

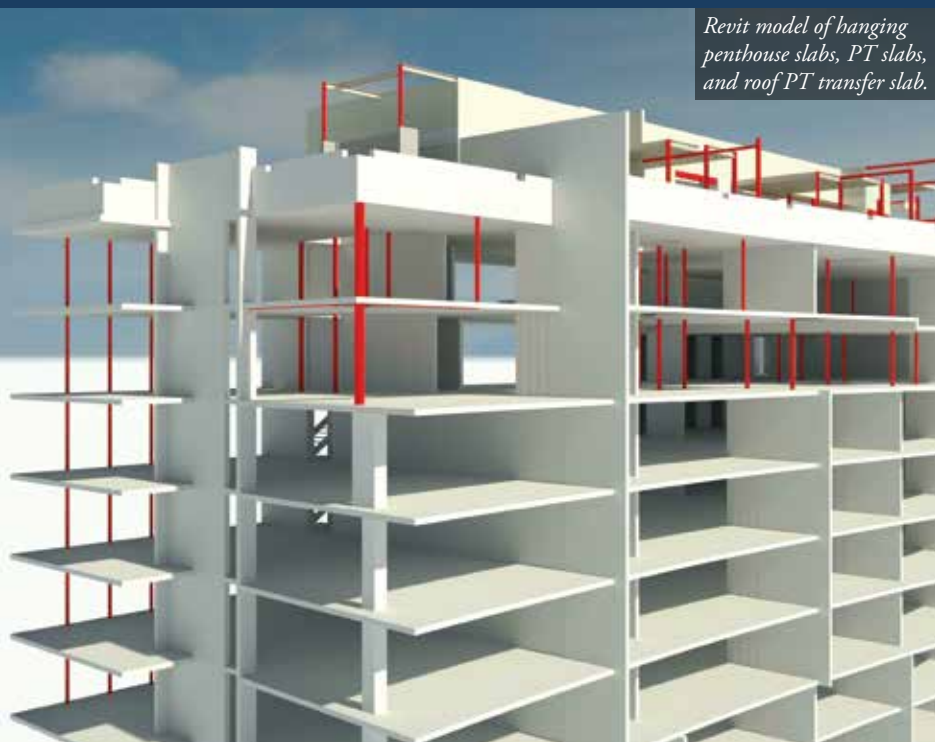


Completed Phase 1 on the left and Phase 2 under construction on the right. Courtesy of AirFrame LLC.

THE RITZ-CARLTON RESIDENCES

Waikiki Beach, Phase 1

*By Steven Baldrige, P.E., S.E., LEED AP,
Fernando Frontera, S.E., LEED AP, and Anantha Chittur, P.E., S.E.*



Revit model of hanging penthouse slabs, PT slabs, and roof PT transfer slab.

A truly striking structure, the Ritz-Carlton Residences Waikiki Beach Phase 1 project in Honolulu, Hawaii, was certainly deserving of the Post-Tensioning Institute's (PTI) 2017 Project of the Year Award, presented to the project's engineer, Baldrige & Associates Structural Engineering, Inc. (BASE). The architects, engineers, and contractors on this project faced several significant challenges but successfully overcame them through the creative use of post-tensioning, resulting in a stunning structure that reflects the Ritz-Carlton's luxurious brand.

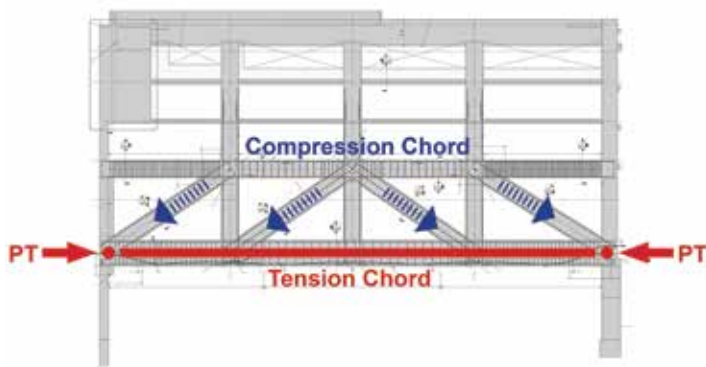
Challenges and Opportunities

Gone are the days of rectangular buildings with uniform grids, perimeter beams, punched windows, and eight-foot ceilings. The current trend in residential projects is sculpted floor plans with higher ceilings and more expansive floor-to-floor glazing. This is especially true in luxury projects where spaciousness and views are of utmost importance. In most cities with height restrictions, there has not been a corresponding increase in allowed building heights to match this trend, leaving the development team with the tough decision between maximizing ceiling height or maximizing the number of floors. Caught in the middle is the floor plenum, the space needed for structure and MEP. Reducing this space becomes critical to minimize the tradeoffs between ceiling height and floor count.

