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Carla Swickerath
Carla Swickerath is a Principal and CEO of Studio Daniel Libeskind. She joined the firm in 1999 when the office was based in Berlin. Carla was the Principal in Charge of the Haeundae I'Park residential development in Busan, Korea and led the project from concept to completion. In addition to the Haeundae I'Park, Carla helped lead the World Trade Center master plan competition and moved with the office to New York City in 2003 when Studio Libeskind was awarded the master plan for the site. She is currently leading a 30 million-square foot master plan in Seoul, Korea, and has residential projects under construction in Brazil and Toronto.

Peter Tillson
Peter Tillson is a structural engineer with Arup, with experience practicing engineering globally in the United States, Australia and New Zealand. He has extensive experience in seismic analysis and the design of airports, multi-story buildings, museums and industrial buildings. This includes all aspects of project management, structural design, phasing and coordination with other specialist disciplines.

"In South Korea, there is an emphasis on family and social relationships. High-density residential developments are preferred because they support a strong sense of community."

The Haeundae I'Park is a 511,805-square meter (5,509,000-square foot) high-density mixed-use development in Busan, South Korea which includes three high-rise residential towers (66, 72 and 46 floors) and a total of 1,631 units. A 34-floor luxury hotel, a 9-floor office building, and a 3-floor retail building have been composed on a landscaped, waterfront site in the second largest city in Korea. Busan, a rapidly growing city with approximately 3.6 million residents, is located on the southeastern tip of the Korean peninsula. It is a bustling port city and a vacation destination, with a dramatic combination of both mountains and beaches as its natural setting.

The I'Park development creates a new, forward-looking image for The Hyundai Development Company (HDC) and a new vision for residential living in Busan. Built on a landfill site along the waterfront, the three residential towers soar to 292 meters (958 feet), 273 meters (895 feet) and 205 meters (674 feet). The highest tower became the tallest residential building in Asia on completion. Essential to the design of the Haeundae I'Park complex is the integration of the development into the Haeundae Marina city site to the west. The marina's development by the same owner (HDC) will be part of the residential amenities for the project and will serve as a public attraction for visitors and residents.

The project is designed as a unique composition expressed in a series of dynamic volumes on the Busan waterfront that harmonize with the landscape and celebrate the city's spectacular setting of mountains, rivers and the sea. The buildings are sculpted to express the dramatic beauty and power of the ocean. The curvilinear geometry of the buildings alludes to their context; the grace and force of ocean waves; the unique composition of the petals of a flower;

wind-filled sails of ships on the water; and by the subtle, elegant curves in traditional Korean architecture.

Design Context

The Korean residential market is unique and the design of the Haeundae I'Park had to respond in a meaningful way to the specific cultural and economic issues. In South Korea it is considered desirable to live in cities and, as with most major urban centers, land prices are incredibly high. Large scale, high-rise developments are the most efficient and profitable way to provide housing that meets the demands of the market. Therefore the market has very rigorous efficiency standards that are challenging to achieve. Design solutions need to be creative and practical to maximize land values. The market's emphasis on ownership also drives the quality, diversity and quantity of residential units which become more than just a living space, but also a major investment for the future. The quality of design, sense of community and amenities provided not only make for very attractive, livable residential developments, but become assets that help the units hold their value over time.

The main challenge of the project was to create a balanced composition with maximum views and livability with a large program on a very dense site. The design had to meet rigorous efficiency expectations and moderate construction costs while maximizing sweeping views of the ocean, the marina, the mountains, the Gwang-An bridge and the landscape and the city of Busan.

To find innovative solutions, multiple strategies for the massing of the program on the site were studied. Instead of simply extruding the typical building footprints to their maximum heights, the footprints of the towers are made of a sculpted shape in plan (see Figure 1), the heights are varied and the profiles are tapered to create a three-dimensional composition on the horizon. The varying heights of the buildings help to break down the overall massing of the residential tower complex (see Figure 2). Instead of simply extruding the footprints of the buildings to an equal height, the design redistributes the allowed massing and height of the towers to create variation in the composition of the towers while meeting the maximum FAR for the development.

The balance of the tower composition as a whole also depends upon the breaking down of the large, solid mass of each tower form. By creating an interlocking tower that is made of two distinct forms, the design allows for only half of the mass to be raised as a tip instead of the entire, large mass of the tower. The intention is to create the most positive effect with the most practical solution.

