High-Rise

By Michael Chusid

Late afternoon sunlight colors the lower floors of the structure, built with 12,000-psi concrete containing high-reactivity metakaolin. The large columns and beams of the moment frame, exposed at the center of the east and west facades, are in counterpoint to the minimal columns required around the rest of the building.

Affluent baby boomers becoming empty-nesters are fueling a demand for luxury urban living. The Californian, a new Los Angeles condominium built to meet the demands of this demographic, breaks new ground in two areas of concrete design and construction: First, it uses new engineering research to minimize interior columns and beams despite its location in one of the most seismically active regions of the country. And second, the building is believed to be the first high-rise structure to use high reactivity metakaolin, a pozzolanic supplementary mineral admixture that boosts concrete strengths to over 12,000 psi.

Developed by the Fifield Companies, the structure is 23 stories high over three levels of subterranean parking and contains 80 opulent units ranging from 2700 to 8000 square feet. Despite price tags that ran into the multimillions of dollars for a penthouse with views of the Santa Monica mountains, the downtown Los Angeles skyline, and the Pacific Ocean, all units were sold before the structure was topped out.

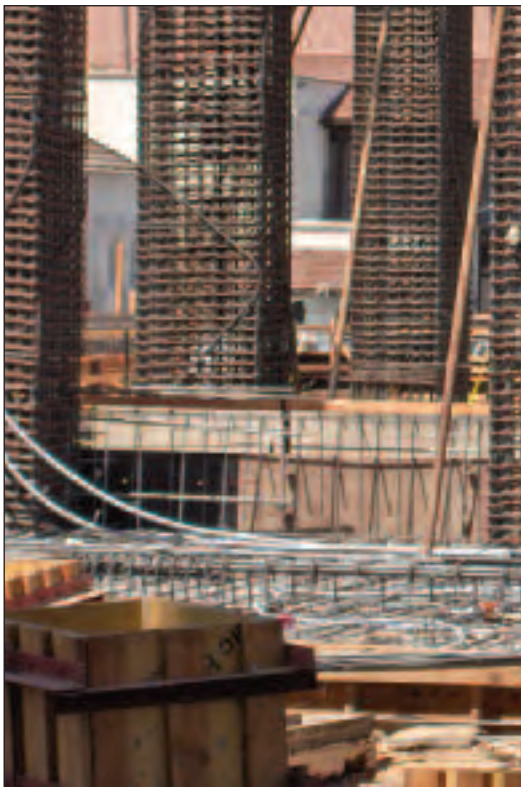
According to Dale Yonkin, executive vice president of Nadel Architects, the project's designer, "The client's goal was to create the most luxurious high-rise condo in Los Angeles, with an architecture that would appeal to more mature buyers who tend to appreciate the warmth of traditional residential design."

This criterion guided all design decisions. For example, the firm selected an architectural precast concrete cladding, fabricated by Clark Pacific Precast, because it offered a rich texture and visual appeal and permitted extensive use of molding and ornamentation.

Structural innovation

Yonkin says that one primary reason for selecting a concrete structure was the superior floor-to-floor sound attenuation provided by a concrete slab compared with steel decking, a feature expected by buyers of the units who, for the most part, were coming from the relative quiet of single-family homes. Also, he explains, "We wanted to offer dramatic, 10-foot-high rooms in the units. Concrete allowed us to use the underside of slabs as a ceiling and reduce overall floor-to-floor height for the project."

Other features intended to appeal to buyers also affected selection of a structural system: Floor-to-ceiling windows that make the most of the high ceilings and spectacular views required



Moment-resisting frame and high-reactivity metakaolin lead to a successful job

Californian Condo

a solution that did not rely on beams around the perimeter of floor slabs or running through units. In addition, the client wanted wide-open floors unobstructed by columns or shear walls in order to maximize net sellable floor area and allow buyers to customize the layout of their units.

