Westview Tower Underside Roof Slab Concrete Repairs

By R. Curtis White Jr.

The Westview Tower Apartment complex is a 34-year-old, 13-story cast-in-place concrete structure in Knoxville, TN. Within a stone's throw of the University of Tennessee, it is a home for the elderly set amid the foothills of the Great Smoky Mountains. The facility had recently changed hands and was in the process of a complete facelift and modernization when the new owner's representative discovered severe structural problems that had been hidden by acoustic tiles placed on the ceiling of the 13th floor living units. Severe delamination of the underside of the flat-plate roof slab was revealed when these tiles were removed. The owners consulted with their structural engineer, who brought in a concrete restoration specialist. The concrete repair specialist, in turn, called a shotcrete consultant.

Material testing started almost immediately on the conventionally-reinforced cast-in-place two-way flat-slab roof. The charge to the engineers was to determine the cause of corrosion of the slab reinforcing steel and develop recommendations for repair. Test results indicated that the underside of the concrete was carbonated up to 2 in. (50.8 mm) deep, which had caused the lower layer of reinforcing steel to corrode and spall the concrete. Further inspection determined that this condition was isolated to the underside of the 13th floor roof slab but extended throughout the entire 10,000 ft^2 (929 m^2) of the building footprint.

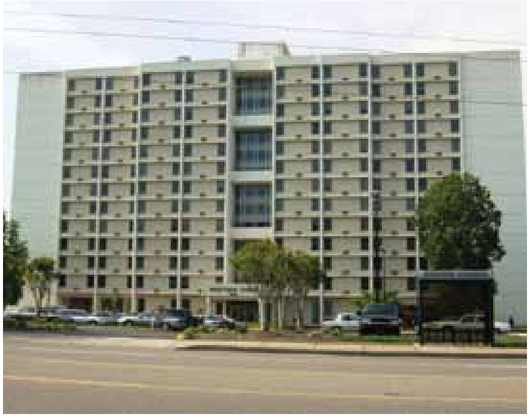

Fig. 1: Westview Towers building

Once determination was made that concrete would have to be removed and replaced to a depth of 1.5 to 2 in. (38 to 51 mm) throughout the entire underside of the slab, attention turned to means and methods. All methods would require the relocation of the residents on the 13th floor and possibly two floors below that. In addition, complete removal of all partition walls would be necessary to provide access to the ceiling. Utilities and chases, however, had to be maintained so that the remainder of the building could continue to be occupied. Parts of the 12th floor would have to be evacuated to accommodate the shoring required to support the compromised roof slab during renovation. Additionally, under a form-and-pour scheme, parts of the 11th floor would also have to be cleared.

Three methods of concrete rehabilitation were proposed and included as acceptable alternates for bid solicitation. These were form-and-pump, form-and-pour, and shotcrete. Based on review of the bids and interviews with the specialty contractors, the shotcrete process was selected by the design team and the owner as being the most confident and time-sensitive approach to limit disruption to the elderly residents and provide for a reliable and verifiable, permanent repair.

A primary concern to the owner was the additional loss of revenue and added expense of relocating the lower floor residents. Any combination

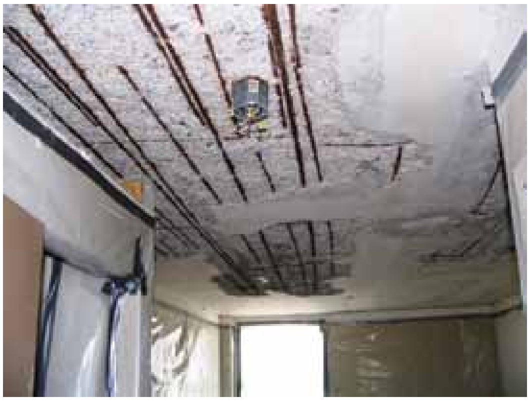

Fig. 2: Severe spalling of underside of roof slab

Fig. 3: Polished section of a concrete core illustrating corrosion in carbonated zone