These strategies not only give the project and the city of Busan a new landmark and a new image of residential development, which in Korea is traditionally quite formulaic, they also help maximize the view corridors of all the apartments as well as bring the most light possible into the site and the developments beyond the site. Redistributing the massing makes the very large development seem more slender on the skyline. Also, the varied forms create unique and exciting spaces between the buildings that add interest and variety to the entire development from inside and out.

The project maintains efficient floor plates and repeatable construction for about two-thirds of the height of each tower. The extruded footprints change shape only at the tops of the buildings, when they taper up, culminating in the tower tips. Even when the tops of the buildings do taper, about half of the floor plate remains the same (see Figure 3). One half of the floor plate is extruded directly to its maximum height with no tapering. The same tower footprint is used in each residential tower, one being a mirror image of the other two, to create the same footprint which eases the efficiency of the development while creating a unique,

Figure 1. Typical residential floor plan © Studio Daniel Libeskind

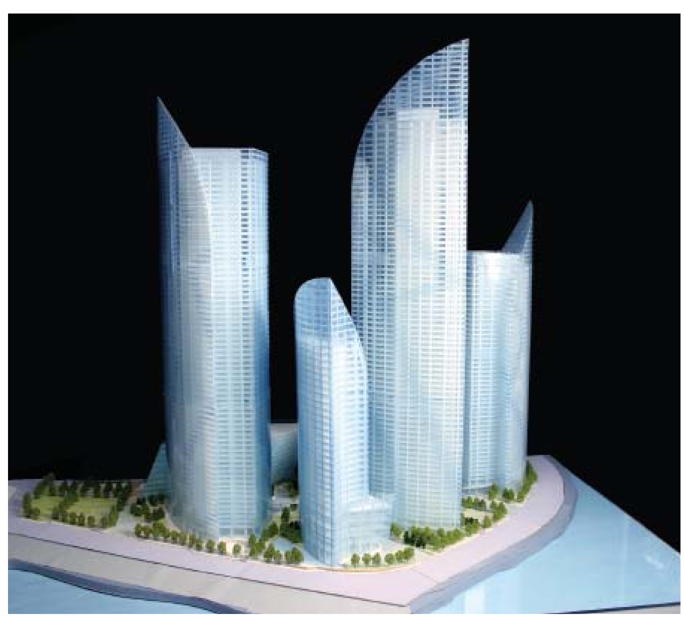

Figure 2. Haeundae I'Park, Busan © Studio Daniel Libeskind

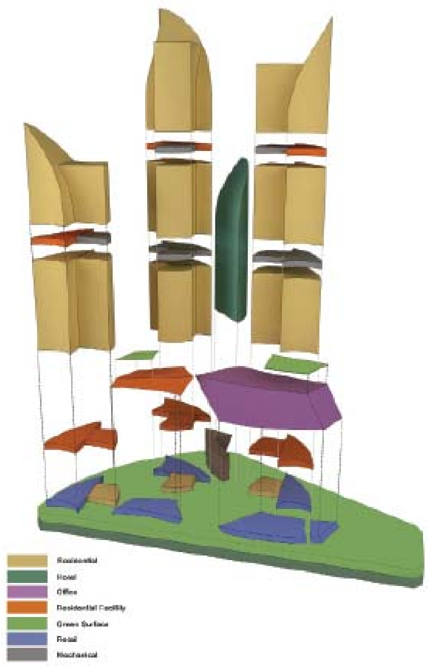

Figure 3. Site mass diagram © Studio Daniel Libeskind

varied design composition and dramatic image on the skyline.

Community and Open Space

A fundamental principal of the design of the Haeundae I'Park was to create a community. In Korea, large-scale, urban residential projects are popular for many reasons including enhanced amenities, maintenance, and security. But most significantly, there is an emphasis on family and social relationships culturally in Korea, and high-density residential developments are preferred because they support a strong sense of community. The distinct image of the project gives residents a clear sense of identity and the project's varied public spaces give the community places to gather. From its inception the design of the project was considered as a complex (a collection of buildings with uses centered on the community) rather than individual towers in a block. This also influenced the multi-generational family-oriented amenities, community services, layout, and circulation of the entire development.