Another trend in residential projects is much tighter tolerances including those for deflection, both dead and live load. The clean lines and thin joints of many high-end glazing systems do not provide much play for the many factors that can impact the final floor profile. Projects with aggressive schedules, where glazing may trail floor construction by only a few levels, do not allow for long-term slab deflections to occur prior to the installation of the glazing systems. For architecturally intricate finishes, the old standards of span-to-deflection ratios, such as $L/360$, may not apply as the glazing supplier, finishing sub-contractors, and architects more frequently require a smaller maximum total deflection regardless of span.

So the challenge becomes, how is structural depth reduced while still maintaining tight deflection criteria? The old "brute force ignorance" method attempts to solve the problem by adding material. Unfortunately, this method likely results in a bulkier slab section. Conventional reinforced concrete slab system studies done for the Ritz-Carlton project showed that the tight deflection tolerances could not be met without an extremely thick slab system. The benefits in added stiffness with increased section depth would be offset in part by the added weight and resulting deflection, making resolution of an efficient system impossible.

A more elegant and dynamic solution that utilizes the complementary materials of concrete (strong in compression) and steel reinforcing (strong in tension) is required. Take that one step further by



Load transfer through the 120-foot PT concrete truss.

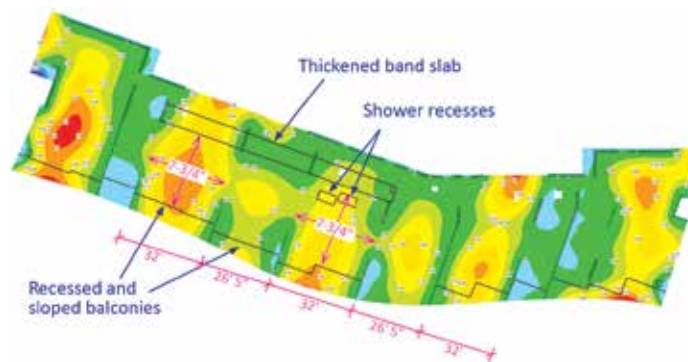
varying the force and location of the steel reinforcing to best match the spans and loadings. Post-tensioned concrete is that solution as it provides the dynamic ability to change how a floor system performs by varying steel tendon drapes and quantity. This solution results in thinner slabs which reduces the overall building weight. A lighter building reduces the gravity load demands on the columns, walls, and foundations as well as reducing the seismic demands.

Thinning up the Floor Plenum

For the Ritz-Carlton project, the residential floor plan was laid out in a long single-loaded corridor so all interior units would face the ocean, leaving the end corner units with views in three directions. With a gentle curve, the overall floor plan stretched approximately 240 feet long and 50 feet wide. The slab had 10 spans in the long direction ranging from 13 feet to 32 feet, with the most repetitive span happening only four times at 26 feet 5 inches. Height limitations were a challenge in trying to fit a 38-story building within an envelope no taller than 350 feet.

The team's goal was to get a 7-inch-thick slab to work to meet these requirements. While the slab system needed to be as thin as possible, it still needed to meet acceptable sound transmission, vibration, and deflection characteristics. With spans up to 32 feet, this would require some creativity. In the narrow direction of the building, standard columns were replaced with thinner, long walls creating a single span condition with cantilevers on both ends. The combination of longwall supports and cantilevers resulted in a very stiff floor system across the width of the building. A side benefit was that the use of thinner load-bearing walls also eliminated any lost sellable area due to structure.

For units with the 32-foot span, a slightly reduced clear height was agreed upon to accommodate a 7¾-inch thick slab needed for these longer spans. The area of this thickened slab, however, had to stop at the inside face of the exterior glazing so that the perimeter of the building appeared to have a consistent 7-inch slab thickness. To further reduce deflections in three of the wider units, a thicker 7-foot-wide x 9¾-inch band slab was hidden in the dropped ceiling in bathroom and kitchen areas. This required coordination with MEP services to not lose ceiling height. The final design of the post-tensioned slabs resulted in slab systems with cladding-sensitive deflections under ⅝ inch.



Deflection plan of typical 7-inch PT slab.

