March 2009

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Meeting the challenges of luxury

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Waikiki and Trump: the former is one of the world's premier vacation destinations; the latter is synonymous with luxury development. The union of these two is the Trump International Hotel & Tower at Waikiki Beach Walk — a 38-story luxury hotel and condominium. This highly desirable address set a world record for sales, selling all 464 units in eight hours for a total of more than $700 million.

The location posed several challenges — severe site constraints, building height and envelope restrictions, and a desire to maximize views and sellable space — and structural simplicity was not a priority. Baldridge & Associates Structural Engineering (BASE) rose to the occasion with innovative solutions to structural problems. The resulting building

Wayne Lunan

Design and Construction Team

Project name
Trump International Hotel & Tower at Waikiki Beach Walk

Owner
Irongate AZREP BW LLC, Los Angeles

Structural engineer
Baldridge & Associates Structural Engineering, Inc., Honolulu

Architect
Guerin Glass Architects, New York, and Benjamin Woo Architects, Honolulu

Contractor
Joint Venture of A.C. Kobayashi, Inc., and Kiewit Building Group, Honolulu

Parking consultants
Thornton Tomasetti, New York

(left) An artist's rendering of the Trump International Hotel & Tower at Waikiki Beach Walk shows the major building transitions.

includes 23 transfer girders, a transfer slab, sloping columns, numerous wall-to-column transitions, unique composite steel plate link beams, and, most critically to the occupants, uninterrupted views of the Pacific Ocean.

Gravity shift

Encompassing nearly 700,000 square feet, the building contains five floors of parking, a pool and spa deck, 17 floors of hotel units, and 15 floors of condominium units for a total of 38 levels. This diverse use leads to a total of 19 structurally unique floors. As is typical with vertical mixed-use projects, the optimum column and wall layouts for each use rarely match the supporting levels below. In this tower, more than 70 supports required a transition, with some elements shifting in plan several times throughout the height of the building. Adding to the challenge was a lack of structural depth, which in many cases prevented the use of conventional transfer girders.

Transition was the theme starting from the very top of the tower. The thirty-eighth floor penthouse units were inset 8 feet from the perimeter of the building to provide a wrap-around balcony at each end. The roof of the penthouse units, however, supports heavy mechanical loads in the center and rooftop terraces on the perimeter. To achieve the appearance of column-free space in the penthouse units, 3-inch steel posts hidden within the window mullion system were used to support the roof structure. To transfer loads from these mullion columns outward to supporting columns below, the penthouse floor's post-tensioned slab was thickened to create a transfer slab at the structure's perimeter.

Architectural relief on the north face at levels 35 through 37 created another smaller offset in plan and the addition of a glazed non-structural facade. Concrete walls 8 inches thick were hidden in the partition walls between units to provide this support. This required four more transfer conditions, provided at the thirty-fourth level by creating a deep corbel that shifted the load approximately 2 feet out to the exterior shear wall.

At the transition from condominium to hotel units, additional floor space was gained by extending a small portion of the southeast side of the building by 6 feet. The building's typical diagonal walls provided support for the hotel floors. The floor area above this transition, however, was supported by 24-inch-diameter concrete columns. To accomplish this transition, the round columns were cast integral with the diagonal walls for a full story.

As the residential tower drops down to its podium at the recreation deck level, discontinuing the expressed diagonal walls achieved dramatic architectural expression. The appearance of the tower floating over the podium was attained by changing the support structure to smaller columns, offsetting portions of the seventh floor inward, and creating a three-story vaulted space at the south end of the building above the sixth floor infinity pool. A total of 19 walls were discontinued at this transition. Similar to the condominium level transition, the diagonal walls were cast integral with the supporting rectangular columns for one full story.

(below) A performance-based design approach to the lateral system yielded a composite link beam with steel plate. This system was able to accommodate the shear demands within the limited depth available. (right) A diverse combination of uses including parking, recreation, hotel, and condominium resulted in 19 unique floor plates.

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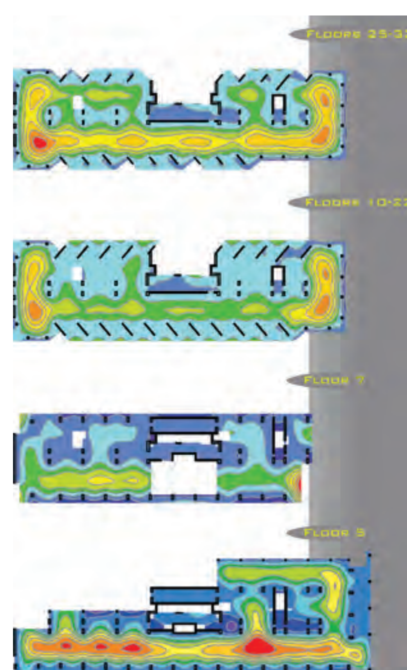

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The parking requirements at levels two through five mandated the transfer of an additional 15 columns. This was accomplished with post-tensioned transfer girders in both downturn and upturn conditions, depending on the available space. A final set of transitions accommodated a 56-foot-wide roadway and loading area through the north side of the building. Sloped columns shifted four tower columns out of the loading dock space. The columns directly above the loading dock were transferred by 12-foot-deep post-tensioned girders. With 36 levels of structure above, careful planning of camber and tendon stressing sequences was required.