Taking advantage of the crescent shaped site, the three residential towers are lined along the edge of the curve. This composition maximizes the waterfront views and allows for the furthest distance from the adjacent residential complexes. The placement of towers is also configured to create the furthest distance from each other, maximizing the light and air between the towers and enhancing the residential experience and apartment views.

The placement of the towers taking advantage of the shape of the site also allows for a generous park to be developed, inviting residents and visitors to enjoy a unique outdoor experience that will provide an open space for the residents as well as the visitors to the site and to the city of Busan. The central green landscaped park provides a communal space at the heart of the project for residents to relax, gather, celebrate, play, and reflect upon the ocean views with spaces for group actives and cultural events (see Figure 4). The park is a special amenity to the residents of the development and it provides the dense city of Busan with a unique public park along the dramatic ocean front.

Throughout the landscape, linear pathways define the pedestrian experience of the site at grade for the public while the curvilinear elevated decking system can be used by private residents between the buildings. To animate the pedestrian experience along the walkways, water features line and intersect the paths. The water features tie the site elements together, create a landscape element of movement and reflection, and relate the site to the views of water beyond.

Communal spaces within the residential towers include event spaces, reading rooms, spa, family spaces for sports, a children's library, cafés, conference hall, art room, and guest house. In addition, in the middle of each residential tower, outrigger floors not only function as structural reinforcing elements but these spaces also play an important role as special residential community spaces. On these floors, residents have unique sweeping, 360 degree views of the city and the ocean while exercising in the fitness center or enjoying the sky lounges.

Engineering

The engineering system is optimized for saving energy and protecting the complex

... active

"At no point in the last 30 years across all the cycle changes have we ever not been active."

Tommy Craig, Senior Vice President at Developer Hines discussing the plan to build a 28-story, glass-and-stainless steel tower at 1045 Avenue of the Americas. From "With Financing Still Rare, New York Developments Start to Rebound," New York Times, September 7, 2011.

Figure 4. Central green landscape park © Studio Daniel Libeskind

Figure 5. Curved façade © Studio Daniel Libeskind

from natural disaster. These systems perform at the highest level in terms of environment, economy and human life. Energy-saving technology such as a cogeneration system generates electricity and heat simultaneously to achieve efficiency of energy consumption in the complex, minimizing the impact on the environment. Also, combined with the cogeneration system, the central hot water supply system allows for a sustainable and livable residential development. Further, given that this site is on a coastline and is prone to the effects of typhoons, flood proofing has been incorporated into the design to prevent significant property damage and loss of critical building systems for extended periods of time.

Wind

Busan is one of the windiest cities in Asia and the dramatic site is right on the ocean's edge. The towers will bear the full force of the yearly typhoons coming from the southeast.

The Korean Building Code (KBC), similar to almost all wind codes around the world, does not account for across-wind dynamic responses or the sheltering or enhancing effect of other nearby buildings. This is often a reason for wind tunnel testing, even in the case of a standard building shape. The unique building shapes were an additional reason to wind tunnel test (see Figure 5). Additionally, typhoon-strength winds dominate the wind climate of the southern Korean peninsula for longer return periods. These typhoon winds are an important consideration in the strength design of new developments. For the shorter return period winds which affect the serviceability design of structures, the more frequently occurring synoptic type winds needed to be considered.

Large differences in loading were obtained between the predictions of the Korean wind code for Busan and the numbers obtained from the wind tunnel study. The wind tunnel results for the residential towers were generally significantly lower than KBC loads, and dropped off faster with decreasing height. With code wind pressures exceeding three times the typical floor live load at the top of the towers, incorporating the reduction in load available from the wind tunnel studies was critical.

Structure

The design team were tasked with building the towers on time and on budget – a schedule and budget established for conventional towers. The structures of the buildings were designed as efficiently as possible within the constraints of the architectural design.

The towers were constructed using reinforced concrete and are supported on foundations at the base of the 6-story deep basement, which covers the whole site. The tapering tip portion of each tower is framed in structural steel.

The three towers have similar but not identical floor plates and a common theme of two interlocking volumes. One volume is an extrusion while the other tapers from approximately two-thirds height to the tip (see Figure 6). The tapering volumes have sloping façades. The interlocking of the two volumes leads to re-entrant corners on the façades, which complicate the behavior of the buildings under wind.

