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The Challenges of Delivering Iconic Tall Buildings Across the World: A Global Technology Transfer



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Abstract

Samsung and the authors' involvement in these major tall and complex building projects have facilitated the transfer of the technologies and best practices to projects globally. The following provides a summary of some of those projects where the authors participated in Early Contract Involvement (ECI), giving them the opportunity to incorporate an exchange of technologies that benefits the project.

Keywords: Complex, Construction Technology, Early Contractor Involvement, High-rise

In the last two decades, the building industry, especially tall buildings, has seen significant advances in the design and construction planning of tall buildings in all aspects. The emerging new cities and the expansion of existing ones has also resulted in many challenging structures that are leaning, twisting, tapering, bending. This is compounded by the use of new material and construction technologies (See Figure 1). The Early Contractor Involvement (ECI) in these iconic and complex structures can lead to significant benefits to the clients that are not realized using traditional contracting. The purpose of this paper is to focus on the benefits of Early Contractor Involvement (ECI) and to provide case studies on several iconic tall buildings. Additionally, this paper explores the concept of incorporating lean construction methods while transferring creative design and introducing new material and construction technologies across the boundaries to deliver projects consistently, reliably, and to the highest safety and quality standards on time and budget.

Structural System

The benefits of the ECI is the final value created for the owner, the finished building, by integrating all the stakeholders (owner, design team, specialty consultants, PM/CM, and general contractor) to exchange information and ideas in real time while fast tracking the construction of the project without clashing that may occur in traditional contracting. Rather than each participant focusing exclusively on their part of the construction without considering the implications on the whole



Figure 1. Signature and Complex Tall Buildings Slender Twisted Tapered Leaning Free Form
(Source: Samsung C&T Corporation)



Figure 2. Highrise and Complex Development Demands for Successful Execution (Source: Samsung C&T Corporation)

process, the ECI brings all participants together early with collaborative incentives to maximize value for the owner. This collaborative approach allows informed decision making early in the project where the most value can be created. The close collaboration eliminates a great deal of waste in the design, and allows data sharing directly between the design and construction team, eliminating a large barrier to increased productivity in construction.

While the world population is increasing exponentially, existing cities are growing rapidly, and new cities are quickly emerging in developed and underdeveloped countries, we are witnessing many missed opportunities, where the cross exchange of technology is not taking place due to the lack of experiences and resources of local professionals and contractors in adopting these technologies because of fear of potential risks in delivering projects to the highest available standards. These are valid concerns, however, Samsung as an experienced international contractor with proper human resources, materials, equipment, and other significant resources, and availability of international procurement offices

worldwide, can quickly and effectively bring the latest design and construction technology in delivering projects successfully and with confidence while at the same time bring these new technologies into the market for future consideration.

An international contractor, such as Samsung, with global experience is an integrator of developed and underdeveloped resources to bring Tall, Mega Size and Complex Building Projects to fruition without compromising the qualities that these projects deserve including, but not limited to:

- Faster construction cycle: Develop/adopt techniques for fast construction cycle (including pre-fabrication, modular construction, Samsung own System, etc.);
- Structural system optimization (VE) for efficient use of material and fast construction methods;
- Incorporating BIM technologies as part of project delivery: Perform all work in BIM to ensure accurate flow of information from structural

design to construction planning, to construction planning, quantity takeoff, etc. The idea is to improve accuracy, efficiency, and speed in bidding;

- New material: Utilize latest advances in materials and damping systems to improve performance while reducing cost and improve constructability;
- Advancements in structural health monitoring programs: Techniques incorporating health monitoring to verify the building behavior & safety during construction and its during its lifetime;
- Sustainability: Engineering modeling to optimize the operation and management of the building using the latest technologies in building management systems in real-time and throughout the lifetime of the buildings. Performing real-time assessment of energy use and making the necessary adjustments to the building systems to reduce energy consumption.

Nowadays, Mega, Tall and Complex Developments procurement methods are shifting from conventional contracting schemes to lean construction contracts, where the early engagement of contractors in delivering the project is paramount to the successful execution of the project. Some of the successful models that are being considered by major developers include ECI through 1) Pre-construction services, 2) release of advanced information to prepare the contractor to submit cost effective design build tenders (where the contractors can bring their best practices), 3) Co-development, where contractor invest into the project and become an integral part of project delivery team, and 4) engaging the construction management to take part of design responsibility. Figure 3 provides a list of on-going significant projects where Samsung has had involvement in delivering projects domestically (Korea) and globally using all of the above models while simultaneously incorporating best international practices.

