Need to Get a Project Completed Efficiently? Employ Shotcrete!

By Ray Schallom III and Randle Emmrich

The foundation work for the Baltimore Hilton Convention Center Hotel, Baltimore, MD, began in 2006. The hotel is located across the street from the Oriole Park at Camden Yards baseball stadium and a couple of blocks south of the busy Inner Harbor area. The developers were the Baltimore Development Corporation for the Baltimore Hilton Convention Center Hotel. The project experienced significant delays in work leading up to the foundation wall placement that triggered a search for time-saving construction alternatives to the original construction plan. The wet-mix shotcrete process was chosen over cast-in-place, and the resultant one-sided form method saved both schedule time and money.

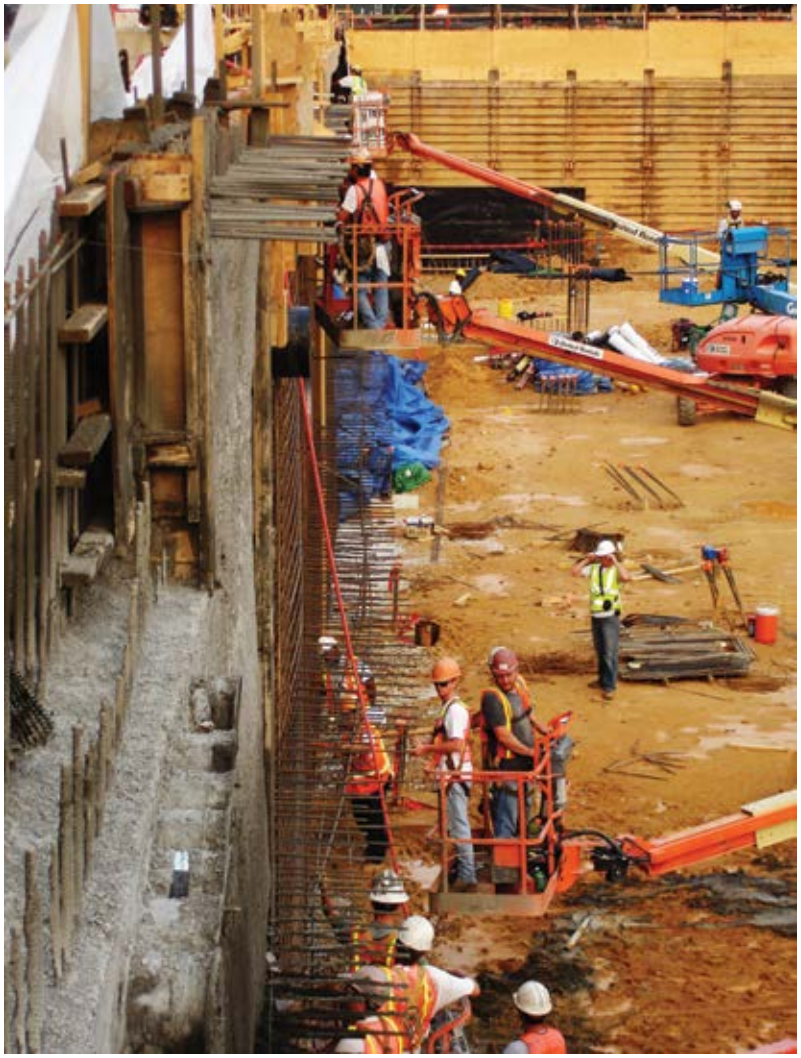

Fig. 1: Lagging and steel I-beam piles with soil anchors. Waterproofing installers and reinforcing bar crew working just ahead of the shotcrete crew

The backside of the wall consisted of drilled I-beams with soil nail anchors and wood lagging placed between the beams to restrain the loose earth behind the wall. Deep-drilled reinforced piles were located every 20 ft (6 m) along the perimeter of the new foundation wall and under each column area in the bottom floor of the excavation. The pile drilling operation had many delays, which pushed the scheduled start for all other work back by several months.

