Condition Assessment and Repair

An Existing Composite Concrete Slab and Steel Beam Framed Parking Structure
Part 1

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In the fall of 2010, a property management company retained Pennoni Associates Inc. to conduct a condition assessment of a large sub-grade parking garage and loading dock located in Center City, Philadelphia. The garage included only two levels of parking beneath two adjacent high-rise office towers; however, the overall footprint of the parking facility involved an entire city block, for a total of over 500 parking spaces. The upper parking and loading dock area consisted of varying thicknesses of a reinforced normal weight and lightweight concrete slab supported by galvanized composite metal deck, which in turn was supported by composite steel wide flange beams. The lower level of the garage was a concrete slab on grade. Constructed during the 1980s, the structure was exhibiting signs of significant deterioration of the wearing surface and the supporting composite metal deck.

Establishing the extent and cause of the deterioration, and identifying appropriate repairs, required a thorough condition assessment of all of the sub-grade loading docks, parking areas and ramps, including visual observations as well as chain dragging of the exposed wear surfaces to determine the presence of sub-surface delaminations. The assessment also involved obtaining core samples for conducting petrographic analysis of the existing concrete and independently testing it for the presence of carbonation and chloride content. Additional cores exposed a number of headed steel studs associated with the composite steel beams to facilitate detection of any deterioration.

Observations and Material Testing

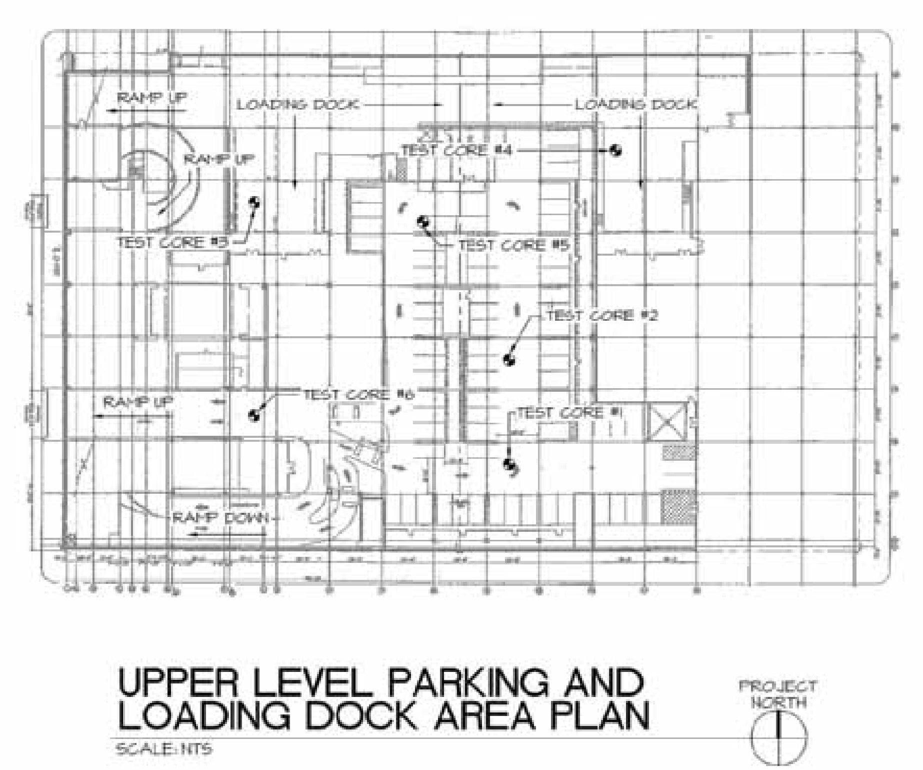
The condition assessment revealed isolated but widespread and significant concrete surface cracking, spalling and sub-surface delamination. In addition, the majority of the framed areas of the sub-grade parking facility exhibited widespread, significant deterioration of the galvanized composite metal deck. Deterioration was also occurring at the exposed structural support steel associated

Typical Surface Spalling and Cracking.

Typical Composite Metal Deck Corrosion.

Composite Concrete Slab and Galvanized Metal Deck Summary Table.

Location	Concrete Slab Thickness above the Metal Deck	Galvanized Composite Metal Deck Depth	Total Slab and Deck Thickness
West of Grid Line 11 (Lightweight Concrete)			
Parking Garage	3¼ inches	2 inches	5¼ inches
Loading Dock	6 inches	2 inches	8 inches
East of Grid Line 11 (Normal weight Concrete)			
Parking Garage	4½ inches	2 inches	6½ inches
Loading Dock	6 inches	2 inches	8 inches



Concrete Core Location Plan.

Deteriorated Headed Stud.

Carbonation Test Results at a Concrete Core Sample.

with the expansion joints and trench drains. One interesting facet of the investigation was that very little of the concrete wear surface deterioration occurred directly above an area of corroded metal deck below. This became evident from overlaying plans of the two damage types.

A total of six concrete core samples of the slab, four in the parking and ramp areas and two in the loading dock area, were obtained for the purposes of conducting a petrographic analysis of the concrete. X-rays of the slab at the proposed core locations, which were all at or in the immediate vicinity of exposed deteriorated metal deck, assured that no electrical conduits or significant internal reinforcement would be damaged during the coring operation. Core sample #5 came from an area of the driving aisle that had been painted, while core samples #1 and #2 came from an area of the driving aisle that had been coated with an epoxy topping.

The petrographic analysis indicated that the concrete was air-entrained (except at core sample #1), included natural sand fine aggregate and manufactured expanded clay lightweight coarse aggregate (except at core sample #4), and exhibited moderately hard paste, very few unhydrated particles, a good paste-to-coarse-aggregate ratio, no ettringite deposits in the water voids, and no micro-cracking.

Drilled powder samples were obtained from the upper one inch of the exposed wear surface adjacent to each core location except #5, which came from the bottom one inch of the core sample that had been in direct contact with deteriorated metal deck. Water-soluble chloride tests of the powder samples indicated that the chloride content, per mass of concrete, was as high as 0.503% (#2) in the upper wear surface and as high as 0.171% (#5) at the bottom of the concrete slab. The average chloride content of the surface samples (#1 through #4 and # 6) was approximately 0.27%.

As a result of the chloride content tests, additional cores from the concrete slab were obtained in order to assess the condition of the headed studs associated with the composite steel beams. X-rays of the slab at the proposed core locations again assured that no electrical conduits would be damaged during the procedure and indicated the specific location of the headed studs. A total of four headed studs were exposed for visual observation in the vicinity of two of the original test cores (#2 and #5) and near other areas of deteriorated metal deck. A core was also removed at a stud located directly below an area of the slab that exhibited surface spalling.

Field tests for the presence of carbonation in the exposed concrete located within wear surface spalls adjacent to the core sample locations using phenolphthalein were positive for the presence of carbonated concrete. Additional carbonation tests confirmed the presence of carbonated concrete in the upper ⅛ inch of the wear surface of core samples #2 and #5.▪

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Part 2 of this article will appear in a future issue of STRUCTURE magazine, and will present a discussion and assessment of the observations and material testing described above. Part 3 will address the resulting repairs.