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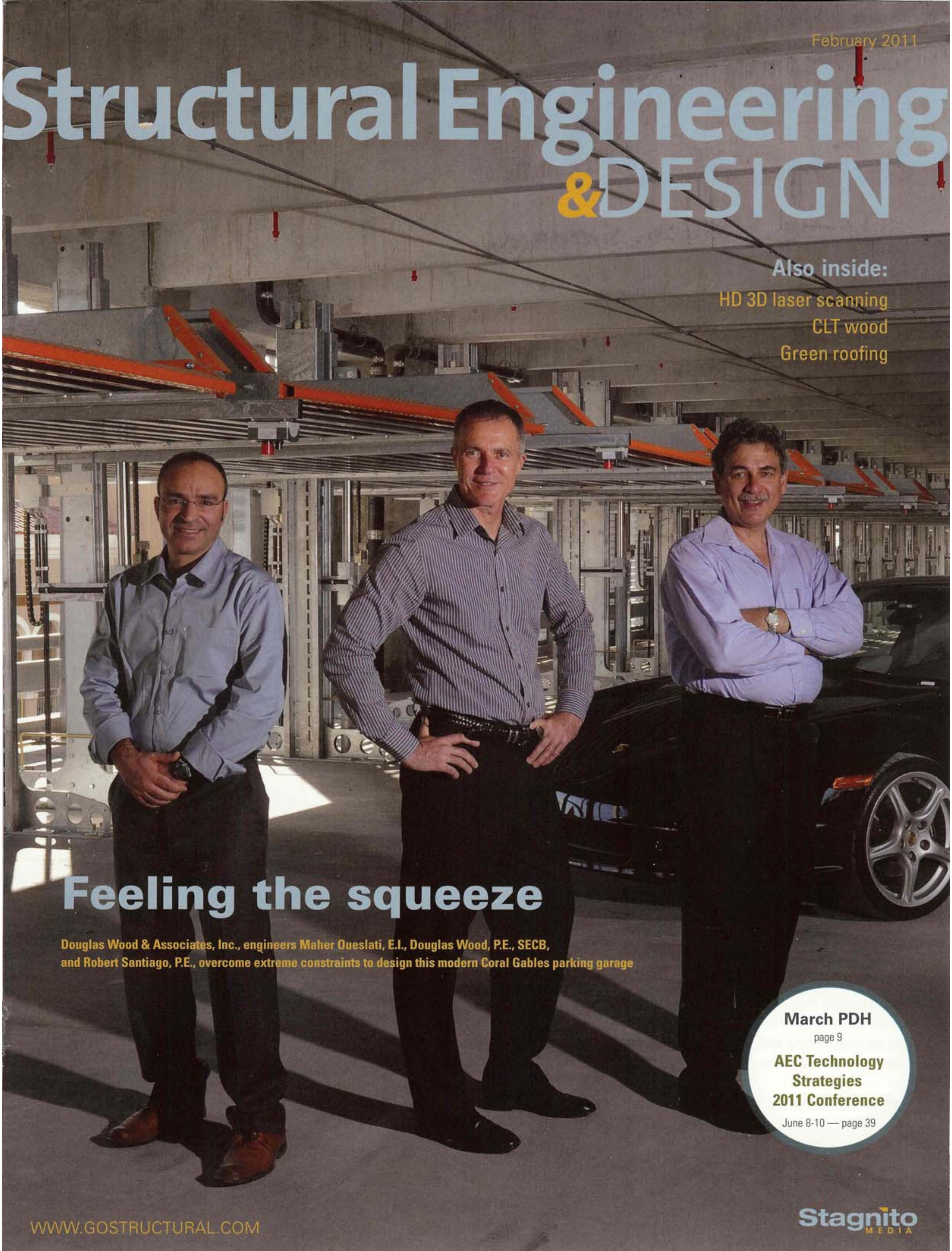
Structural Engineering & DESIGN



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Feeling the squeeze

Douglas Wood & Associates, Inc., engineers Maher Oueslati, E.I., Douglas Wood, P.E., SECB, and Robert Santiago, P.E., overcome extreme constraints to design this modern Coral Gables parking garage

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FEELING THE SQUEEZE

Team overcomes extreme constraints when designing and constructing a modern parking garage

By Douglas Wood, P.E., SECB, Robert Santiago, P.E., and Maher Oueslati, E.I.

