REPAIR FOR LOW CONCRETE BREAKS ON DOWNTOWN DENVER PROJECT

By Orville "Bud" Werner II, P.E.

It is an unprecedented time to be working in Denver. Individuals and businesses are relocating at a swift pace to the city, recognizing its natural beauty, strong business climate, and forward-thinking leadership. In fact, the city's projected growth rate over the next five years is more than four times the national rate, according to *The State of Downtown Denver*, a report released last year by the Downtown Denver Partnership.

As the city's density increases, the number of parcels available for development in the downtown area will shrink. According to Denver's Open Data (City and County), only about 3 percent of the parcels within the City and County are vacant land. As a result, developers are willing to consider more extensive remediation of brownfield sites for their projects.

Against this backdrop of facts, the design team wrestled to identify solutions for a notable downtown project: 16M. This LEED-certified, mixed-use commercial site houses 115,000 square feet of office space over five floors, 36 luxury apartments on the top four floors and 13,000 square feet of retail space. This project's layout speaks to how developers can manage tighter spaces and smaller lots – and overcome the issues that may result.

When work was well underway on 16M, a concrete producer for the project contacted CTL|Thompson after the concrete at the second-floor parking deck did not achieve the specified design strength. The structural engineer of record carefully analyzed the slab using the lesser strength achieved and found a region of the slab that would not provide adequate support for the design loads, as built. The flexural strength in this area of the concrete slab was insufficient when analyzed using the reduced concrete strength.

No one on the project anticipated this problem. In fact, many steps were taken to ensure a smooth build. Early tests indicated that the concrete met the required design strength, yet some pours did not perform as expected. The project team faced practical – and potentially costly – concerns as to whether to tear out and replace the existing slab, which would disrupt and delay work on the building.

When CTL|Thompson's materials lab team received the call, most of the project design team, with years of experience in high-rise construction, considered slab replacement to be the presumptive repair option. CTL|Thompson expected this option to come with a high price. Another option considered included new support beams below the problematic area. This option was also expensive and potentially unacceptable, as it would limit clearance in the main driveway location of the lower level parking lot.

Prior work with Department of Transportation and road and bridge developers led to the suggestion that carbon fiber be used to improve the strength of the area in question. This solution could be implemented with the concrete in situ, preventing the need for a teardown. Commercial construction rarely needs such a fix, as it is primarily used to reinforce roads and bridges, but the firm believed it would work and careful study bore out the results.

Carbon fiber material has been used for more than two decades and possesses a strength that is significantly higher than steel reinforcement in concrete. The Colorado Department of Transportation uses it occasionally on bridge repair and highway construction projects. The strong, thin layer of carbon fibers, encapsulated in a resin film, can be adhered with epoxy to the surface of concrete, akin to putting a cast on a broken arm. In this case, when installed

below reinforced post-tensioned concrete, the carbon fiber places additional tensile reinforcement at the bottom of the slab. This lower layer of tensile reinforcement increased the effective depth of the slab sufficiently to reduce the compressive stress at the top of the slab to within the capacity of the reduced concrete compressive strengths. The unique application provided a structurally sound repair that, in the small area, required less than 500 square feet and was far less costly than replacement.

Most importantly, the application allowed the existing concrete to stay in place and work to continue. External tensile reinforcement uses strong, flexible fibers that are not subject to corrosion – a key consideration for structures such as parking garages, which are exposed to aggressive levels of sand and road salt in the Denver climate.

There are other advantages of using carbon fiber in this type of application, such as:

- There is no compromise in the floor-to-ceiling clearance in the area of repair.
- The repair is nearly invisible to passing occupants or visitors. Anyone looking closely at the underside of the slab in the area of the understrength concrete would see only a slight difference in texture and color compared to the rest of the underside of the slab.
- Where other repair methods include a risk of damaging steel during concrete removal, this repair required no cutting or chipping into the concrete that encases the existing unbounded tendons.

After additional discussion and investigation, including the structural engineer of record's evaluation and endorsement, the developer recognized this solution as the best possible scenario – one that was safe, efficient, and kept construction on schedule.

The case of 16M has shown that viable solutions to initially perplexing problems exist, even if they are borrowed from other fields.

Success is based on the ability to develop a strong coalition among the contractor, the supplier, specialty repair contractors and the engineer of record. This healthy working relationship among all parties involved led to an outcome at 16M that minimized the expense of repair and retained the structure's value.▪

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Project Team

Owner: Integrated Properties
Structural Engineer: Monroe and Newell
Architect: Gensler
General Contractor: Milender White Construction
Repair Contractor: Restruction Corporation
Materials Consultant (for repair): CTL|Thompson, Inc.