The typical residential floor slabs are 250 millimeters (10 inches) thick with no drop panels or column capitals. Mechanical slabs are 350 millimeters (14 inches) thick. Beams are provided around significant slab openings.

Columns are generally square or rectangular to coordinate with the planning and were sized based on maximum 60 MPa concrete.

The lateral force resisting system consists of a central concrete core with link beams, fin wall, concrete outriggers and belt trusses mobilizing perimeter columns at mechanical levels. Floor slabs were included in the lateral analysis model.

Outriggers were initially conceived in concrete to maximize stiffness, but were changed to steel, because coordination with the mechanical equipment was simpler and it is easier to release and relock the steel outriggers to release creep and elastic stresses caused by differential shortening of the columns and core. The design incorporates double-story belt trusses at mechanical levels connecting to the outriggers. The outriggers are located at one-third and two-thirds of the tower's height (see Figure 7). The tapering tip of each tower is also designed as a structural steel frame.

The lateral structure of the tallest tower is highly stressed under the design level wind event. The design utilizes slabs in the lateral system to enhance the lateral stiffness of the tower and help control wind drifts. High reinforcement ratios in the lower level core walls and steel sections in some link beams were also required.

Additional vertical steel was provided in the core walls to maintain the effective wall

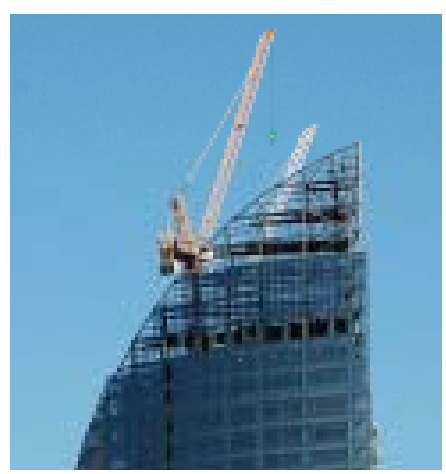

Figure 6. Tapered tip © Studio Daniel Libeskind

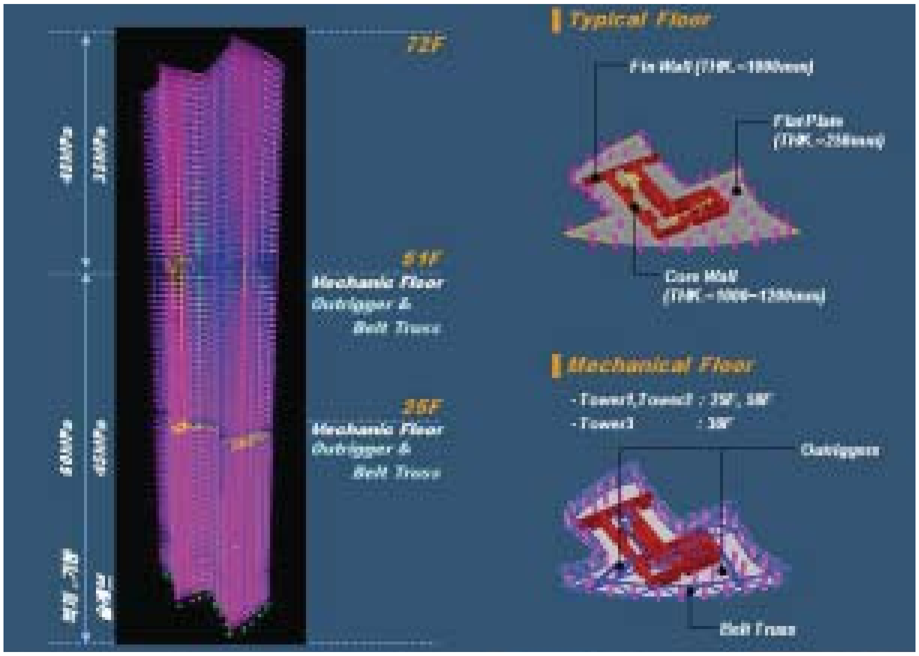

Figure 7. Tower structure diagram © Studio Daniel Libeskind

section's axial stiffness to the high tensions caused by the wind loads. An iterative analysis procedure was adopted. Axial forces and moments in each wall pier were extracted from the initial analysis models and the piers were analyzed for cracking using Oasys ADSEC. In cases where the wall was found to have a cracked section modifier lower than the value of 0.8 assumed in the analysis, the steel percentage was increased to reduce the amount of cracking, and increase the effective E of the section. Overall, the steel percentage was increased to maintain the assumed stiffness modifier of 0.8.