As the owner and architect first presented to us the conceptual design for the overall project — building of a new 15-story office tower and a new parking garage, as well as renovation of a seven-story 1960s office block — it was clear that there would be numerous project challenges. It also was immediately apparent that building the parking garage would be the most challenging of the tasks. The garage, it appeared, was being squeezed from every angle.

Squeezed by time

The overall project previously had been conceived and preliminarily approved by the city under the zoning rules in effect at the time. While the owner awaited market conditions, the city was busy modifying its zoning code. Therefore, the design team had only three-and-a-half months to take all three buildings from conceptual design to building permit. If this wasn't accomplished, the new zoning rules would apply, and the entire project would be scuttled.

Squeezed by dimensions

The building site for the garage is approximately 100 feet by 335 feet, and it is bounded by public streets on two sides and public alleys on the other two sides. Luckily, the zoning in this urban neighborhood allowed nearly complete coverage of the site. Nonetheless, the sum of the minimum dimensions required by the zoning code for three parking space depths and two aisles is 98 feet. That left only two feet of width for the exterior façades, exterior columns, interior columns, and vehicle barriers. Clearly, this would be an issue.

With the overall floor dimensions restricted to 100 feet by 335 feet, and allowing for necessary areas for driving aisles, stairs, elevators, and handicapped-accessible parking spaces, the architect determined that the maximum number of spaces that could be configured on a full floor was 99.

Squeezed by height

The site zoning restricted the garage building to a maximum height of eight stories and 97 feet to the top parking