Factors that directly affect the success of high-rise and complex building projects include engaging the clients in making the right decision at the appropriate time. This may include, but is not limited to, the following factors in an effort to optimize the cost, enhance quality, and to deliver the project in the shortest possible time:



Figure 3. Samsung's ECI in different Contracting Schemes (Source: Samsung C&T Corporation)

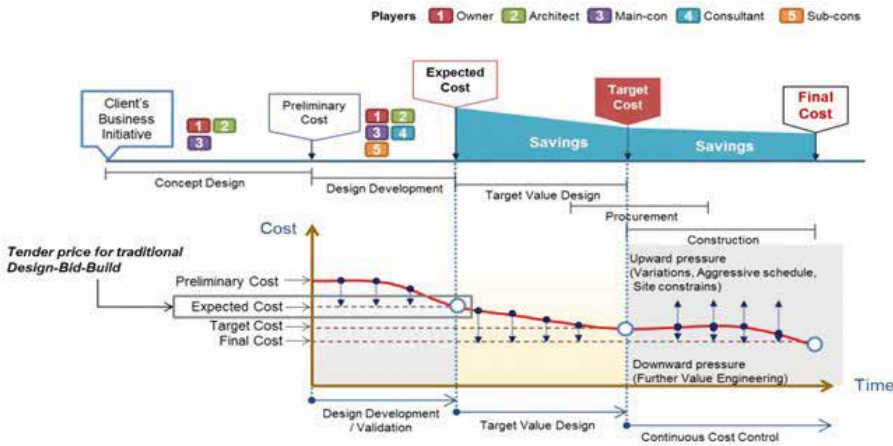


Figure 4. ECI Objectives to Cost Control Model during project life cycle (Source: Samsung C&T Corporation)



Figure 5. Icon Hotel, Dubai, UAE (Source: Samsung C&T Corporation)

- Review of factors affecting schedules: This includes, but not limited to local weather, holidays, government permits/approvals, release of design packages, soil and foundation conditions, and their impact on enabling works, equipment procurements, availability of skilled engineers and labors, productivity of local labor for all trades, site logistic and planning, etc.

The objectives of all clients is to ultimately control project cost and the construction schedule as they have direct bearing on the financial viability and success of the development. The ECI must results in controlling the project budget that often starts higher than the client may be able to afford. The ECI can be a vehicle where the contractor can guarantee the client a realistic budget from the onset and design the project to a budget that cannot be exceeded whence the design is agreed upon by all the stakeholders (See Figure 4 for cost control model and objectives).

- Value Engineering at all stages of design: This includes the selection of material and building systems without prejudice. The most cost-effective solution is integral and that solution must not focus on a particular system, but on the interrelation of all systems (architecture, shape/ geometry, structure, facade, vertical transportation, mechanical systems,

electrical systems, sustainability/ environmental strategy and lifecycle, etc.);

- Constructability review and construction methodology, including site constraints;
- Cost review at all stages of design to confirm project budget, including review of local market conditions, international procurement strategy;

Case Studies: Samsung's ECI in International Tall Building Projects

Samsung and the authors involvement in major tall and complex building projects globally have facilitated the transfer of the technologies and best practices. The following provides a summary of some of these projects:

