KALIA TOWER

One-story-tall Vierendeel trusses span three floors over a 60′ wide access road.

(top) Kalia Tower commands the most prominent entrance to the Hilton Hawaiian Village Beach Resort and Spa in Waikiki.

Waikiki's first all-steel-framed hotel tower achieves breakthrough in economy and speed with a new composite construction system

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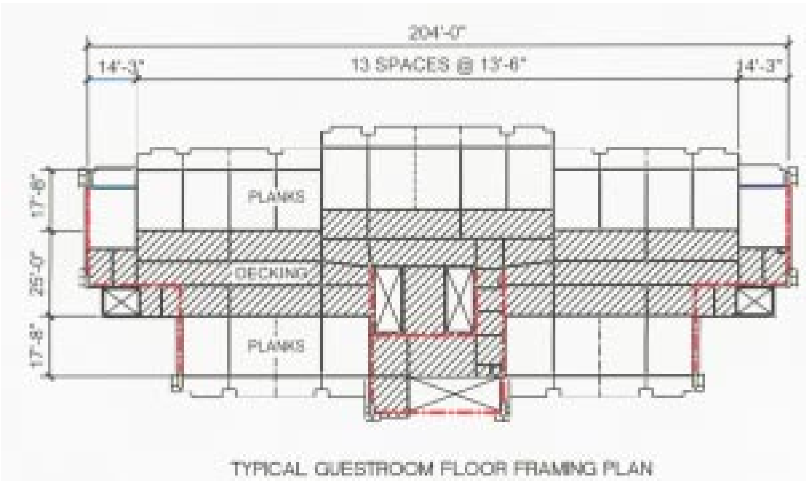
Waikiki has long been described as the primary economic engine of Hawaii's visitor industry. After nearly a decade-long economic slowdown, the revitalization of this resort destination is being lead by the new 453-room Hilton Kalia Tower, the first new hotel structure built in Waikiki since 1990. The 22-acre Hilton Hawaiian Village Beach Resort and Spa is the largest property managed or owned by Hilton Hotels Corporation with 2,998 rooms.

Planned and constructed during a period of tenuous economic climate, the success of the 24-story 300′ tall high-rise hotel depended on design innovations to achieve greater economy than conventional building framing systems. Through the use of a new composite structural steel and precast concrete structural system, significant savings in cost and schedule were achieved, and its structural engineering helped bring the 355,000 sq. ft. project within a $64 million construction budget. The system includes cast-in-place deep drilled shafts rather than driven piles (saving an initial $1 million) and a light composite steel braced frame structure with 6″ thick precast concrete floor slabs, saving approximately $1.75 million over a conventional post-tensioned concrete structure. The owner additionally realized the benefits of a five to six-month quicker construction schedule and a lighter building with less foundation elements (resulting in $1.25 million additional savings in foundation costs).

A multi-story pumping test of a concrete-filled tube. The mock-up was then dissected and inspected.

Designed by the internationally-recognized architectural firm of Wimberly Allison Tong & Goo, the site imposed significant challenges. One of the most obvious design issues was the view-blocking potential of the adjacent 100′ tall Mid-Pacific Conference Center and parking structure, situated on the ocean-facing side of the building site. The challenge was converted into a functional advantage by creating a 2-story bridge from the tower to the conference facilities at a height of 40′ above the entrance roadway. The connection allowed expansion of the Coral Ballroom and provided a new executive conference center. Within the footprint of the Kalia Tower building, 42,000 sq. ft. of two-level space are devoted to the Mandara Spa and the Holistica Hawaii Health Center. Above these two stories, a private pool, sundeck and fitness center are placed on top of the bridge at the 85′ elevation above grade. The 40′ tall first floor provides a dramatic lobby that can accommodate mature palm trees, as well as Bishop Museum's interactive Hawaiian Cultural Activities Center.

As a result, the lowest guestroom floor is 100′ above grade—providing an ocean view over the Mid-Pacific Conference Center for one-half of the rooms. The remainder of the rooms have an unobstructed view towards the mountains over the open space of the adjacent Fort DeRussy park.



Schematic plan of the steel-precast slab composite framing system. Red indicates lines of bracing.

The project, originally conceived and brought into design development in mid-1997, was over budget. Reconfigured with the objective of achieving greater cost efficiency, several estimators and contractors directed by the owner's construction manager, Construction Management & Development, Inc. (CM&D), performed intensive cost analyses.