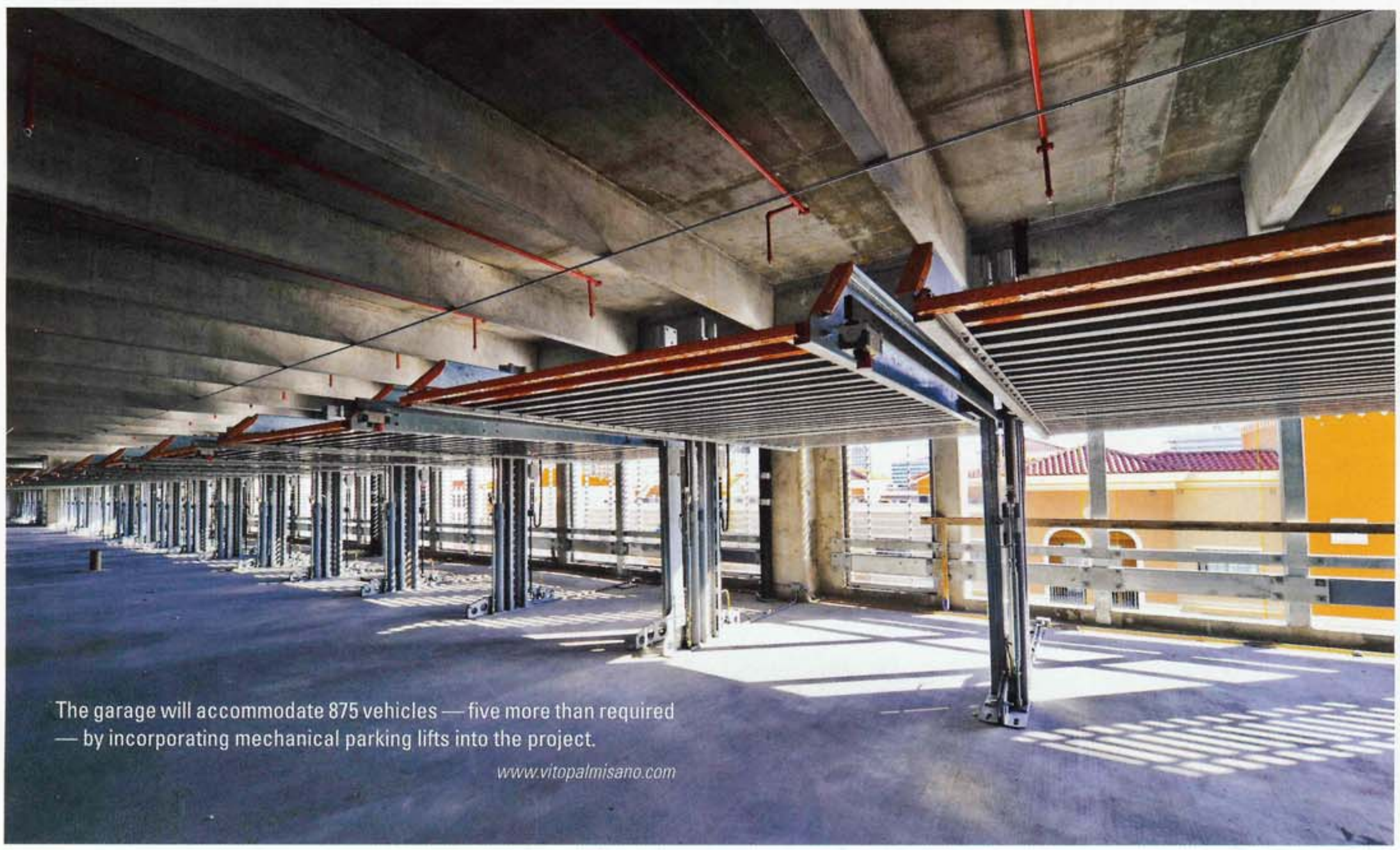
396 Alhambra Parking Garage

Owner
396 Alhambra, LLC, Miami

Structural engineer
Douglas Wood & Associates, Inc., Coral Gables, Fla.

Design architect
Fullerton-Diaz Architects, Coral Gables, Fla.

Contractor/Construction manager
Balfour Beatty Construction, Dallas



The garage will accommodate 875 vehicles — five more than required — by incorporating mechanical parking lifts into the project.

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Spotlight: Douglas Wood & Associates, Inc.

Q&A with the structural engineer


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Douglas Wood & Associates, Inc.'s Douglas Wood, P.E., SECB (DW), discussed the 396 Alhambra Parking Garage with Structural Engineering & Design Editor Jennifer Goupil, P.E. (JG).

JG: What was the first task you needed to do to get started on the design?

DW: Our first task was to determine what we believed would be the structural systems that would most cost-effectively satisfy the performance criteria. Because of the compressed design schedule, we needed to make this determination quickly and to move right into analysis and design. We brainstormed on ideas within the office, taking advantage of our collective experience. We then bounced our ideas off the architect and construction manager. Obtaining consensus, we were off and running. While we proceeded with the selected systems, we simultaneously developed concepts for two alternative systems, and we assisted the construction manager with cost estimates. This exercise confirmed that our initial choice ... was correct.

JG: What software did the design team use for the project design?

DW: For our design of the concrete frame and shear walls, we developed a three-dimensional structural model using ETABS (Extended 3D Analysis of Building Systems). For the design of the foundation (pile caps and grade beams) and also for the design of the elevated floor beams, we used SAFE (Slab Analysis using Finite Element Method). Both [programs are products] of Computers and Structures Inc. of Berkeley, Calif.

JG: How did the owner-required sustainable design goals affect the structural systems selection?

DW: The project is a LEED project. Forty percent of the garage building was allocated to the existing office building renovation project, for which a silver LEED certificate level is anticipated. The remaining 60 percent of the garage was allocated to the new office tower building, for which a gold LEED certification level is anticipated. Structural contributions to sustainable design of the garage included the use of reinforcing steel with a high percentage of recycled content and the use of fly ash as recycled content in the concrete.