The delays leading up to the foundation wall installation included the wall waterproofing, pipe and duct work blockouts, and reinforcing bar installation. Before this project, all building foundations in Baltimore had been formed and cast with concrete. The original drawings called for two-sided, conventional cast-in-place concrete formwork. Hensel Phelps Construction Company, the general contractor, familiar with the wet-mix shotcrete process from their West Coast projects, proposed shotcrete to the owner and design team as a viable solution to recoup the lost time in the schedule. It took some convincing before the developer and design team agreed to use the shotcrete process over cast-in-place concrete. However, once the use of shotcrete was approved, bids were sent out to several shotcrete contractors. Coastal Gunite Construction Company (Coastal) was chosen for the project. The construction team then initiated the submittal process. Having no one on the design team with wet-mix shotcrete foundation experience made approving submittals a challenge for Coastal and Hensel Phelps.

Fig. 2: (a) The corner of this photo was the starting point for shotcreting; and (b) one of the biggest challenges faced was the wall reinforcing steel moving out 4 in. (100 mm) by the weight of the shotcrete

Fig. 3: Mockup with waterproofing—one of many reinforcing bar and waterproofing configurations Coastal faced. The blowpipe operation was key to keeping the rebound, overspray, and water out of the wall sections

The project's testing firm retained Consultant Ray Schallom to train their inspectors on the proper application of wet-mix shotcrete. Several meetings were required to establish and identify which ASTM test documents were to be used and who was paying for the tests specified by the structural engineer. Two different mockups were built with different wall layouts to evaluate shotcrete placement on lagging waterproofing. The mockups were set up to show the performance of waterproofing strips when shooting stopped for the day and commenced later. Another preconstruction test examined how much water could be sprayed on the waterproofing before it would activate. The mockups also allowed the owners to see what their foundation would look like after it was shot and finished.

One would think having most of the designers present in the weekly project meetings would have made getting the shotcrete submittals approved on a timely basis easy. Unfortunately, this wasn't the case, and approvals often took longer than expected. When the submittals were finally approved, Coastal shot and finished the preconstruction panels. The shotcrete crew had to wait to install the grade wires, check the tightness of the reinforcing bars, and set up the equipment while drain tile was installed under the new wall reinforcing steel. To make it even more difficult, the bentonite waterproofing could not be installed until the day of shooting wet-mix shotcrete. Wetting down the reinforcing bars was challenging because too much water would activate the bentonite waterproofing material.

There were hiccups along the way with concrete quality control (QC) issues including temporary shutdown of the shooting operation, much to the displeasure of Hensel Phelps' Superintendent. The ready mix concrete supplier's QC personnel, Hensel Phelps' Project Engineer, Coastal's Superintendent, and both inspectors drove to the concrete plant to try and determine what had gone wrong with the concrete. As it

Fig. 4: Large ballast rock caught on the grate. The smaller pieces that managed to slip through the grate caught in the reducer

Fig. 5(a) and 5(b): Congestion in front of the next wall sections to be shot

turned out, the loader operator had dug into the ballast rock below the sand with his bucket and contaminated the entire sand pile.

Thus, the concrete was delivered to the site with the large ballast rocks that caught on the wet-mix pump grate. The smaller rocks that made it through the grate hung up in Coastal's 2 in. (50 mm) shotcrete line. Other cast-in-place concrete projects going on down the street were using concrete buckets and didn't notice the problem. The batch plant concrete was quickly adjusted and a test load of concrete was batched for Coastal to shoot on the wall. When the concrete went through the system with no additional pumping issues, it was decided to bring the concrete from another plant for better QC of the concrete and safety of the shotcrete crew.

This now posed an issue of the 90-minute placement window. The plant with the contaminated sand pile was only 10 minutes away while the other plant was 30 to 45 minutes away without traffic. Master Builders (now BASF) was consulted to provide admixtures that could extend the truck delivery time and give Coastal the 90 minutes to shoot the shotcrete on-site without rejecting the truck. Master Builders supplied Delvo ESC pucks (hydration control additive) to delay hydration of the concrete to gain the extra concrete delivery time without jeopardizing the quality of the concrete. The Delvo ESC pucks made it easy to field-mix in the truck (one puck equates 1 hour for 1 yd^3 [0.76 m^3] of hydration control in the truck). This would cover the delivery time and give Coastal at least 90 minutes to empty the truck.