One of the issues to be addressed was the foundation cost. The site investigation indicated that about 500 150′ long friction piles would be required for a concrete-framed structure. However, after a full load test of an installed caisson was conducted at the site, the geotechnical engineer recommended using deep cast-in-place drilled shafts. A total of 64 drilled shafts, 125′ long and developing up to 850 tons of working load capacity were required to support the main tower. In addition to the significant cost savings, Hilton decided to use drilled shafts to preclude any business disruption from the extended noise and vibration associated with pile driving, especially since the structure is near to the resort's five other residential towers and its major meetings spaces, as well as residential units in the neighborhood.

Martin & Chock (the project's structural engineers) developed several alternate composite steel framing systems for the owner's evaluation and comparison against a conventionally framed post-tensioned concrete flat plate and shear wall system. The lighter structure steel structure had an advantage because of the site conditions. The owner selected a composite steel system comprised of single 6″ thick precast concrete floor slabs for each unit, welded directly into a supporting structural steel braced frame. The 6″ thick precast prestressed concrete planks were of a standardized 13′-6″ module width, encompassing the guestroom living area and exterior balcony. The planks were designed for $\frac{1}{8}$″ camber, or nearly flat for better fit-up on the steel beams. This full thickness precast slab has no subsequent topping pour, and its plastered soffit is part of the ceiling finish. Framing depth was minimized by careful steel layout coordinated with the long-span precast planks and the room architectural dimensions, interiors and the mechanical and electrical systems (see schematic framing plan). Typical story height is 9′.

Coordination requirements included: blockouts for the erected steel columns, embedded electrical conduits with precisely located stub-outs, balcony slopes and curbs, drain/downspout and plumbing riser blockouts, blockouts and inserts for the welded connections to the steel frame, connections between the planks, and inserts for doweling into the adjacent cast-in-place and steel decked portion of the diaphragm. This central cast-in-place diaphragm in the guestroom bathrooms, corridors and service core provided shear transfer to the collector beams and to the lateral-load-resisting braced frames. A poured concrete diaphragm or cast-in-place concrete topped chord element is associated

Long-span framing of the pool deck, spa and conference center.

The integrated erection of structural steel with precast slabs resulted in a net savings of five to six months in construction schedule.

with connectivity to all lateral load resisting elements.

The steel structure was optimally designed for minimum steel weight with the added stipulation that bracing field connections make use of bolting in lieu of welding. Additional cost benefits were realized by the use of concrete filled tubes (CFT) columns at the eight principal chord locations of the braced frames. As typically designed, these elements were filled with concrete by pumping into a small access port, enhancing the column's effective area. This increases the stiffness of the braced frames while reducing plate thickness (and steel tonnage) of the fabricated column shaft. The Kalia Tower CFTs have a high aspect ratio in a 15x48″ section, which was necessary to maintain the dimensional regularity of the guestroom module and eliminate the interior planning problems and wasted space consumed by pilasters. Intermittent internal vertical stiffeners were used to limit the b/t ratio of the column plates, a minimum of $^3/_4$″ thick. These eight CFT columns reduced the quantity of steel in the primary columns resisting wind overturning, saving approximately $750,000.

Analysis of the tower for wind load included survey estimates and efficiency ratings of individual structural members of the lateral load resisting system, consisting of a braced core and exterior braced frames. Design criteria are for 105 mph peak gust wind speed, Exposure D and seismic zone 2A. Monitoring of steel quantities and value to engineering conducted as an integral part of the design resulted in savings equivalent to two full floors of framing. Overall structural weight is over 30% lighter than the comparable concrete system for this building configuration.

The steel erector was responsible for both steel framing, plank erection and its connections in an integrated construction sequence producing two guestroom floors per week. The planks also provided a greater initial stiffness to the framework during construction once the connections were made. The planks weigh 23,000 lbs. each, and shoring of 13 beams per floor against a minimum of two completed floors was required to develop composite beam action after plank welding for dead and live loads.

Framing speed was faster than a concrete framed solution for both the lower floors and the typical guestroom floors (where it was twice as fast). Steel erection began on the first week of March 2000 and was topped-off on June 28, 2000, taking four months to complete the 24-story frame together with the precast planks and metal deck. This period included one month for erection of the first three stories and the connecting bridge to the Coral Ballroom. Framing for the lower levels involved eleven transfer girders, five long-span vierendeel trusses, and a multi-span girder truss. Total project construction time from August 2, 1999 notice to proceed until opening day on May 16, 2001, was 22 months—approximately 5 to 6 months earlier, or 20% quicker, than would have occurred with a concrete framing scheme. Shortly thereafter, the hotel guestrooms were completely sold-out, yielding an earlier revenue stream estimated to be more than $100,000 per day.

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