JG: What sustainable aspects were pursued by the team?

DW: The following sustainable aspects were pursued by the design team: Five percent of the parking spaces are designated for low-emission cars; the concrete and metals recovered from the demolition of the existing parking garage were sent for recycling; an under-slab Stego Wrap 15 Mil Class A Vapor Barrier by Stego Industries, LLC, was used as a contamination barrier; flyash was used to replace up to 40 percent of the cement in the concrete mix; steel with high recycled content was used for the concrete reinforcement bars; and energy-efficient lighting was used in the parking garage, along with sensors to turn the lighting off when not used.

Firm Facts

Founded in 1992, Douglas Wood & Associates, Inc. provides structural engineering services for all types of building uses including residential, commercial, theatrical, recreational, industrial, institutional, educations, municipal, aeronautical, and military. In addition, the 16-person, Coral Gables, Fla.-based firm provides historical building evaluation, restoration, renovation, and additions as well as legal and insurance support services.

deck. Also, to keep the street frontage animated in this urban neighborhood, zoning required that the street level be designed as retail space, along with continuous pedestrian arcades along the two street frontages. Therefore, it would be possible to construct a maximum of only eight full parking decks. Based on the occupied floor areas of all three buildings, zoning regulations required a minimum of 870 spaces. Unfortunately, eight decks at a maximum of 99 spaces per deck yield only 792 spaces — a 78-space shortage.

Squeezed by aesthetics

The city's architectural review board also weighed in on the project and required that the mass of the garage be mitigated with articulation of the street façades. Along with other devices, the architect was able to accomplish this by creating two vertical indentations in the long side façade, thus visually separating the one solid mass into three smaller ones. These indentations resulted in the loss of 16 parking spaces. To further mitigate the mass of the building, the architect also created a horizontal recess across the central section at the sixth floor. This resulted in the loss of another 12 parking spaces. The total possible parking space count, then, was reduced from 792 to 764 — now leaving a 106-space shortage.

Solution: Make more space

There simply wasn't going to be enough deck area to accommodate the required 870 parking spaces. The design team had to figure out how to create more space. Two ideas quickly emerged.

First, above a height of 13 feet from the sidewalk, zoning regulations allowed architectural façade features to extend up to 8 inches into the right-of-way. Therefore, by setting the bottom of the second floor structure above this elevation and by taking advantage of the site being completely surrounded by right-of-way, the design team was able to push the façade features out by 8 inches all around the building. Although this didn't entirely solve the plan dimension problem, it was a definite step in the right direction.

The other significant idea for creation of additional space was the introduction of mechanical parking lifts. Zoning regulations allowed a portion of the required parking spaces to be accommodated in mechanical lifts. Therefore, the parking space shortage could be overcome with the use of mechanical lifts. Of course, these lifts needed additional height. Each of the two upper stories needed to be raised 3 feet, 5 inches.

The structural solutions

Our first endeavor was to determine the structural systems that would most cost-effectively provide the necessary performance.

Despite the opportunity to push the façade elements out by 8 inches, there still remained a lack of space for columns and vehicle barriers. Zoning regulations required additional parking width adjacent to walls, but also allowed a maximum 6-inch-wide by 12-inch-long encroachment in the back corner of a parking space. Therefore, the size and placement of each column and shear wall had to be carefully coordinated with the mostly predetermined parking space layout. To keep within the allowed parking space encroachments, many of the interior columns had to be limited to a size of 12 by 24 inches, and they had to be centered exactly at the intersection of four parking stalls. This need to closely coordinate and adjust column locations and dimensions according to the maximized parking space layout led us to the conclusion that cast-in-place columns and beams would afford us the level of design freedom we needed. The lack of space along the exterior façades, coupled with the masonry and stucco finish favored by the city's architectural review board, also led us in the direction of cast-in-place concrete for the exterior beams and façade features.