of forming would have required two floors of shoring due to the larger demolition areas required to make forming feasible. The necessity of forming around all the utilities and chases further complicated the forming option. In addition, a form-and-pour approach would have required many breaches of the roof membrane for access holes to place the concrete. In contrast, using shotcrete allowed for the demolition and placement operation to proceed in 5 ft (1.5 m) wide strips or one-quarter of a bay width in the short dimension of the building plan. Rapid strength gain allowed the contractor to leap-frog the strips to keep the operation continuous; and because shotcrete requires no forms, the utility penetrations were handled with ease. Now that the demolition and applied load had been significantly reduced, only one floor was required for shoring and only one-half of that floor at a time. Because the bond between the shotcrete strips was equal to that between the sound roof slab and the shotcrete, cold joints and suspect epoxy bonded joints behind formwork were eliminated.

Demolition was performed using hand-held pneumatic chipping hammers. Hydrodemolition was also used where possible. This presented its own challenges with capturing water above 11 floors of occupied space (remember all the utility penetrations?). In the end, it was more cost effective to continue the hand demolition. The extent of removal was verified by using a phenolphthalein solution on the chipped surface. Phenolphtalein is a pH indicator that turns bright purple on noncarbonated concrete. A purple color indicates the carbonated concrete had been effectively removed. After removal and confirmation with phenolphthalein, the reinforcing steel and concrete surface was blasted with abrasive, cleaned, rinsed with clean water, and left in a surface saturated dry (SSD) condition.

As a part of the bid process, the shotcrete contractor proposed using a polypropylene-fiber-reinforced, silica-fume enhanced, dry-mix shotcrete for the replacement material and process. The shotcrete material was site-batched using local aggregate and Type I/II portland cement. Five percent by weight of cement was replaced by micro-silica, which was introduced at the same time as the cement and sand. The batching process took place at ground level and the material was delivered to the 13th floor using a 1300 ft^3/m (36.8 m^3/m) air compressor and 1.5 in. (38 mm) material hose. Domestic water pressure on the working floor was sufficient for the water ring.

Initially, ground wires were strung to control grade, elevation, and flatness (a prime concern because the finished shotcrete would be the exposed ceiling). The ACI-certified nozzlemen had to place the material overhead to tight tolerances so that minimal finishing was required and bond was not compromised while working the plastic material. After the first few strips were completed and finished, a 10 ft (3 m) straight edge was used to mark the grades and the shotcrete was hand-trimmed to those marks. Finally, a light flash coat was applied to hide any trowel marks and the entire ceiling was given a textured paint coat for the final exposed ceiling.

To ensure that a quality product was delivered by the contractor, bond testing was performed in accordance with ASTM C1583-04, "Standard Test Method for Tensile Strength of Concrete Surfaces and the Bond Strength or Tensile Strength of Concrete Repair and Overlay Materials by Direct Tension (Pull-Off Method)." Bond strengths ranged from 90 to 250 psi (0.9 to 1.7 MPa) with failure typically occurring in the parent concrete. Compressive strengths generallyranged from 3500 psi (24 MPa) in 3 days to

Fig. 4: Concrete core illustrating corrosion within carbonated zone

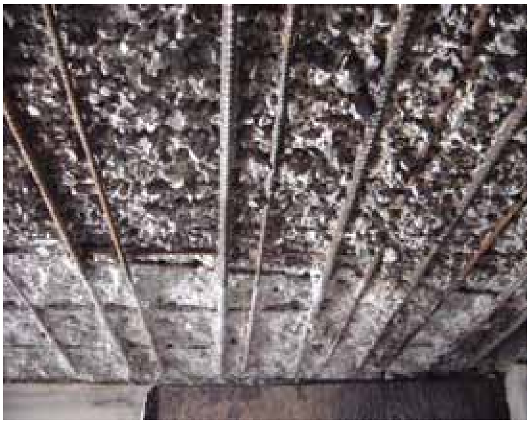

Fig. 5: Underside of roof slab illustrating difference between chipped area and hydrodemolition