To meet these criteria, structural engineer Englekirk Partners drew upon recent research it had conducted, along with the University of Southern California and the University of California at Irvine, under the sponsorship of Southern California's Carpenter/Contractor Cooperation Committee. This "C4" study investigated heavily reinforced moment frames designed to be rigid at beam-column connections and flexible at the midspan of beams and columns. Each midspan acts as a hinge, within the elastic limits of the steel reinforcing, to allow a structure to flex without damage during an earthquake.

According to Lawrence Ho, a principal at Englekirk, his firm relied on the C4 findings to develop a structural core of moment-resisting columns and beams capable of resisting seismic forces. Ho says, "Pulling a moment frame to the core of the structure is not the most traditional design. However, we compared it to shear wall and a dual moment framed/shear wall systems and found it was the most effective approach to meet the architectural design criteria." The approach allowed the size of perimeter columns to be reduced to allow for large areas of fenestration. Beams supporting the post-tensioned floor were formed within the 8-inch depth of the floor slab to maintain an uninterrupted ceiling plane and the floor-to-ceiling window height.

For moment-frame columns below the seventh floor, Englekirk specified concrete that would develop compressive strength of 10,000 psi after 56 days and 12,000 psi after one year. In addition to resisting seismic forces, the high-strength concrete allowed column sizes to be reduced up to 50 percent, helping to maximize floor space. On upper floors, diminishing seismic loads allowed for the use of more conventional concrete mixtures, and 6000-psi concrete was used in decks. The 12,000-psi con-

PHOTOS: ENGLEHARD CORPORATION

Left: Heavily reinforced columns were required to constrain the forces that would accumulate in the 12,000-psi compressive-strength concrete. The moment frames were engineered with rigid column-beam intersections and ductile zones at midspan to allow the building to flex in an earthquake. Above: Careful attention to sealing the bottom of forms was required to prevent the 12,000-psi concrete, with its high slump and small aggregate, from leaking during vibration.

Top: 12,000-psi concrete was used in the moment-frame columns below the seventh floor level, and 6000-psi concrete in the surrounding deck. Careful communication among the batch plant, the pump operator, and the crew in the building was required to coordinate placement of the two mixtures.
Middle: The project topped-out twenty-three stories above grade. Most of the concrete crew stayed together for over a year, achieving peak productivity at a floor per week.
Bottom: An exterior view of the tower.

crete was required to have greater than ordinary ductility to accommodate the flexing action of the moment frames; for similar reason, its compressive strength was not allowed to exceed 14,500 psi. The project is believed to be the first to use a moment-frame system based on the C4 research and the first high-rise in Southern California to use such high-strength concrete.

Rock hunters

Developing the mixture for the 12,000-psi concrete was a team effort that included Englekirk, general contractor Webcor Builders (a CC100 firm), ready-mix provider Catalina Pacific Concrete, and Twining Laboratories, the quality assurance and materials consultant retained for the project. Inspectors for the City of Los Angeles were also brought into the approval process early in the project so they could witness testing of mockups and gain confidence in the proposed construction methods.

Edward Kirk, Webcor's preconstruction project director, says the "biggest problem with the mix was finding a suitable coarse aggregate. Most local rocks didn't provide the strength we were looking for and would have caused shear problems." After pricing aggregate imported from Canada, the team initiated a search for an acceptable local stone. Numerous samples had to be tested before the project team identified a crushed stone from Lytle Creek in the nearby San Bernardo mountains that fit the bill. Complicating project logistics, Catalina Pacific had to build a ground storage area for the stone in its Alameda Street ready-mix plant.

Choosing metakaolin

The next challenge was to select a pozzolanic supplementary cementitious material to boost the strength of the cement paste. Kirk explains, "We considered a number of mixtures, but almost immediately took all but two out of play, one with silica fume and the other with high reactivity metakaolin (HRM). The pozzolans were the same price, and we were concerned about workability due to the rebar congestion and about strength gain. So we built a full-sized, two-story mockup of the column and beam connections with silica fume in the first story and metakaolin on top of that. We placed the mockup six months ahead of construction and then looked at the strength-gain curves. Both did well at the start, but metakaolin had a better curve and higher strength at 56, 90, and 180 days." After construction of the project was already underway, the metakaolin mix, made with Engelhard Corporation's MetaMax HRM, reached the target 12,000 psi at 365 days.