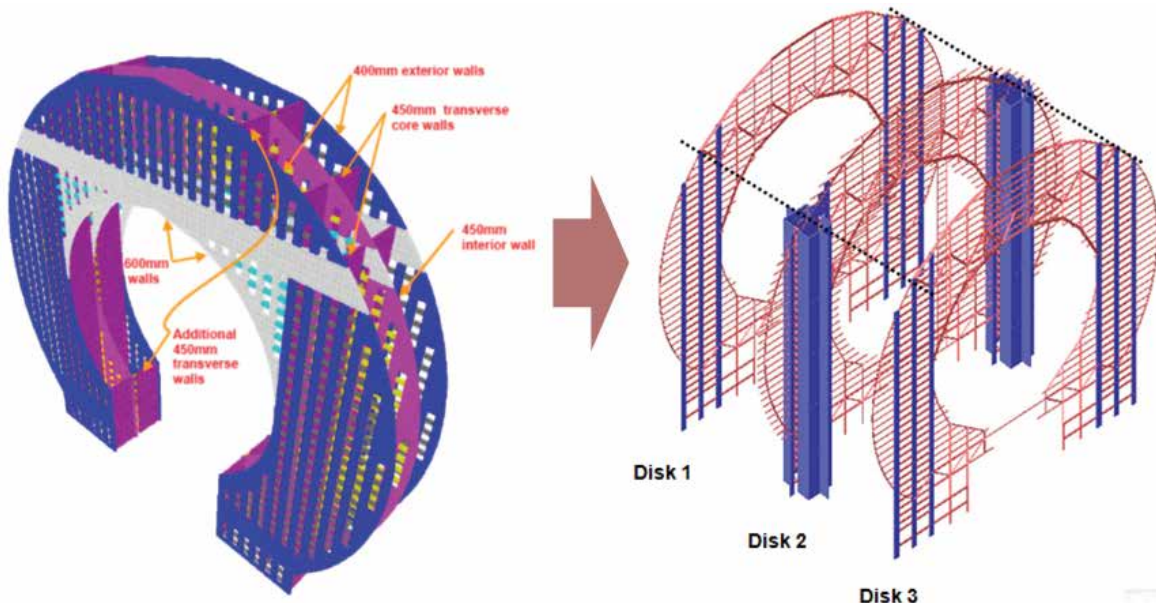


Figure 6. Icon Hotel VE (Source: Samsung C&T Corporation)

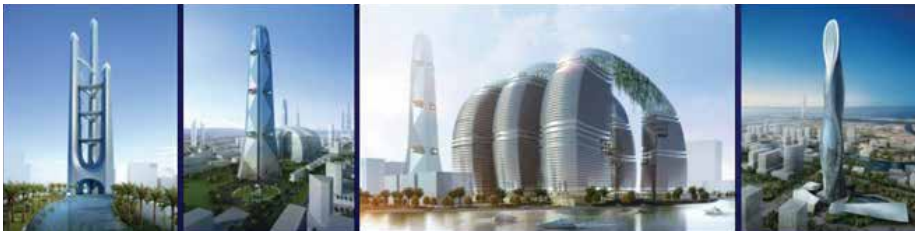


Figure 7. Jumeirah Gardens, Dubai, UAE (Source: Samsung C&T Corporation)

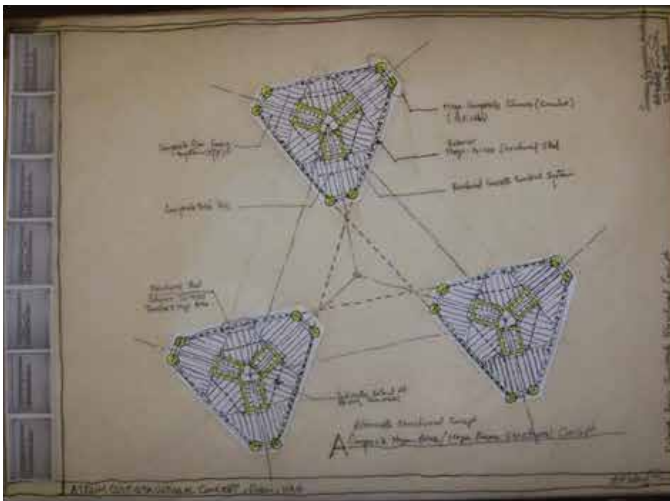
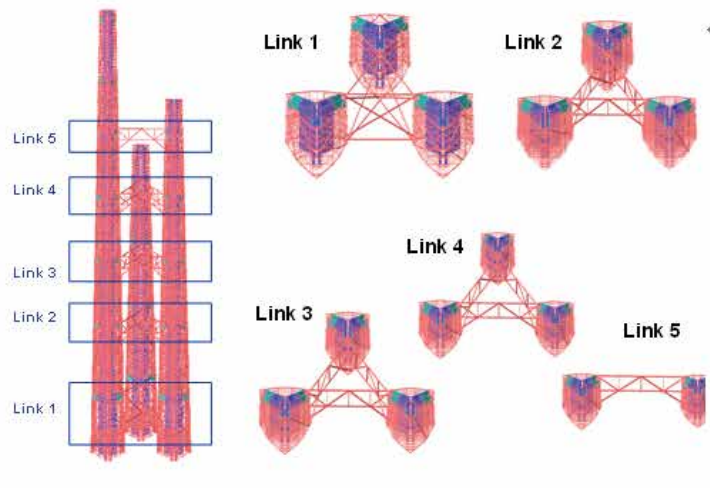


