2024 Outstanding Architecture | New Construction Project

Math, Science & Shotcrete

By Ryan Oakes

We had just finished shooting some mockup panels for a column repair at NC State University on the Civil Engineering building where we had to prove that we could shoot around reinforcing bars between #11 and #18 (#36M and #57M) in size with very little clearance between bars. The mockups went well, and the general contractor (GC) realized that the shotcrete process might help them with a completely different problem on another project — one that would prove to be most unusual.

It took me a minute to wrap my head around what they were asking: It was challenging to understand what they were describing on the phone because it seemed so unlikely. Though the shotcrete process of placing concrete is extremely versatile and well suited for many applications, it seems we get called for the more interesting projects as well. A site visit proved necessary.

The repair was at a Middle School in Holly Springs, NC. Summer break had already started, so the situation was urgent: They needed a solution before school started back up, as one of the challenges included repair locations not just on campus but directly adjacent to class rooms. If the work fell into the school year, students would be trying to

ABOVE:
Fig. 1: Maintaining a clean surface with an air lance

RIGHT:
Fig. 2: Spraying and finishing from man lifts

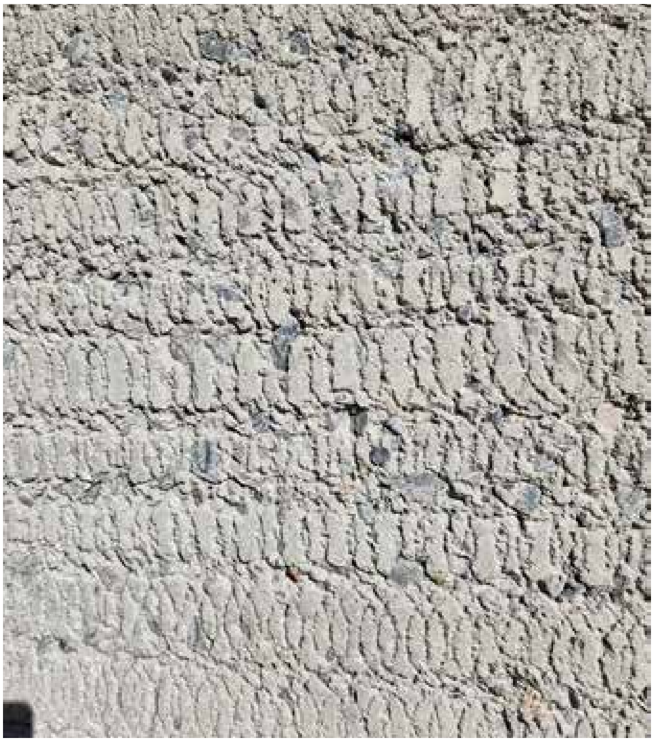

Fig. 3 Surface profile of tilt-up panel concrete after water jetting

focus on learning while contractors were outside trying to complete repairs. To aggravate the timeline further, proposals were needed, meetings scheduled, and approvals granted before any work could take place.

The building was a 40 ft (12 m) high tilt-up concrete structure clad with brick panels that had cracked and would soon begin falling off — not ideal for students walking underneath — and they had already started the demolition.

Once they started demolishing the structure, the GC and engineering team realized that the proposed brick panel system would not work on the existing tilt-up walls as the walls were not plumb or straight in any direction. In fact, they were trying to figure out why the walls were wavy and how on earth they could correct the situation. The walls were anywhere from 0.5 in. to 2.5 in. (13 mm to 63 mm) out of plumb both vertically and horizontally, sometimes over the whole 40 ft, and sometimes over just a few feet. The tolerance for the new cladding was 0.25 in. in 10 ft (6 mm in 3 m). It seems the original tilt-ups were cast on uneven ground. They needed to make the wall plumb and the leveling material needed enough strength to support the anchors for the brick cladding, as the anchors weren't long enough to reach the parent material in many locations.

