Nebraska Medicine looked to its past to find the right structural solution for its new parking garage.

Second Time AROUND

BY RYAN CURTIS, P.E.

All photos: Ryan Curtis

NEBRASKA MEDICINE has been at the forefront of patient care, research and education for several years.

The Omaha-based facility recently became a household name, as it is home to one of the largest biocontainment units in the Unites States and assisted with multiple Ebola patients during the West Africa outbreak in 2014. As one of the leading academic medical centers in the Midwest, with over 1,000 physicians and a rapidly expanding campus, parking capacity on-site has not been able to keep pace with increased demand.

Relief came in the form of a new eight-story, 730-spot parking garage. A steel superstructure coupled with a post-tensioned parking deck was selected, a framing scheme that is somewhat of an anomaly among parking garages in the region. So why did Nebraska Medicine buck the trend? Because they had been very pleased with the performance, cost and appearance of a similar, adjacent parking garage that was built more than three decades ago.

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If it Ain't Broke

The existing "Lot 5" garage—built in 1983 by the same design and contractor team of Leo A Daly and Kiewit Building Group—is six stories tall and houses 677 cars. Its structural system was somewhat unique for its era in that the design incorporated a one-way sloped ramp climbing upwards and a high-speed spiral exit ramp. The lateral force resisting system used cast-in-place reinforced concrete shear walls, and with the overall plan dimensions of 335 ft long by 112 ft wide, the steel beams spanned the transverse direction of the garage with two long-span bays of 56 ft. The deck construction is composed of steel frame bents at 21 ft center-to-center, with no framing members spanning between columns, and a 6-in. post-tensioned deck.

Lot 5 has proven itself over the decades, recognized by the owner as the most durable and lowest-maintenance garage on the medical center's campus. Given this success, coupled with the fact that the new "Lot 6" garage would be built right next door, the owner decided to use Lot 5 as the template for the Lot 6 garage.

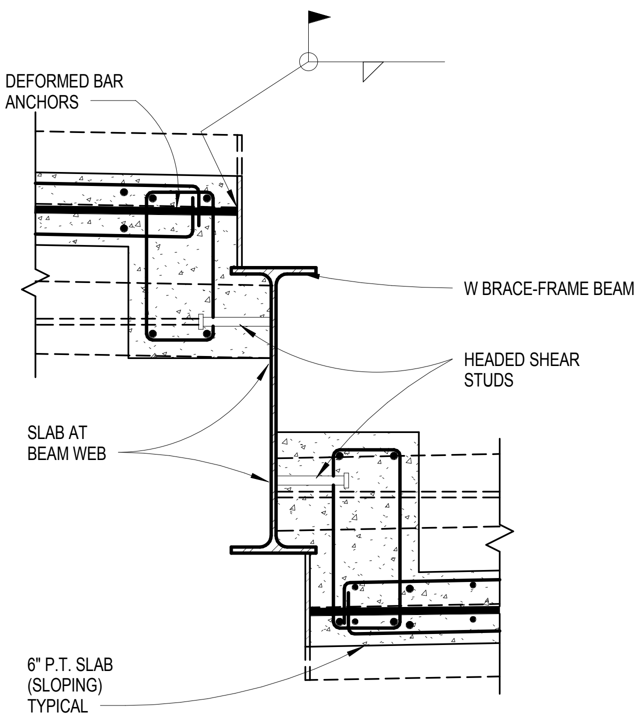
Big Sister

Coined the "big sister" of Lot 5, Lot 6 shares many features with its little sister. The garage uses wide-flange steel columns and beams as the superstructure, and a two-part coating system was used on all steel framing members. The first coating consists of a heavy zinc primer (2.5 to 3.5 mils) and the second is an epoxy coat (8 to 10 mils). Final touch-up coatings were applied in the field in the final weeks leading up to substantial completion. The deck system was also constructed of a 6-in. cast-in-place post-tensioned slab (described in AISC Design Guide 18: *Steel Framed Open Deck Parking Structures* as historically the most durable deck for Omaha's climate zone, Region B).

The garage is rectangular in plan, 325 ft long by 116 ft wide, and uses a double-helix ramp system with one-way traffic and crossover locations where sloping decks intersect. This was deemed the most efficient method of moving cars in and out of the structure during peak times for staff.