Moreover, Ron Dehlia, recently retired from his position as Catalina Pacific lab supervisor, says, "Silica fume's ultra-fine particles can make it difficult to handle in the batch plant." This was especially of concern because the concrete producer had to hand-load the mixers with sacks of whichever pozzolan was selected. Robert Cleeland, sales manager at Catalina Pacific at the time, adds, "Silica fume has an exceptionally high water demand and would have required more superplasticizer than metakaolin. We decided metakaolin was more user-friendly."

While Catalina Pacific is guarding the exact recipe of its proprietary 12,000-psi mixture, it is reputed to have about 11 sacks per cubic yard of a tertiary blend of Type II portland cement, fly ash, and metakaolin; ⅜-inch Lytle Creek crushed stone aggregate and Catalina Pacific's standard sand; superplasticizer and retarding admixtures; and a water-cementitious materials ratio of 0.35 for a slump of about 10 inches.

With so much cementitious material in the mix, the project team was also concerned about heat of hydration in the 4-foot-thick moment-frame columns. Kirk says both tested mixtures "put out the same heat—about 250 degrees at the center of the column. Still, we were able to strip forms the next day without thermal cracking. In fact, the concrete with metakaolin looked really good, giving us smooth, dense, uniform appearance and consistent coloration." This saved his firm the expense of sacking exposed concrete in the parking garage. Boris Stein, vice president of materials engineering and research at Twining Laboratories adds, "The concrete was almost crack-free." He speculates that, "The concrete developed strength fast enough to resist tensile stresses due to heat."

High reactivity metakaolin complies with ASTM C 618, Class N, as a natural pozzolan. Anthony Reed, busi-

ness development manager for MetaMax HRM, says, "The benefits of using metakaolin in concrete were only recognized in the 1990s, so the industry is still discovering how it improves concrete's strength, durability, workability, and appearance. While the Californian is the first high-rise to be built with HRM, designers are already proposing it for even taller structures."

Learning curve

Few people involved in the project had worked with such a high-strength mixture before, so they learned a few lessons the hard way. Superplasticizers added to the 12,000-psi mixture produced slumps up to 10 inches, making it easy to pump and consolidate. When vibrating one of the first columns poured, however, the highly fluid mixture liquefied and flowed out around the base of the forms, leading to a decision to foam-seal all subsequent column forms.

A more ongoing challenge was to coordinate placement of two very dissimilar mixtures. Placement of the 6-inch-slump, 6000-psi concrete, used in the moment-frame beams and on the deck, had to be stopped 2 feet away from columns. 12,000-psi concrete would then be brought in to fill the voids over the column and maintain the floor-to-floor vertical continuity of the high-strength concrete. Moreover, the high-strength concrete had to be placed before the 6000-psi concrete began setting to avoid formation of cold joints between the columns and the surrounding concrete. This required careful coordination of the trucks, pumps, and cranes at ground level to get the right concrete to the right location at the right time.

The retarder—required due to potential delays in traffic and placement—plus the other chemicals in the 12,000-psi concrete put the concrete into a "coma" for up to four or five hours, after which it would harden in a flash. More than once, someone working on the hardened deck concrete would step into the still plastic concrete over the columns. This was a common hazard because crews would start laying out and placing column forms in the afternoon over concrete decks that had been placed the same morning.

Through such aggressive measures as this, Webcor's crews were able to pour a floor each week. Even though Southern California experienced this past winter the heaviest rains in over 100 years, the project topped out in June and residents will begin moving in before the end of the year.

Summarizing the project, Cleeland believes, "everyone on the project team was open-minded about sharing information on the new engineering and construction techniques and collectively figuring out how we could get to the goal line." After a moment of reflection, he adds, "Together, we pulled off something that people thought could not be done in Los Angeles." ■

—Michael Chusid, FCSI, is an architect and a frequent contributor to concrete and construction magazines. He can be reached at www.chusid.com.

For information on metakaolin, ***circle 1*** *on the reader service card or go to www.engelhard.com/metamax.*