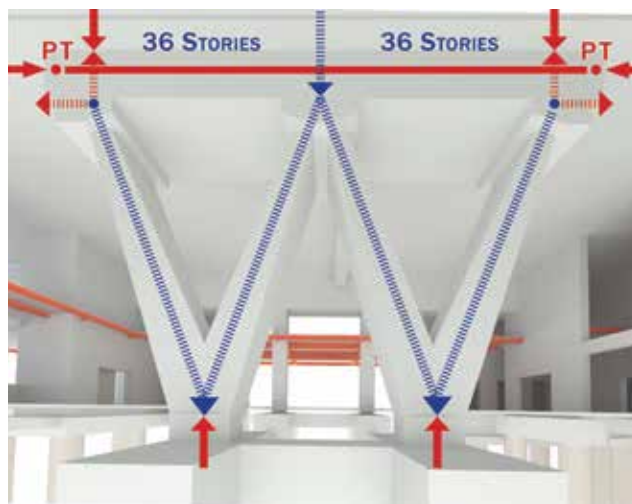
While the basic grid remained the same through the 30 residential levels, there would end up being 11 unique floor plans. Each of these required adjustments to the post-tensioning forces and drapes to provide the required strength, and to manipulate and minimize the deflections of the floor system. The most challenging of these floors were the two-story penthouse levels which were designed with spectacular double-story atriums. Since atrium and stair openings did not align with any of the supporting structure below, edges of the openings were supported by hanging the penthouse post-tensioned slabs with 32 steel "skyhook" columns from the roof transfer slab. The roof not only had to support the loads from the hanging columns but also the loads from heavy mechanical equipment, rooftop terrace pools, and landscaping at the roof level. This was achieved by utilizing a post-tensioned concrete slab with post-tensioned upturn concrete beams. To maximize views in the corner units, concrete wall supports were replaced with a series of small HSS 5x3 steel columns designed to be hidden in the glazing mullions to give the appearance of 40-foot-long glass walls at each side of the elevator core.

Transfers

The residential tower sits on two amenity floors with two pools, restaurants, and a spa deck; five floors of parking; one floor of back-of-house space; and an entry floor with a gracious interior porte-cochere. These diverse uses add seven more unique floors. As the optimum column and wall layouts for each use rarely matched the supporting levels below, offset and sloping columns were incorporated throughout the project to shift support locations through varying floor layouts. In this tower, more than 50 major transitions were required for the vertical elements, with no columns going to the ground in their original location and 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 except at the podium floors where 17 post-tensioned transfer girders in both downturn and upturn configurations were used to reposition tower columns and walls to transition through the parking levels.

The ground floor loading dock space created another significant challenge due to a number of constraints that would not allow the podium vertical elements over the loading dock to extend down to the foundation level. Site constraints included very



Load transfer through the W column.

The Post-Tensioning Institute's Project Awards are presented every two years and recognize excellence in post-tensioning applications. Structures utilizing post-tensioning as a structural component and that were completed or rehabilitated in the past seven years are eligible. Entries are judged by a jury of industry professionals and on seven different

traits: creativity, innovation, ingenuity, cost-effectiveness, functionality, constructability, and aesthetics. For the 2017 PTI Project Awards, 39 projects were considered in six categories: Buildings, Bridges, Parking Structures, Slab-on-Ground, Industrial/Special Applications, and Repair, Rehabilitation, and Strengthening. (www.post-tensioning.org).

tight spaces for trucks to maneuver, city utility easements, and access requirements for an adjacent retail loading area. This meant that an area of the building with spans of 50 to 120 feet had to be column-free. In order to support the seven floors of podium structure above, four post-tensioned transfer girders and a two-story post-tensioned concrete truss were designed to span the full 120 feet. Post-tensioning was used in the bottom chord of this truss to help control deflections.

The layout of the interior porte-cochere would require the tower columns above to shift over one-half bay. This could have been achieved with deep transfer girders but only to the detriment of a desired double-height ceiling in the area. An alternate series of four sloped columns arranged like a "W" met the layout criteria and ceiling height requirements. Post-tensioning was used in the capping beam at the top of the W to assist in the resolution of large horizontal forces created by the sloping of the tower columns.

Conclusion

Construction of The Ritz-Carlton Residences Waikiki Beach, Phase 1 was completed in April 2016. Through the use of post-tensioning along with the hard work and innovation of the architect, the structural engineer, and the contractor, Waikiki now has an iconic structure worthy of both name and location. ■



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Project Team

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General Contractor: Albert C. Kobayashi, Inc., Honolulu, HI

Architect: Guerin Glass Architecture, New York, NY, and Honolulu, HI

Post-Tensioning Supplier: Suncoast Post-Tension, Houston, TX

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