The extensive six-level basement serves all buildings and houses service and delivery functions and parking. Away from the building footprints the column grid is a regular 8-meter (26.2-foot) or 8.2-meter (26.9-foot) grid with a repetitious, simple construction to allow for maximum construction speed. The basement slab construction for suspended levels is a 250-millimeter (10-inch) reinforced concrete flat slab construction with drop panels.

The plaza level slab atop the basement parking garage structure is designed to support significant soil and traffic loadings acting together.

An existing slurry wall from a prior development start was integrated into the basement design and supplemented by a new slurry wall. The basement construction is adjacent to the sea and extends substantially below sea level.

The foundations for the towers consist of closely-spaced caissons supporting a large mat foundation.

To optimize the design and avoid issues during the construction phase, the engineers calculated and analyzed the settlement before construction to adjust the design to anticipate and remedy any issues typically caused by the settlement like curtain wall frame alignment, glass breakage and sagging slabs, so they could be avoided.

Façade Design

The façade design for the project had two major design criteria: high performance and cost effectiveness. To that end, the project employs a hybrid façade system that has the look of continuous glazing on the exterior like a traditional curtain wall, while performing like a window wall system spanning from floor to floor. The hybrid curtain wall system is more effective in cost, load transfer and deflection resistance than a typical curtain wall system that spans multiple floors (see Figure 8).

The envelope thus utilizes a glazed exterior wall system with overall thermal transmittance of 1.68 $W/m^2 \cdot K$ and shading coefficient of 0.41. The system is made up of 24-millimeter (0.94-inch) thick reflective Low-E insulating glass units and an insulation aluminum bar system that is anchored to the building structure at each floor level. An interior glazed system is utilized for ease of installation and maintenance from each floor level.

To create an efficient system, only three standard modules of glass are used. The typical horizontal module dimensions are 1,000; 1,100; and 1,200 millimeters (39.4, 43.3, and 47.2 inches), depending on the column spacing. The typical spandrel module at partition walls is 500 millimeters (19.7 inches). The typical floor height is 3,200 millimeters (126 inches) – spandrel 1,250 millimeters (49 inches), vision 715 millimeters (28 inches) (fixed) + 1,235 millimeters (48.6 inches) (operable). The penthouse floor height is 3,500 millimeters (137.8 inches) – spandrel 1,250 millimeters (49 inches), vision 715 millimeters (28 inches) (fixed) + 1,235 millimeters (48.6 inches) (operable) + 300 millimeters (11.8 inches) (fixed). For ease of production and maintenance, there is only one glass type. Spandrel panels have a metal shadow box set back from the glass.

The building maintenance unit system is located on the rooftop mechanical level with gondolas travelling on rails along the building perimeters. The Davit Type gondola assembly consists of a swivel arm extendable up to 20 meters (65.6 feet) horizontally and 40 meters (131.2 feet) vertically.

Sustainability

Together with a strategy to harmonize the design with the environment, landscape, and community of residents, the design focuses on making a sustainable, environmentally-responsible residential development with a green building certification accredited by the Korea Land & Housing Corporation. A few examples of the means used to achieve the certification are design components like water tanks for rainwater collection that have been installed in each tower; sustainable, eco-friendly materials used to minimize strain on the environment; a high performance building envelope; a green roof system; and biotope (water/land) that will provide a healthy, livable environment for the inhabitants. The project was also designed with co-gen and centralized systems. For the interior environment, each residential unit is equipped with individual temperature control systems and built with materials containing less toxic substances. In each unit there are different sustainable design elements including radiant floor heating, a heat recovery ventilation system, high-efficient condensing boiler and ceiling cassette type of air conditioner with outdoor units for higher efficiency. Space for plantings in the interior public spaces and energy control systems in the public areas are also utilized to preserve energy.