The next challenge on the project was to tie and anchor the reinforcing bars more securely. The first wall section Coastal shot broke the minimal anchors and ties, and the section bulged out 4 in. (100 mm) from the weight of the shotcrete. Fortunately, that wall section was at the stairwell and did not interfere with the building structure. By adjusting the grade wires, Coastal and Hensel Phelps were able to reshoot the section to take the bulge out of the wall. This is something that cast-in-place concrete could not do. It was apparent from the bulging problem that the reinforcing bars had to be tied at a much closer spacing as well as increasing the number of wall anchors and ties before the shotcrete operation could proceed (refer to Fig. 2(b)).

Once the shotcrete operation began in earnest, the crew planned to start in one area and work their way around the foundation so that the other trades could follow. Hensel Phelps moved

Coastal a couple of times to shoot in other areas that later would be the scaffold stairwell and the shear wall area. This made it difficult for the reinforcement placing crew and waterproofing installers to stay in front of the shotcrete crew (Fig. 1 shows three crews working side-by-side).

It was also found that the concrete quantities used were not matching the calculated quantities from the project drawings. The drawings detailed the wall as 14 in. (350 mm) thick, while the actual wall thickness measured between 16 and 19 in. (410 and 480 mm) thick on average. The shear wall measurement increased to 200 yd^3 (150 m^3). The transition into the second stairwell ranged from 1.33 to 5 ft (0.4 to 1.5 m) thick with only two rows of reinforcing steel. Adjusting cast-in-place form widths to accommodate these thickness changes would have been extremely difficult and costly. By using the wet-mix shotcrete process, these significant thickness variations were easily accommodated by adjusting the finish grade wires and using an alkali-free accelerator at the nozzle to shoot the thick sections with no sloughing.

Then Hensel Phelps began to push the shotcrete operation to make up time caused by the drilling and QC delays. All the contractors on the job had to work around the pile drilling company, which was still drilling piers and chipping down a few that were cast too high above the floor elevation. Vibration on the reinforcement from the chipping of the piles had to be monitored to prevent disturbing the freshly placed shotcrete.

All shotcrete placement and finishing was performed out of man lifts to stay ahead of the plumber who was installing the drain tile along

Fig. 6: Different operations on this project were trying to get in and work making it difficult to perform the shotcrete placement while staying out of everyone's way

Fig. 7: Keeping the walls and reinforcing steel wet in front of the shotcrete was a challenge so as not to activate the bentonite waterproofing or create a muddy mess for the equipment to drive on

Fig. 8: Tight working conditions Coastal had to work in daily to allow other trades to work. The wall waterproofing and reinforcing bar installation had to stop due to the dirt ramp that was in the way. Spraying water on the walls made a muddy mess and had to be dug out, replaced, and compacted before any equipment could be driven over it

Fig. 9(a) and (b): Finished wall with the floor waterproofing being installed, and the same wall after it was finished

the wall. Piping was also being installed into the floor area along with the floor drain pipes. This made pre-wetting the walls prior to shooting and water curing the newly placed shotcrete a problem for other site work. The exposed soil in front of the wall would hold the water, leaving a muddy mess and making it impassable for equipment and crews until it was drained or replaced.

Even with all the challenges and delays faced by Coastal on this wet-mix shotcrete project, they managed to gain back most of the excess time used by the pile drilling company and the QC issues. Overall, about 4 months of schedule time were recovered along with significant cost savings by using shotcrete instead of cast-in-place concrete construction.

In conclusion, logistics, schedule time, and costs played key roles in the selection of the wet-mix shotcrete process over conventional cast-in-place construction. You may also want to check out many previous articles in *Shotcrete* magazine's archives (**http://shotcrete.org/pages/archive-search/archive-search.asp**) on sustainability. Before selecting your contractor, make sure they are a qualified shotcrete contractor who has an experienced qualified crew with ACI Certified Nozzleman.

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Fig. 10: Finished wall with other trades stockpiling gravel for the floor installation following right behind

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