Figure 8. Jumeirah Garden VE (Source: Samsung C&T Corporation)



Tall Building Case Study 1: Icon Hotel, Dubai, UAE

The Icon Hotel, which is part of the Dubai Promenade in Dubai, is a new waterfront development and represents cutting edge architecture. This building has a unique 'donut shape' with significant design and buildability challenges in the field of structural engineering. The wheel shape tower is 160m high with an external diameter of 165m, an internal diameter of 78m and a depth of 35m. It was designed to accommodate hotel and residential occupancies. The building's primary structural system is composed of two concrete core walls placed 96m apart on either side and partially coupled by mega steel trusses at an upper mechanical floor as well as long-span steel arches located at the top to accommodate the required shape of the building. This paper presents the structural engineering design approach used to evaluate the seismic behavior of this building by implementing performance-based design methodology. The analysis results show that the building will behave in a desired manner during anticipated seismic events.

Samsung was selected as the preferred contractor on the project and provided pre-construction services, including attendance to soil improvement at Palm Jumeirah, during the enabling work package. Samsung's

involvement resulted in significant cost savings through value engineering, an alternative structural and foundation systems and construction method, earlier construction and time saving (more than 4 months), and a constructability review, which facilitated the building permit process by giving confidence to the building authority that the project can be built safely. The project was cancelled.

The original structural design of Icon Hotel was composed of three punched disk walls, which needed a huge amount of temporary structures. Additionally, large horizontal deformations of the walls during construction were expected before the top part of disk walls completed. Samsung suggested an alternative structural system as a combination of two center core walls and steel framings linked by steel braced trusses at the top. The alternative structure minimized building deformation during construction due to reduced weight, reduced temporary structures, saved construction time, and enhanced safety during construction.

Tall Building Case Study 2: Jumeirah, Dubai, UAE

The first phase of Jumeirah Garden City was composed of six main blocks of high-, mid- and low-rise office, retail and residential

buildings, two hotels and a high-end shopping area. Handover of phase one was expected to start by the end of the fourth quarter of 2011 and the whole phases were to be fully ready by 2013. Jumeirah Garden City contains a huge park which surrounds all the residential apartments, villas and other office and commercial buildings. This development primarily consists of the re-development Satwa and Al-Wasl, with the inclusion of newly developed islands off the coastline of the primary land mass development. The developer Meraas was planning eight landmark buildings in Jumeirah Garden City, however, many such as 1 Dubai, 1 Park Avenue, and Meraas Tower were cancelled due to financial issues. The project also included Park Gate, which comprised a complex of six buildings. The self-reclaimed artificial islands looking up to the east bay and coastal areas were mainly designated for residences, but also contain hotels and resorts.

Samsung Involvement: A massive project, it required equally massive resources with extensive experience and management capacity to deliver the project. Samsung performed due diligence reviews of all building systems, including VE and constructability. Alternative structural systems and construction methods were also proposed, resulting in significant cost and

time savings. The Project was cancelled due to financing difficulties. However, some of the structural systems, materials proposed, construction methodologies and techniques developed for fast construction cycles are transferable to future projects.

The original 1,000m high towers are composed of 3 independent towers structurally. The linked bridges between towers are suspended using cable structures for observation decks. The mega brace and frame system which is structurally linking three towers by trusses between towers is developed to enhance the efficiency of the lateral system. Because of the high aspect ratio of the tower and the sensitivity of the floor airfoil geometry to wind excitation, extensive gravity and wind engineering management was considered during the early development of the structural concept to control the wind forces and building serviceability. In addition, the relative column shortening between the vertical elements was also carefully considered to reduce its impact on the structural member performance. The gravity load support structure (core walls and columns) are strategically located and

proportioned at the building extremities to attract the maximum gravity load to maximize their resistance to lateral loads. In addition, the reinforced concrete core walls and mega columns are designed on equal stress basis under gravity loads.

