Keeping Corrosion Contained

BY WING HO, P.E.

Corrosion doesn't need to mean the end for a steel parking garage.

THE SEPTEMBER 2006 MSC STEELWISE ARTICLE "Are You Next?" (available at www.modernsteel.com) suggested steel-framed parking garages built with a cast-in-place concrete slab on metal deck is suitable for less atmospherically corrosive regions. In fact, many steel-framed parking structures have been built in regions where corrosive de-icing salts are used and freeze-thaw cycles are present. As with all parking garages, an effective maintenance plan is the key. But what about a garage where maintenance has not kept up?

A program of repair, or a combination of repairs and partial reconstruction, often can be implemented to extend the service lives of steel-framed garages and avoid demolition. Such a rehabilitation program, completed mid-last year, was the case with a 25-year-old steel-framed garage in New Jersey.

The Existing Conditions

The framing of the garage was similar to that shown in Figure 3-2 of the AISC *Design Guide 18*. It had two 60-ft structural bays in the short direction and several 25-ft bays in the long direction. Heavy wide-flange girders spanning 60 ft connected the wide-flange columns in the short direction. Wide-flange filler beams and open-web bar joists at 4 ft on center spanned between the girders. The 4-in.-thick floor deck consisted of 3 in. of cast-in-place concrete over a 1-in. metal deck, reinforced with welded wire fabric. The slabs were built compositely with the beams, joists, and girders. Slopes were built into the slabs to drain water away from the exterior walls toward floor drains adjacent to interior columns.

All corrosion was typically initiated by water and de-icing salts entering cracks in the slabs. The salt and water trapped in the cracks then corroded the welded wire fabric and the metal deck. After the metal deck was corroded through, salt and water trickled down and affected the beams, joists, girders, and columns. The thin-gauge metal decks typically suffered the most severe corrosion, with the heavy steel girders and columns sustaining corrosion on the surfaces only; the filler beams and bar joists exhibited various degrees of corrosion. As a result, only the corroded slabs, beams, and joists needed to be replaced or repaired, while the girders and columns only required cleaning and repainting.

The Rehabilitation Program

Located at the high points of the slabs, the exterior walls and the adjacent floor areas had less contact with moisture and were in better condition than the interior floor areas. Therefore, only the slab areas and framing away from the exterior walls were repaired or rebuilt. During demolition, "picture-frame" slab areas along the exterior walls were maintained to preserve the diaphragm action of the slab to stabilize the exterior walls. Temporary bracing was also provided to limit the unbraced lengths of the girders and columns before the new slabs were installed.

Alternative slab systems were considered, including a cast-in-place concrete on Filigree system and a post-tensioned system. However, the increased dead load of these alternatives made them unsuitable for the replacement of the corroded framing. The only feasible option was a similar steel-framed system with cast-in-place concrete on metal decks. Since the minimum uniform design live load under the 2006 International Building Code is 40 psf and the existing structure was designed for a 50-psf live load, the replacement slabs could be 10 psf

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heavier without overstressing the existing girders, columns, and footings. This allowed a thicker replacement slab to be used. In the final design, a 5-in. replacement slab consisting of 3.5 in. of cast-in-place concrete over a 1.5-in. metal deck was selected. This thicker replacement slab was more cost-effective, as it required fewer filler beams. The filler beams were spaced at 8 ft, 6 in. on center. The thicker slab also provided adequate clear cover for the reinforcing steel.

When the corroded slab areas were saw-cut and removed, the typical cut edge was made at 3 in. from an existing bar joist, leaving a 3-in.-long slab overhang. During the erection of the new framing, a new filler beam was installed 3 in. away from the cut edge, or 6 in. from the existing bar joist. After the new slab was poured, the existing bar joist was connected to the new filler beam so that they would act in unison under live loads. Located directly over this combined steel member, the joint between the new and existing slabs was kept tight because it only experiences minimal stresses and movement. However, these joints were further protected with sealant and waterproofing coating as recommended by AISC *Design Guide 18*.

Methods and Materials

To maximize the durability of a rehabilitated steel garage structure and minimize future corrosion opportunities, the following methods and materials were used to keep water from entering the slabs, weep water out of the slabs, and make all metal parts more corrosion resistant:

- G90 galvanized metal decks were used as forms only. The slabs were reinforced with low-carbon, chromium reinforcing steel bars (ASTM A1035).
- Vented metal deck or holes in the bottom of the metal deck were provided to weep water.
- Galvanized wide-flange shapes were used to replace corroded filler beams and joists.
- Shear connectors for composite action were mechanically attached.
- Decks were attached with mechanical fasteners.
- Conduits were eliminated from slabs; cracks tend to form along embedded conduits.
- Details were configured to prevent water from accumulating on the structure.
- All joints in slabs were sealed with a waterproofing coating, following the recommendations in AISC *Design Guide 18*.
- Existing structural steel was cleaned and painted, following AISC *Design Guide 18*.

All structures can experience corrosion problems in harsh environments, and steel-framed parking structures are no exception. However, modern methods and materials are readily available for their rehabilitation, and new construction can be designed and built with much less maintenance required. For this 25-year old steel-framed garage, the majority of the structural components were suitable for reuse. A program combining repairs and partial reconstruction was easily implemented to restore the structure and extend its service life, and this project serves as an example for other steel garages requiring the same kind of attention. MSC

What to Fix First? Prioritizing Repairs

Very often, the construction budget and the requirement to maintain a certain number of available parking spaces combine to demand that repairs to a garage be performed in phases. The following are some ideas to consider when setting the priorities of repair items:

- First, close off heavily corroded areas. Stabilize these areas with temporary shoring if the damage is so severe that the capacity is insufficient. Perform repairs of these areas.
- Second, remove all overhead loose materials that may fall and inflict bodily injuries or property damage.
- Third, repair the joints and waterproofing coating on the top-level deck. Also, ensure that the drainage system captures the water from this level. Water intruding through or conveyed by the top-level deck could trickle down and affect all other levels. If the top-level deck is watertight and draining properly, there is much less water left to deal with, the building and the new repairs will be subject to a less corrosive environment, and the garage will enjoy a longer service life.
- Lastly, concentrate repair efforts on what is essential to safety and extending the service life of the building. Generally, it is not necessary to repair everything!