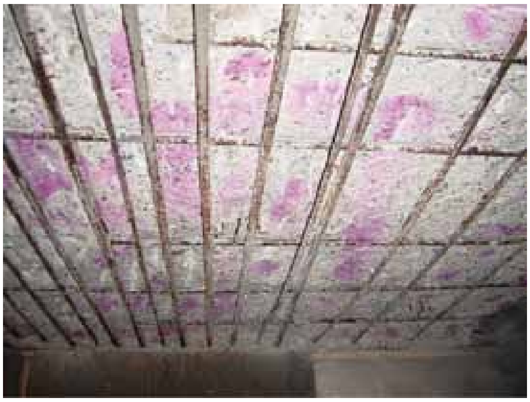

Fig. 6: Carbonated concrete removed and carbonation checked with phenolphthalein

Fig. 7: Removal of existing concrete alongside completed shotcrete repair

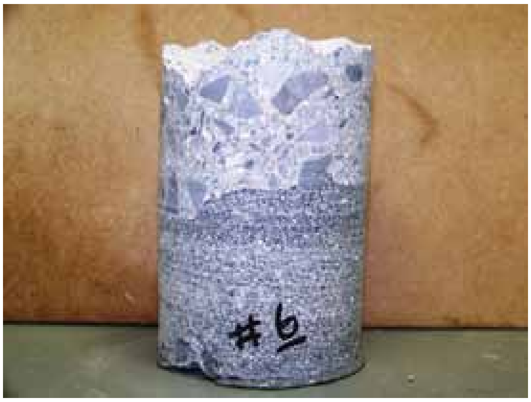

Fig. 8: Bond test core with failure within the substrate concrete

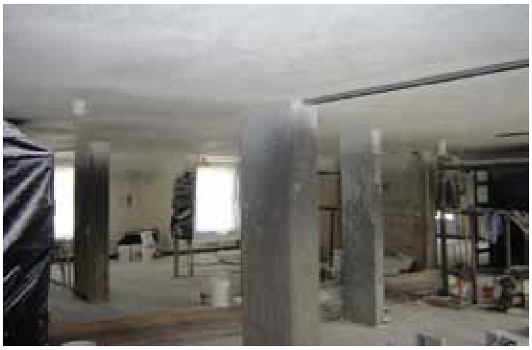

Fig. 9: Completed repair

10,000 psi (69 MPa) in 28 days. Bond tests, cores from shotcrete panels, manual sounding of chipped and completed surfaces, and phenolphthalein solution checks were all good inspection and quality assurance techniques. The confidence of the owner, the knowledge of the engineers, the selection of shotcrete, the experience of the contractor, the ACI certification of the nozzlemen, and the experience and skill of the finishers were all keys to the success of this project.

The concrete repair portion of this project was completed in approximately 90 days including shoring installation while maintaining occupancy for the elderly residents in the lower 11 floors. Most of the occupants got to know the workers on a first-name basis, inquired about the progress regularly, and were relieved when the work was completed and they could return to their accustomed peace and quiet in the Tennessee hills.

Westside Tower Repairs

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R. Curtis White Jr. *is President of Coastal Gunite Construction Company, a 25-year-old firm specializing in the repair and restoration of concrete structures using the shotcrete process. Coastal Gunite is active east of the Mississippi River completing shotcrete projects for new basement wall construction, sewer rehabilitation, bridge restoration, building rehabilitation, and seawall reconstruction. Coastal Gunite has won awards from the American Shotcrete Association (ASA) and the International Concrete Repair Institute (ICRI) for bridge repairs in the Florida Keys, tunnel restoration in West Virginia, and cooling tower rehabilitation in northern Florida. White is a long-time member of ACI Committees 506, Shotcreting, and C660, Shotcrete Nozzleman Certification, and ASTM Committee C09.46, Shotcrete. He is one of the authors of the AASHTO-AGC-ARTBA Task Force 37, "Guide Specification for Shotcrete Repair of Highway Bridges." White is a founding member of ASA and ICRI.*