Tall Building Case Study 3: Star Residence, Kuala Lumpur, Malaysia

The Star Development project will include the construction of three high-rise towers – a 57-floor, 251m high tower and two 58-floors, 265m tall luxurious residential towers. Once completed, the development will comprise with one of the tallest residential towers in Kuala Lumpur. The construction work began on November 7th 2014 and is expected to be completed by 2019, including enabling works and full fitout works. Alpine Return Sdn Bhd, selected Samsung as the preferred contractor for the project though ECI to be part of the Project Delivery Team. Samsung proposed significant VE, by reducing the structural material for the vertical elements by approximately 25%, while enhancing the overall structural behavior and maximizing the sellable floor area and overall apartment



Figure 9. Star Residence, Kuala Lumpur, Malaysia (Source: Samsung C&T Corporation)

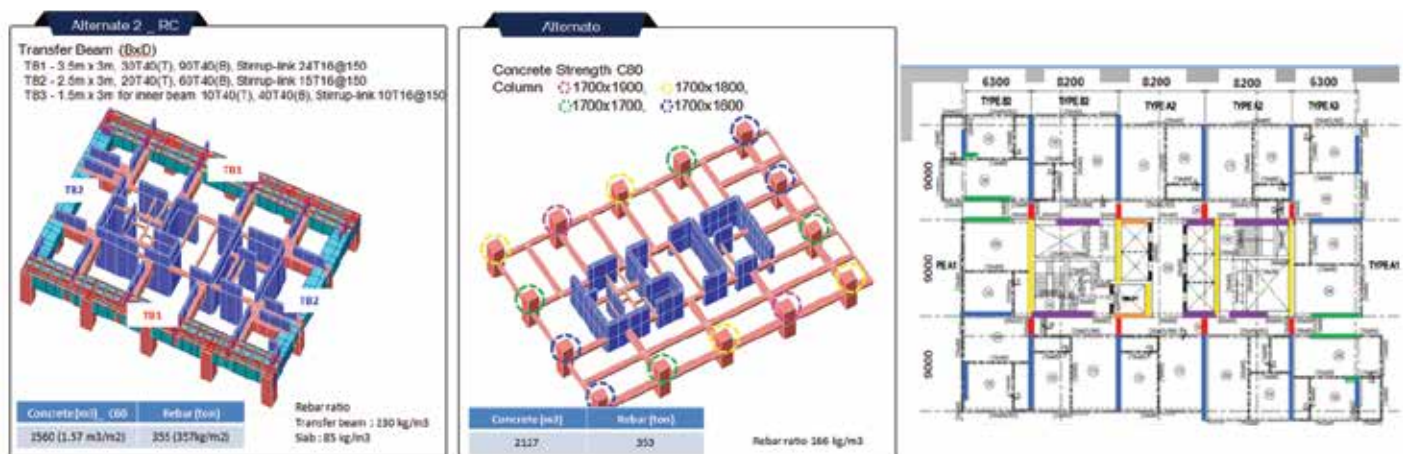


Figure 10. Star Residence VE (Source: Samsung C&T Corporation)



Figure 11. Lakhta Center, St. Petersburg, Russia (Source: Samsung C&T Corporation)

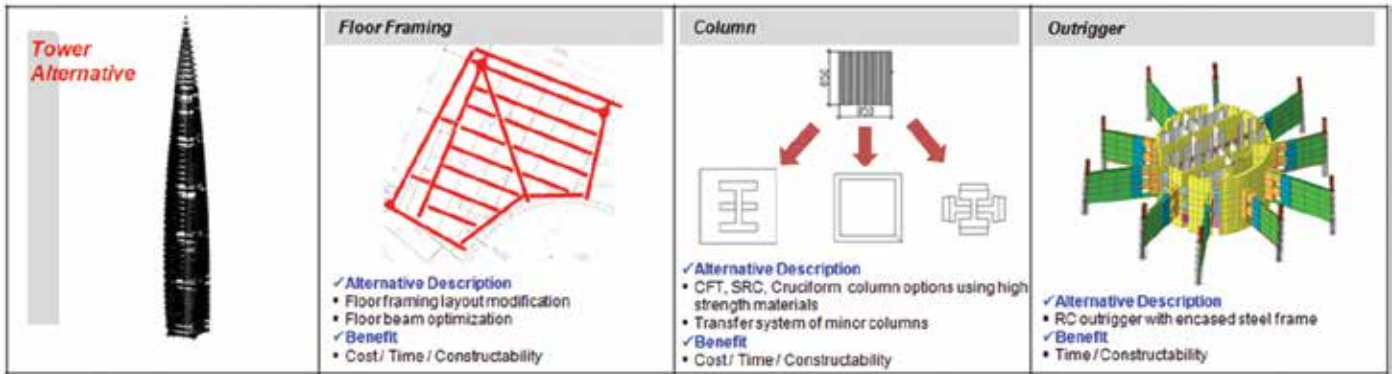


Figure 12. Lakhta Center VE (Source: Samsung C&T Corporation)

layout. Samsung utilized full top-down construction for the construction of the project to time and cost (a semi top-down construction was initially considered). The project is presently under construction in the heart of Kuala Lumpur's CBD.