In all parking garages, it is desirable to span clear across an aisle and the spaces that open to it. The lack of available deck area for this garage made clear spans essential. Choice of the structural system for the decks was driven by this need for 40-foot and 60-foot clear spans, along with compatibility with the cast-in-place columns and beams, economy, and structural depth. The depth of structure was limited by the zoning code's 97-foot height limit to

By the numbers: 396 Alhambra Parking Garage

Size, shape, and type

Number of square feet:	295,000
Number of stories:	8
Structural system:	Composite concrete system consisting of prestressed, precast joists and beam soffits with cast-in-place beams and slabs; reinforced concrete columns; and shear walls
Foundation type:	Reinforced concrete pile caps on augercast piles

Quantities

Tons of rebar:	1,846
Cubic yards of concrete:	11,615
Square feet of deck:	262,000

Project schedule and costs

Design completion:	3.5 months
Construction completion:	9.5 months for primary structural systems, 22 months total
Costs:	Parking garage: $18.5 million; Total project (three buildings): $168 million

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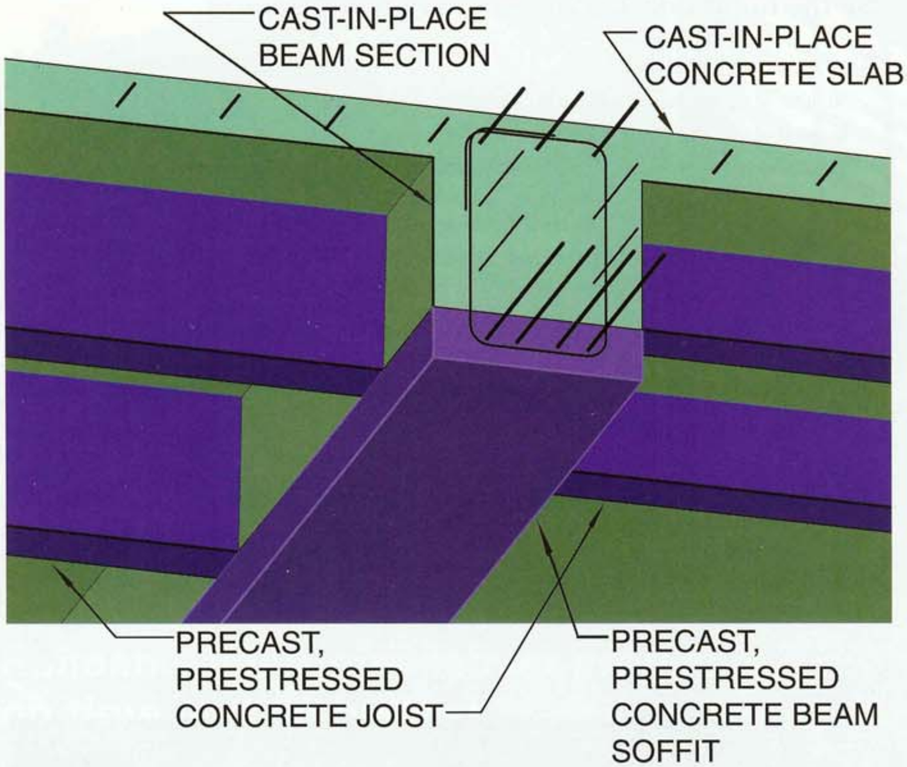
The 396 Alhambra Parking Garage was dimensioned to fit into the existing lot size, which was too tight to begin with. These restricted dimensions required close coordination with the architect, as well as keen awareness of the city architectural review board's requirements.