Some options they were considering were polymer-modified hand-applied mortars which would be both cost and time prohibitive considering the areas and thicknesses needing rehab. With that approach, they could have likely completed the demolition before the start of school, however, all subsequent work would have to be completed during the school year and between classes.

We offered using dry-mix shotcrete placement to efficiently place varying thicknesses of concrete to create a plumb wall that met the requirements for placement of the brick panel product that would follow. Given that the tilt-up walls were extremely smooth and hard from being cast on foam boards, and because of foam being embedded in the near surface of the walls, they needed to be mechanically roughened. We tried a few surface preparation tools and ultimately went with hydro-demolition using a 40,000 psi (275 MPa) water jet. This provided an excellent rough bonding plane for the shotcreted concrete to adhere to.

Once all demolition and surface prep were complete, we used a grid pattern of piano wire to establish a finished plane in both the vertical and horizontal directions. This step was critical in ensuring the finished shotcreted surfaces would align with existing dimensions of the building. The piano wire was secured with fiberglass rebar that was doweled into the tilt-up panel concrete and epoxied in place. Since everything would be covered with the brick panels later, and because fiberglass is non-corrosive, we simply cut the bars flush with the finished shotcrete surface upon completion.

The vertical piano wires were set at slightly under 4 ft (1.2 m) widths. Our finishers then followed the wires with their finishing rods to assure the wall tolerances were maintained. Experienced shotcrete finishers can cut to a wire without pushing the wire into the freshly placed shotcrete material. The horizontal wires were run behind the vertical wires to help support them, as they were 40 ft long. The horizontal wires also allowed us to gauge the left to right tolerances of the structure.

It sounds simple on the surface, but the undulation of the substrate was substantial. Imagine floating 100 4 ft x 8 ft (1.2 m x 2.4 m) panels of insulating foam boards on a

Fig. 4: Highly tensioned piano wire used as thickness guides. Wires are held in place with fiberglass rebar, doweled into tilt-up panel concrete and left in place but cut flush with the finished surface.

Fig. 5: Wavy foam molded tilt-up concrete substrate, undulating up to 2.5 in. in any direction.

lake with boats driving all around and being able to freeze them in place with the push of a button. Then pour concrete on top of that. You can imagine the undulation we were up against: Any given area of 4 ft x 8 ft was tilted at some degree differently than the adjacent 4 ft x 8 ft spaces. This highly irregular pattern encompassed the entire length of the building. Though I was never told the source of the original cladding failure, I can imagine that it began with something as simple as the anchors not reaching far enough into the tilt-up panel substrate because of the undulation.

Overall, there were approximately 6000 ft^2 (560 m^2) of walls to correct, while working entirely from man lifts. All walls were 40 ft high and had windows and doors which could not be removed, presenting even more unique dimensional challenges regarding our finish tolerances. The window and door openings had been cast in the original wall panels so their flanges matched the adjacent surfaces prior to demolition. We had to 'cheat' the lines and 'bend' the shotcrete placement to match while honoring the allowable 0.25 in. in 10 ft tolerances mandated by the brick cladding company. To add insult to injury, the brick plinths at the bottom of the wall were staying and the top of the walls were as much as 2.5 in. out of plane left to right or out of plumb top to bottom. It was quite the puzzle, but we managed to provide the desired 0.25 in. tolerance over 40 ft for the majority of the project, much better than the 10 ft requirement.

Fig. 6: Smooth steel trowel and sponge float used to finish concrete beams for a precast look and feel.

Having areas with as little coverage as 0.5 in. and as much as 2.5 in., we could not include any wire or steel reinforcement. Instead, natural jute fibers were included in the dry-mix concrete mixture which was produced by our volumetric concrete trucks. These fibers helped to reduce rebound and provide internal curing of the thin sections because of their hydrophilic nature. They also helped 'hang' the extensive areas of concrete we were spraying.

The aggregate choice was a blend of a coarse natural sand and a washed granite screening. It met an ACI 506 gradation No. 1, with the largest aggregate passing a 0.375 in. (10 mm) by 100% and 2% retained on a #4 screen with 12% retained on a #8 screen. This made for a smooth wood float finish as prescribed by the coating company that would follow our work.