Original material strength for the walls and columns of Star Residence Tower was designed with 60MPa cube strength concrete, which is the maximum strength normally used in Malaysia. Samsung investigated higher strength concrete and proposed 80MPa concrete, which could reduce much of the volume of concrete in the core walls and columns. With the reduced weight, the number of piles and king post steel sections for top-down construction also could be reduced.

**Tall Building Case Study 4:
Lakhta Center, St. Petersburg, Russia**

Lakhta Center is a large scale project consisting of a modern business center in Primorsky district of St. Petersburg, exercising a wide range of public functions with a developed public transport infrastructure. Lakhta Center was implemented as a pilot project for an integrated development of the area, and the construction of a mini city on the outskirts of St. Petersburg, a sustainable district for life and work. The headquarters of Gazprom Neft and other Gazprom Group companies will be at the center of the cluster in Primorsky district, to be surrounded by business enterprises. The projects' objective is the construction of a cluster in St. Petersburg meeting the world standards of the construction of a business and public environment. It is aimed at increasing the level of business activity in the city and the North-western region as a whole.

The concept of the project implies the construction of a large office center and a scientific and educational complex. For the citizens, it is planned to build a sports

complex, a children's techno-park and a series of free public facilities, including shops, restaurants, cafes and other services. A large attention in the project will be paid to the improvement of the transport situation in Primorsky district.

The need for a developed business and public infrastructure is caused by the urgent tasks faced in the economic and public life of the city. An integrated approach to the arrangement of the urban space will allow creating necessary conditions for the development of business, attracting large companies and creating new highly paid jobs. A new business area will absorb the business load, which is unusual in the center of the city. Together with additional revenue brought into the city from new investment companies, it will enable the preservation of the unique image of St. Petersburg.

Samsung C&T has been involved in the project. It will deal with the development of the working documentation on the whole

complex as well as optimization of processes and works completion dates.

Original structural design of Lakhta Tower had several unpractical sections and details, especially in the main columns, outriggers and connections. Samsung suggested steel composite elements to substitute for pure steel elements; Steel solid columns to composite columns and RC wall type outrigger to steel braced RC wall type outrigger. Different steel arrangements for the typical floor framing were proposed to simplify the steel to core wall connection. With the alternative structural design, a significant amount of steel could be saved and the constructability was improved.

**Tall Building Case Study 5:
Yongsan Landmark Tower, Seoul, Korea**

Renzo Piano Building Workshop is the Design Architect of this 111-story office



Figure 13. Yongsan Landmark Tower, Seoul, Korea (Samsung C&T Corporation)

