SMART THINKING

Careful design and proper detailing methods can minimize the erection challenges of long-span, steel-framed parking garages.

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More and more often, engineers are selecting structural steel as a cost-effective material for parking garage construction. However, owners often wonder about the feasibility of erecting a large number of structural components within the fast-track construction schedule commonly associated with multi-family projects. When Gables Residential decided to develop the second phase of their Meyer Park site in southwest Houston, they engaged Alliance Structural Engineers of Houston to design a 296-unit apartment project that included a 500-space parking garage. Stephen Sweet, Senior Vice President of Gables wanted a budget-friendly, erector-friendly steel parking garage with a maintenance-free finish.

Tom Bellace, structural engineer of record, selected long span, composite and unshored steel framing with a galvanized finish to meet the criteria, and the owner concurred. The typical composite floor beams would be castellated and hybrid cross sections using cellular technology. Bellace recognized that input from a fabricator, detailer and erector was essential in the engineering process in order to meet the owner's challenge, and a design-detail team was organized.

PLANNING THE GARAGE

Site conditions, including a lake amenity, required that the four-level garage abut three apartment buildings and be linked to four other buildings. Residents gain access to the garage from three separate pedestrian bridges at each level and from the breezeway ends of the adjacent buildings. Two 62′ wide, parallel parking bays with 90 degree parking and 9′ wide spaces were included. The garage columns, located on either side of the bays, were placed on a 27′ grid to coordinate with the parking space module. Jump ramps at each end provided the vertical transitions between levels and was required to align the floors of the parking bays with the adjacent apartment buildings. This ramp configuration results in a half level vertical offset between parking bays. The garage is separated from the adjoining buildings with a masonry firewall, and the open sides are faced with a pre-finished metal fascia. The typical traffic restraint system consists of pre-tensioned cables around the perimeter and along the ramps and offset ends of the parking bays.

IDENTIFYING ERECTION DIFFICULTIES

The structural design of the long span composite beams required 30″ deep sections weighing 50 plf. The typical decks were designed using 3″ deep, 20 gage composite metal decking with 3″ of high strength, normal weight concrete topping. The deck framing was supported by W24x62 girders at the bearing perimeter and W8x58 columns located at the center of the garage, which eliminated double girders at the offset between bays. Using RAM Structural System soft-

Interior view of completed garage. Note the x-bridging, used to stabilize the long-span steel members during erection.

ware, structural steel framing weighing in at a modest 7.8 psf was developed. With the basic structural design complete, the design-detail team reviewed the framing system and identified five erection concerns to be addressed by the structural design:

- Predict real camber to account for cellular beam behavior
- Alleviate lateral buckling of long span beams
- Relieve torsion in spandrel girders
- Orient column flanges to reduce bolt sharing
- Address reliability of connections with the galvanized finish.

ACCOMMODATING LARGE CAMBERS

The magnitude of camber associated with long-span steel framing can present erection problems. It is common for calculated dead load deflections of clear spans in excess of 60′ to be greater than 2.5″. Calculated mid-span dead load deflections were 2.8″. SMI Steel Products (the fabricator of the cellular beams) was consulted regarding camber issues, and they found that the cellular beams do not behave as deflection calculations indicated. John Coulson, P.E. formerly Engineering Manager of SMI, recommended that the fabricated camber be 75% of the theoretical value. The coordination of this camber produced flat surfaces after placing the concrete topping and installing various fixtures and hardware.

ERECTION BUCKLING

Once erected, long span beams are laterally unstable until the metal decking is attached. Erecting relatively light members with large cambers is cumbersome due to the natural tendency of the member to concurrently twist and sweep. To prevent this instability, Alliance specified that three lines of bolted X-bridging (at the quarter points of the beams) to be installed during erection. At the erector's request, solid-web sections using W16x26 wide flange beams were provided at the ends of each bridging line. The solid bridging provides resistance against the thrusts induced from twisting. Thus, the bridging kept the long span beams planar and in position during the erection process.

SLOTTING RELIEVES TORSION

As concrete placement progressed, the beams deflected and "evened out" the camber. This deflection caused torsion in the supporting girders that had to be addressed, because the twisting of the supporting girders would be visually apparent as a "lean" in the traffic posts, attached to the girders prior to concrete placement.

In order to accommodate the beam end rotation, SMI's detailers recommended that single plate shear connections with short slots be detailed instead of standard double angles. The slip provided by the slots allowed the end rotations in the beams to occur without twisting the girders. Also, the base plates of the traffic posts were elongated to "jump" the flanges of the girder and beam connection. The jumper plate was supplied with a shim space for field leveling. After concrete placement, the posts remained upright, without any noticeable lean.

REDUCING BOLT-SHARING

The interior column line between parking bays at the center of the garage typically includes a large number of steel sections, and erection is complicated due to the number of pieces in close proximity to each other. Traditionally, double girders at the edge of each offset bay are provided to support the long span beams on each side of the common column line. Also, two lines of traffic posts are commonly used. The additional girders and posts reduce erection speed with unnecessary picks. Alliance eliminated this condition by deleting the double girders (and posts) and replacing them with one-piece columns at the ends of each long-span beam. The columns provided support for the beams and were integrated with the traffic restraint system. In addition, all connections at this column line were detailed with standard beam-to-column connections. The interior columns were oriented with their flanges towards the long span beams, which reduces bolt sharing. The exterior columns were oriented with their flanges towards the spandrel girders, further reducing bolt-sharing connections. This framing and connection

In the last bay of bridging, a W-shaped member replaces the x-braces to help resist any horizontal thrust induced by the bridging.

concept generally provided the same relative rotational stiffness at the ends of the long span members, which allowed the beams to deflect similarly during concrete placement.

COMPOSITE ACTION WITH GALVANIZING

The galvanized finish on the steel framing was provided by a hot dipping process, and members longer than 40′ were dipped twice. The galvanized finish on the long span beams created a special problem with fusion reliability of the headed studs to be field applied through the galvanized metal decking. The headed studs were required to develop composite action between the beams and the concrete slab to support vehicular live loads including impact. Alliance and SMI developed a method that prevented the top surface of the top flange of the steel beams from being coated during the galvanizing process, using a thermal paint that could be applied to the top flange prior to dipping. The paint's heat resistance protected the top flange during galvanizing. Sample beam sections were prepared with the paint and galvanized, and headed studs were shot through the metal deck. A testing lab reviewed the sections according to ASTM standards and concluded that total fusion of the studs was achieved. By specifying this process, the headed studs were installed in the field during construction with remarkable success.

The design-detail approach for this parking structure provided an important "check" step during the engineering process that allowed the designers to identify erection difficulties. By integrating the technical experiences of the structural engineer, the fabricator, detailer and erector during design, the design/construction team avoided many common problems and pitfalls. In conclusion, the Meyer Park garage was successfully erected and constructed because of the cooperative interaction of the design detail team. All of the team members shared their ideas towards the common goal of designing an erector-friendly, structural steel parking garage. In the words of erector Russell Clements, "All of the parts went together like a hand in a glove."

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