Another unique challenge presented was in dealing with the precast decorative concrete beams left in place at the top of the walls. It was clear upon close evaluation that not only did they make alignment of the finished surfaces difficult, but they could soon crack and fall down. Replacing them with new precast units would delay the project by 6 months or more, so we offered to remove them and replace them with shot-in-place, hand carved beams in a fraction of the time and for a fraction of the cost compared the precast

Fig. 7: Removing the decorative concrete beams, with equalized anchor points, by crane. Once under tension, the workers could pry the cracked beam off the safety bolts. The beams were then lowered into a dumpster with minimal effort. No pieces were dropped to the ground below.

alternative. The availability of this option for the distressed beams exemplifies the true flexibility of shotcrete.

The first obstacle in replacing the beams was to remove them. We were not contracted for demolition, but found ourselves jumping in to help meet deadlines. The existing beams were fragile, 40 ft in the air and had apparently been bolted in place by the demolition crew to stay in place. It was clear that any wrong move could cause these 20 ft (6 m) long beams to fall to the ground. We had to remove them between classes and surgically, so we employed techniques used in high-angle mountaineering and rescue to secure the beams as whole structures, then carefully cut the bolts and released them to a crane, where they were placed in a dumpster to be hauled off. The whole process went so well that it left little more to tell.


Fig. 8: Finished walls after cladding

Working with the engineer on the project, we then proposed doweling the substrate with fiberglass rebar and reinforcing the ornamental elements with fiberglass rebar. The bottom of these elements were formed to provide us a beveled edge to shoot to and minimize fallout waste on the newly shot walls. The beams were shotcreted in place and carved to the finished tolerances. Finishers using a steel trowel and sponge float created a more refined, smooth finish to closely emulate a pre-cast product.

Though all parties made a valiant effort to get the project done by the original deadline, invariably, delays prevented us from starting prep or shotcrete until after the start of the school year. This created a most interesting element of the project, in working around young children, parents in school pick-up lines, teachers, and after school sporting events. It was a dance, to say the least. We would find ourselves moderating noise levels between math and science classes, stopping work for children to walk from indoors to an outdoor classroom, and managing safety during children being dropped off and picked up, which was right where we were working. Anyone who lives near a school or has small children knows what that looks like!

With all these obstacles, we finished on budget and within our extended allowed time, even with the added scope of the concrete beam replacement.

We completed the shotcrete work in 9 days, considerably faster than any other option. This project truly highlights so many of the virtues of the shotcrete process: We can adapt to non-uniform shapes while creating unique shapes of our own, work with little or no formwork, and adhere to vertical surfaces with nothing to help hold the fresh concrete in place. We can start and stop while working around various obstacles or for adverse weather. We can use basic concrete materials that are equal or superior to factory-created features and at a fraction of the cost. And we can do all that really fast!

2024 OUTSTANDING ARCHITECTURE | NEW CONSTRUCTION PROJECT

Project
Math, Science & Shotcrete

Project Location
Holly Springs, NC

Shotcrete Contractor
Revolution Gunite*

Architect/Engineer
Dewberry Engineering

Materials Supplier
Revolution Gunite*

General Contractor
Progressive Contracting

Owner
Wake County Public Schools

**ASA Sustaining Corporate or Corporate Member*

***Ryan Oakes** is President of Clearwater Construction Group, Inc., Revolution Gunite, and Revolution Pool Finishes, all of which are award-winning firms in their respective trade. As Technical Director for Revolution Gunite, he continually aims to raise the bar in the shotcrete and construction industry. Oakes is a member of ACI Committee 506-Shotcreting, and ACI Subcommittee 506-H-Shotcreting Pools. He also serves as Secretary to ACI Committee 322-Concrete Pool & Watershape Code. Oakes serves as Chair of the ASA Pool & Recreational Shotcrete Committee, a voting member of the ASA Contractor Qualification Committee, and former Board of Directors for ASA.*