Lateral challenges

The project is located on the island of Oahu, Hawaii, a moderate seismic zone subject to infrequent hurricanes. The size and significance of the project justified a more rigorous approach to determining wind loads, and thus a wind-tunnel study was performed by RWDI Consulting Engineers & Scientists. Because of the height of the structure and its relatively light weight, seismic forces were reduced to the point where wind forces governed the design of nearly every lateral element, and thus the wind study was well worth the investment.

Ordinary concrete shear walls are employed as the basic lateral system, as the project falls in Seismic Design Category C. A stair core toward one end of the building is balanced by the exterior wall on the opposite end, with a central elevator core in between. The geometry of all three main lateral elements is governed by architectural demands, and thus all three change form several times along the building height. This complicated both the design and the construction of these walls, particularly the concrete forming system. Adjustable self-climbing forms were used on all three sets of walls, but only above the parking levels, where the geometry variation required hand-set forms.

Two link beams cross the central corridor at both the elevator and stair cores. The extremely tight floor-to-floor distances left little height for these beams. As a result, the shear demand exceeded the maximum concrete capacity in many of the links. Steel wide-flange beams were considered as an alternative, but were rejected due to anticipated congestion issues. To eliminate the conflict between the vertical reinforcing steel and the steel beam flanges, BASE proposed replacing the flanges with rebar and keeping only the web as a vertical steel plate. This composite system, with concrete surrounding a steel plate with shear studs, has been used internationally and on a small number of projects in the United States, but is not recognized by the IBC and has limited supporting literature. A design procedure was developed using basic engineering principles along with research from the University of Hong Kong. Approval of this performance-based approach was granted by the local building authority through a third-party review process. This link beam system allowed the building to perform without additional structural elements, and the plates were successfully installed by the contractor with minimal construction issues.

To take full advantage of the ocean views, the residential units were rotated 40 degrees from the building axis toward the makai (ocean) end of the structure. In place of columns, structural walls were inserted into the partition space between units to serve as the primary gravity elements. With each square inch being valuable, negotiations with the architect reduced the structural wall thickness from 8 inches to 7 inches, and finally to 6-1/2 inches. These 19 diagonal walls joined the three main lateral elements, but unfortunately could not continue to the ground. These walls landed on rectangular columns at the eighth level, creating a significant discontinuity in the lateral stiffness of the structure. Initial analysis revealed that the continuous lateral elements received an additional 3,000 kips of lateral shear at the transition floors due to the "prying" effect at the base of the diagonal walls. To alleviate this problem, horizontal gaps were introduced

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(left) Completed parking level transfer girders leveraged both upturned and downturned designs, depending on available space. (right) A 56-foot-long transfer girder on the second level was one of 23 required on the project.

in the ends of these walls at each story, leaving a continuous wall length sufficient to carry the gravity loads. This gap reduced the in-plane flexural stiffness of these walls, dramatically reducing the excess shear transferred at the transition floors. In this manner the structural requirements were satisfied while meeting the strict architectural demands.

Height restrictions

Squeezing 38 floors into a 350-foot height limit was no easy task. To meet all of the project requirements, the slab system needed to be as thin as possible while still maintaining acceptable sound transmission, vibration, and deflection characteristics. The majority of the slab areas were only 6 inches thick, with 6-1/2-inch-thick slabs at the condominium levels.

One unexpected benefit of the height restriction is the structural efficiency created by the thin floor system. Overall structural weight was reduced by as much as 30 percent, reducing column, wall, and foundation requirements. As seismic load is proportional to the structure's weight, the lateral load requirements were reduced as well. While not intended to achieve LEED points, this structural approach qualifies under innovations in design. Even with all of the vertical load transitions, this structure required less concrete and reinforcing steel per square foot than other recently constructed tall buildings in Honolulu.

Conclusion

The Trump International Hotel & Tower topped off in December 2008, and occupancy is expected toward the end of this year. Because of the hard work and innovation of the architect, the structural engineer, and the contractor, Waikiki will soon have an iconic structure worthy of both name and location. ▼

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