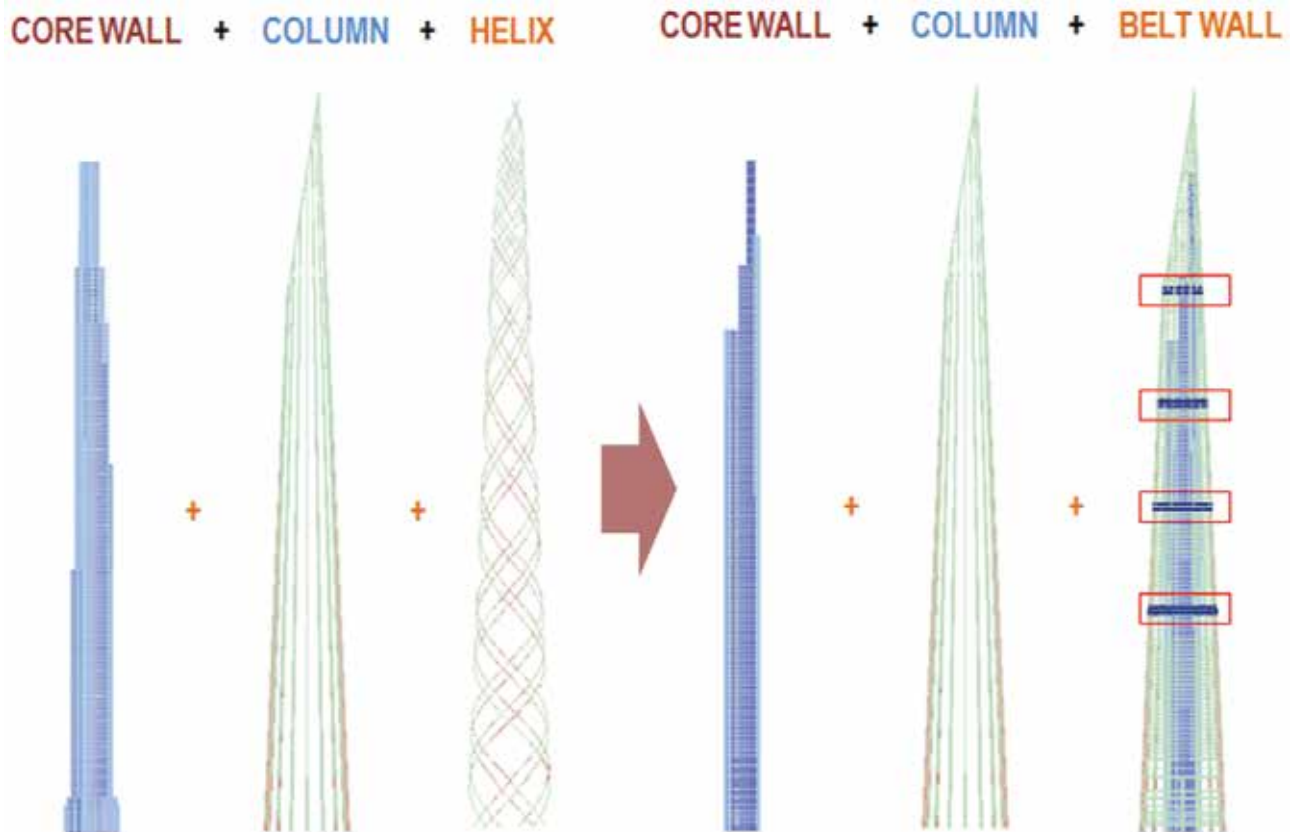


Figure 14. Yongsan Landmark Tower VE (Source: Samsung C&T Corporation)

tower and mixed-use podium building which will be the centerpiece of the Yongsan International Business District in Seoul, South Korea. Adamson Associates is the Executive Architect for the new 620 m high Landmark Tower which will include an Office, Assembly and Retail Complex of approximately 262,000 gsm above-grade and 6 to 7-level below-grade structure that incorporates parking and mechanical/service areas. The tower will house the offices of global businesses and offer a wide range of high-tech functions.

The program also includes support spaces, amenity / benefit facilities, a dining hall, a public restaurant, an observation deck, a membership club, as well as a business center and above-grade retail locations in the project podium.

In the early stages of the project, Samsung provided a design management service including review of the following:

Geotechnical Investigation

Prior to the geotechnical investigation, a preview meeting was requested for removal of pile structure. Samsung suggested additional boring would be required for pile and raft foundation system analysis. After receiving a part of the geotechnical investigation and data, including Bore Hole logs, the Samsung engineering team provided technical analysis and comments.

Tower Structure System

Samsung was requested to provide technical advice about the structural system by Arup, the project structural consultant. Samsung suggested an alternative structural design and engineering for optimal cost and schedule.

Cladding

Due to the double skin façade and curved glass installation, elaborate technical engineering efforts were required. A review of various curtain wall types was carried out and as a result of Energy Simulation in the SD phase, alternatives for several solutions were considered.

LEED & BIM

LEED certificate was to be acquired but the score could not be confirmed. Therefore, a preliminary study was necessary. Building design was coordinated and developed based on BIM.

In order to deliver the successful completion of this project within 48 months, pre-construction service was critical, enabling immediate schedule impact analysis and constructability review. Samsung completed and provided an over 100-page CD review report after an internal review meeting apart from the pre-construction contract.

The critical issue of the Yongsan Landmark Tower construction was to reduce the

construction period to meet the completion date requested by the client. The original system has helix bracing as the main lateral system. But the helix bracing resulted in some delay in floor the construction cycle due to the difficulties of connection of the braces on every floor. Samsung proposed to engage belt walls at mechanical floors instead of helix braces and to simplify the core wall design, which made a 3-day cycle of the typical floor construction possible.