While cast-in-place concrete shear walls were used in the Lot 5 garage, the double-helix geometry of Lot 6 resulted in the need for an alternative lateral load resisting system. Due to a much tighter construction schedule—and current code-driven open-air requirements for garages—concentric brace frames with wide-flange braces were selected as the lateral force resisting system for Lot 6. Two steel braced frames are located in the transverse direction of the rectangular garage, both occurring where the parking deck ramps are "flat." However, one braced frame was located with its strong axis along the longitudinal direction situated one bay south of where the double-helix ramps intersect at a vehicle crossover location, which presented a unique challenge with regards to lateral load collection. In order to transmit diaphragm forces from the two sloping ramp slabs into the collecting members of the brace frame, a 24-in.-deep wide-flange cross beam with concrete encasements was employed. By using headed studs and attaching plates to the beam webs, the detail was compatible with the sloping ramps as they ramped up and down at varying locations. In addition, the steel braced frame provided visual openness to people walking or driving through the parking garage and eliminated blind spots at vehicle turns.

Another unique feature of Lot 6 was the post-tensioned slab design. In Lot 5, post-tensioning was used in only the longitudinal direction of the garage, with conventional reinforcing being used in the short direction. Because post-tensioning slab design methods have evolved since the construction of Lot 5, the design team decided to use post-tensioning in both directions for Lot 6, as this was deemed a better measure in sustaining slab compression forces to aid in crack control and overall slab durability. With post-tensioning in both directions and composite beams now parallel to the short-span post-tensioning, several design and detailing enhancements were employed to ensure the compatibility of both systems. In reviewing *Effects of Slab Post-tensioning*



▲ A detail of the sloping slabs at the braced frame.

◀ Lots 5 (left) and 6 (right).

▼ Erecting the braced frame.

▲▼ Braced framing (above) in the new Lot 6, which is eight stories tall and can accommodate 730 cars. It was built adjacent to the existing Lot 5.

The garage is rectangular in plan, 325 ft long by 116 ft wide.

In the steel scenario used in Lot 6, deck formwork began as soon as the slab below (supporting the forms) reached appropriate strength (usually three to five days).

Lot 6 uses a double-helix ramp system with one-way traffic and crossover locations where sloping decks intersect.

on Supporting Steel Beams (Sharma and Harries, 2007) and Design Guide 18, the team concluded that any effects of the post-tensioning on the composite action of the steel beam and slab assembly were negligible. As stated in Sharma and Harries, "The flexure-induced strains associated with post-tensioning are approximately 10% of those associated with the transfer of full dead load to the beams (as the forms are released). Additionally, bottom flange strain associate with the axial post-tensioning force and that associates with flexure-induced forces virtually cancel each other."

With two-way post-tensioning and composite beams, the detailing of the slab and beam interaction was critical to minimize the potential for cracking caused by slab restraints with a volume-changing post-tensioned deck. For example, to isolate slab shortening from the restraint provided by the structural steel framing, a bond-breaker was applied to the top flange of composite beams for the first 5 ft at each end. In addition, no shear connectors (headed studs) were allowed to be installed within the 5-ft zone. When shortening of the slabs occurs, this detail allows the slabs to "slip" without restraint that may have caused cause cracking. At brace frames where a high concentration of diaphragm shear collection occurs, additional bars were placed in both longitudinal and transverse directions of the braced frame strong axis. This distribution of reinforcing steel strengthened the diaphragm and also provided more shrinkage crack control. Also, the detailing of the post-tensioned slabs around the steel columns included isolation joint material at the column surfaces to minimize any detrimental cracking caused by restraint from the rigid steel column element.

On the Clock

With approximately one year to design and build the parking garage, the steel framing was essential to the speed of construction. In a cast-in-place scenario, slabs must be placed and columns must be cast

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The braced framing design provides visual openness and eliminates blind spots at vehicle turns.

prior to shoring up the decks for the next level. In the steel scenario used in Lot 6, deck formwork began as soon as the slab below (supporting the forms) reached appropriate strength (usually three to five days). The short cycle for each round of shoring, pouring and re-shoring allowed the contractor to keep the project on time. With approximately 800 tons of structural steel used in the project, the steel erection took four months.

For the precast skin along the perimeter of the entire garage, the panels were designed to span laterally to column supports every 21 ft. At each steel column, precast column wraps were used vertically from the foundation to the roof. Each connection contained field-welded anchors and various slotted supports held off the columns, allowing movement of the panels to occur under various loading scenarios. Using field-installed steel connections to join the precast skin with the wide-flange columns facilitated adequate flexibility and tolerances on-site as well as allowed proper alignment of the precast panels.

Completed in December 2015, Lot 6 improved upon the success of its parking predecessor, and may just provide the template for future parking projects on the Nebraska Medicine campus. ■

Owner
Nebraska Medicine, Omaha

Architect and Structural Engineer
Leo A Daly Company, Omaha

Design-Build Contractor
Kiewit Building Group, Omaha

Consultant
Walker Parking Consultants, Chicago

Steel Team

Fabricator
Paxton and Vierling Steel Co., Carter Lake, Iowa

Detailer
Industrial Detailing, Inc., St. Louis

Erector
Davis Erection, Omaha

➤ Steel framing provides long, clear spans in the new garage.