Many of the sustainable approaches not only conserve resources, but provide a cost benefit to the client with reductions in the operational costs of the buildings. In order to minimize energy loss caused by stack effect, the vertical transportation system was designed with many energy saving elements. Three different zones (parking shuttle, low-rise and high-rise) were planned to reduce the vertical air flow. In addition, air-tight vestibules with revolving doors are installed on all ground level lobbies to prevent air influx. On each level, the common corridors were divided into smaller zones with doors to block horizontal air movement. As a result of these strategies, a 4% cost benefit is anticipated to be achieved for public areas. In addition, elements like lighting systems in the public area are equipped with timers and high efficiency lamps that reduced the operational costs for lighting by 7–15%.

Innovation

Residential complexes are developed and built mostly by major companies in Korea. Each large corporation has a housing development and construction company as part of their business. This creates a lot of competition in the market that translates into constant-improvement and a relatively high quality of living for consumers. These large companies all have a very diverse portfolio of goods and services. Large, high-density residential projects allow these companies to create a market for their goods and services while these projects act as significant branding and marketing for all the products and services provided by the company. Each company invests significantly in research and development for their products and the market is driven by an ever-advancing desire for innovation. This highly integrated approach creates positive competition that benefit the buyers of these developments. The strong sense of competition also raises the bar for the design ambitions of each development as well as a commitment to innovation. The Korean market is driven by very sophisticated buyers with constantly increasing standards.

The Hyundai Development Company had the highest ambition for design, technology and quality of life for residents. Their forward-thinking approach certainly influenced the design process and inspired a collaborative sense of creativity and innovation. HDC was not only the client but the construction manager for the project as well. This configuration allowed for a collaborative process with the client, design team and contractors working closely together from the inception of the project. The construction department was often collaborating with the design team to solve complex issues by applying their experience in construction to all aspects of the design, ensuring that innovative or unprecedented design solutions were feasible, economical and buildable.

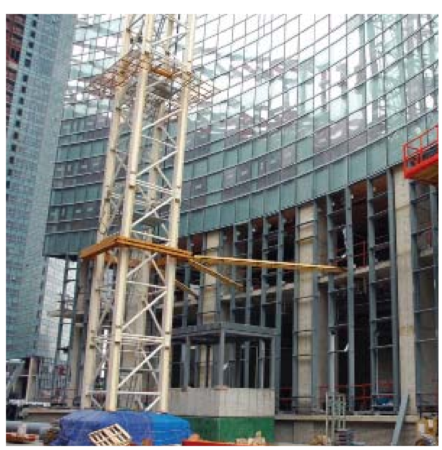

Figure 8. Curtain wall © Studio Daniel Libeskind

Conclusion

The Haeundae I'Park is part of a new era of residential living in Korea. An essential lesson learned from the project is that inspiration in design need not be fettered by formulaic requirements. Design solutions had to be particularly innovative and creative yet practical and efficient to meet all of the necessary standards. In fact, the demanding criteria were seen as a challenge and a source of inspiration and a motivation for inventiveness from the design team.

The project's success lies not only in the design and technical innovations, but in the spirit with which the project was realized. The large-scale, fast pace and high expectations for the project demanded a significant amount of collaboration. The design team, composed of consultants from New York and Seoul, worked together seamlessly, led by a collaborative client with a clear vision, to complete the project on schedule and on budget. ■

Project Data

Completion Date: 2011
Height to Architectural Top: T1: 273 m (895 ft), T2: 293 m (958 ft), T3: 205 m (674 ft)
Stories: T1: 66, T2: 72, and T3: 46
Total Area: 511,805 sq m (5,509,000 sq ft)
Primary Use: Residential
Project Developer: Hyundai Development Company
Design Architect: Studio Daniel Libeskind
Architects of Record: Kunwon, Hanmi
Structural Engineer: Arup, Dong Yang Structural Engineers Co.
MEP Engineer: SYSKA Hennessy; Hyun Woo
Main Contractor: Hyundai Development Company
Geotechnical Engineer: Saegil E. & C Co.
Landscape Consultant: Ctopos
Curtain Wall Consultant: Wallplus
Fire Protection Consultant: Yung-Do Engineering Co.
Lighting Consultant: LPA