dimensional Finite Element Analysis Model (FEAM) of the soil structure interaction and a detailed construction sequence analysis model was carried out to predict the foundation settlement and the actual load distribution to the piles. An extensive Geo-monitoring program consisting more than 2600 devices was provided to monitor the overall behavior of the pile-reinforced-soil-mass block, which included 336 strain gauges, 40 soil pore measure transducers, 95 vertical mass displacement transducers, 10 pressure cell transducers at the bottom of the lower slab of raft foundation, 2136 box foundation force transducers and one independent optical foundation settlement survey program that monitors the total foundation settlement at both the top of the lower slab and the box foundation.



Geotechnical Conditions, pile layout and foundation system

The Box Foundation System was constructed in 3 stages: 3.6m bottom raft foundation as first cast (20300m3), fin walls and middle slab and final cast on the 2m thick top slab. Detailed construction sequence analysis with heat of hydration analysis (considered concrete temperature rise, curing and cooling) and restraining the effects of boundary elements, was performed to verify the behavior of the Box Foundation System. The analysis also conformed the construction method and sequence would not result in thermal, shrinkage or cracks.

Wind engineering is one of the primary concern in the planning and design of tall buildings as it has major impact on the overall tower design efficiency, wind load and human comfort and perception to motion due to dynamic wind excitation. Several wind tunnel testing regimes and programs at RWDI, along with wind engineering desktop studies were performed to verify the expected favorable wing engineering treatment for the tower. The 3-diemensinal Finite Element Analysis Model to yield pile foundation flexibilities (static and dynamic), flexibility of the outrigger floor slab and the box foundation system was carried out. This FEAM model indicated the total displacement of the tower under maximum design wind load was within H/500 drift limit.

Lakta Center is located in very low seismic area according to Russian Codes and Standard. However, it is important to review the impact to the tower with effects of far earthquake and with long period contents since the tower is designed for long period. Site specific seismic hazard analysis that takes into account the regional tectonic environment, historic seismicity of the region, effect of near and far earthquake was reviewed.

An extensive survey and real-time structural health monitoring programs were developed for Lakhta Center Tower to verify the behavior of the structural system during construction and under building's permanent loads. This including verification of the assumptions and design parameters used during design stage, especially the tower superstructure and foundation system. The SHM program included measurement of foundation settlement, column shortening and lateral building movement during construction. This SHM program also can measure the overall building behavior after construction/in use.

After approximately two hours, Mr. Ahmad ended his online presentation with Q&A session and also discussion session with the moderator and participants. And the WEBINAR talk ended at around 5:30pm.

Lakhta Center