Of the structural systems considered, it was determined that the structural scheme using cast-in-place concrete slab and beams composite with precast-prestressed concrete joists and beam soffit was the most cost-effective.

the top deck, coupled with the need to raise the second floor beams above the 13-foot elevation (where the 8-inch projections into the right-of-way are allowed) and the need to provide extra height for the mechanical car lifts on the upper two floors. We quickly determined that the system that would most readily meet these criteria was comprised of prestressed, precast concrete joists (16 inches deep for the 40-foot spans and 24 inches deep for the 60-foot spans) with a composite, cast-in-place concrete slab. The minimum slab thickness was set at 4 3/4 inches to obtain the required two-hour fire rating. These prestressed joists are a proprietary system that has been readily available throughout Florida for more than 40 years, and they have been widely used for a variety of building types. This system also can include prestressed, precast concrete beam soffits (with beam stirrups). The remaining depth of each beam above the precast soffit is cast in place along with the slabs. The joist ends are embedded in the sides of the beams. This results in a composite beam-joist-slab system of relatively compact depth. For economy and speed of construction, we decided to take advantage of these precast beam soffits for the interior beams.

In order to achieve the desired aesthetic effect of a façade with texture and depth, the numerous façade elements needed to be 14 inches thick. Therefore, with an 8-inch projection into the right-of-way, each of these vertical and horizontal elements had to be notched around the structural beams at each floor level. This would, of course, be a forming challenge for the contractor, particularly along the rear alley façade, where the horizontal bands had to be notched around the sloping ramp beams. These notches also presented a structural design and detailing challenge because the notched vertical elements also needed to resist vehicle impact loads. To provide adequate shear capacity at the notches, and to provide adequate shear transfer into the floor, we developed a detail of vertical and horizontal dowels along with additional ties as shear reinforcement in the columns.

Also, because of the lack of building width, the vehicle barriers along the exterior walls could not extend inward of the interior faces of the façade elements. Also, since the façade openings were to be filled with aluminum grilles, the horizontal deflection under vehicle impact load of a tensioned-cable barrier system was unacceptable. Therefore, we designed the vehicle barriers using horizontal steel tubes set flush with the interior faces of the vertical elements. These tubes, along with their associated connection plates, were galvanized after fabrication and field-bolted for corrosion protection.

With only three-and-a-half months to design all three buildings in the project, we proceeded with haste to design the garage structure using the composite precast/cast-in-place structural system. To be sure that this system was indeed the most cost-effective, however, we simultaneously presented the preliminary architectural design to a precast concrete provider for consideration of a fully precast system. As suspected, however, the need to vary column size and spacing and the need to provide a deep façade with significant notching (including the sloped notches along the ramp beams) proved to be problematic for a fully precast system.

The mechanical vehicle lifts also presented a loading challenge. The lifts chosen for this project are supported on one short, narrow steel channel at each side of the parking space. Therefore, the weights of both the raised vehicle and the lift itself are concentrated in these two locations. Since the parking spaces do not align with the concrete joists, there were many different vehicle loading patterns on the slabs that needed to be analyzed. Our analysis indicated that the slabs needed to be 6 inches thick in the areas of the lifts. Because of restrictions on the structural depth and the cost of placing unnecessary concrete thickness in the driving aisles, the 6-inch slab depth was accomplished by lowering the slab forms between the joists only in the areas of mechanical lifts.

The design was successfully completed, and building permits for the entire project were issued ahead of the pending zoning change.

The last squeeze

The structure was, however, to be squeezed just a little bit more — this time, from below. Part of the site had previously been occupied by a gas station. Prior to construction of the building that occupied the site after the gas station, it had been determined that the ground had been contaminated by gasoline leaking from underground tanks. At that time, the tanks were removed, and a clean-up was completed and certified. Groundwater quality standards, however, were tightened in the ensuing years. Upon removal of the existing building, groundwater testing was conducted, and it was found that sufficient contamination remained to make the ground water unsuitable for disposal into the nearby stormwater system. Therefore, it was necessary to assure that no groundwater left the site, and this meant that dewatering of pile cap excavations had to be eliminated. Therefore, while pile installation proceeded for column foundations, we quickly redesigned the shear wall, elevator, and tower crane pile caps to raise them above the water table. The five-foot deep elevator pits required us to relocate piles outside of the pit areas so that the pits could be recessed into the pile caps.

With this final squeeze on the structure overcome, the contractor proceeded with construction, and the garage will soon be ready for occupancy. It will accommodate 875 vehicles — five more than required. ▼

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