Differences and Similarities of Shotcrete Specifications

By Cathy Burkert

In my years of working as a shotcrete contractor in the state of Illinois, the Department of Transportation (DOT) has revised the shotcrete specification numerous times. This article will briefly discuss the differences and similarities between the state's previous specification, "High Performance Shotcrete," and its most recently adopted version, "Structural Repair of Concrete." Even though both specifications have the same expectancy—to repair concrete using the high-quality shotcrete method—they differ in ways that are both beneficial and detrimental to the shotcrete industry.

Overview

In June 1994, the Illinois Department of Transportation (IDOT) adopted the "High Performance Shotcrete" specification. Other sister state agencies, such as the Illinois Toll Highway Authority and the city of Chicago, also soon followed in the adoption of this specification. Unfortunately, most agencies did not often list this item for concrete repair on projects but instead used a formed concrete repair specification. The previous specification for formed concrete repair had no procedure for the placement of concrete. As a result, contractors were using "bird's mouths" on forms and pouring concrete in by bucket. On many repair projects, the agencies would have clearly benefited from using the shotcrete process rather than the form-and-pour method. In my experience as a contractor on various projects, we would occasionally submit the shotcrete process for consideration, especially in difficult placing areas such as overhead repairs. These agencies had previous poor experiences with gunite (dry-mix shotcrete) and did not feel that shotcrete was as good as formed concrete repair. Problems with poor-quality gunite were predominant at a time when sand and cement were site-mixed before the widespread availability of prebagged materials, and there were resultant failures due to poor-quality control of mixture proportions. Problems also arose from unqualified contractors who didn't really know shotcrete. These contractors attempted to place shotcrete using inadequate equipment, untrained nozzlemen, and improper curing, which resulted in poor-quality shotcrete.

Twelve years later, in March 2006, with much more knowledge, confidence, and information about the wet-mix shotcrete process, IDOT, followed by their sister agencies, adopted a new specification—"Structural Repair of Concrete." This specification combined both formed concrete repair and the wet-mix shotcrete process, allowing the contractor to choose the method of placement for the project.

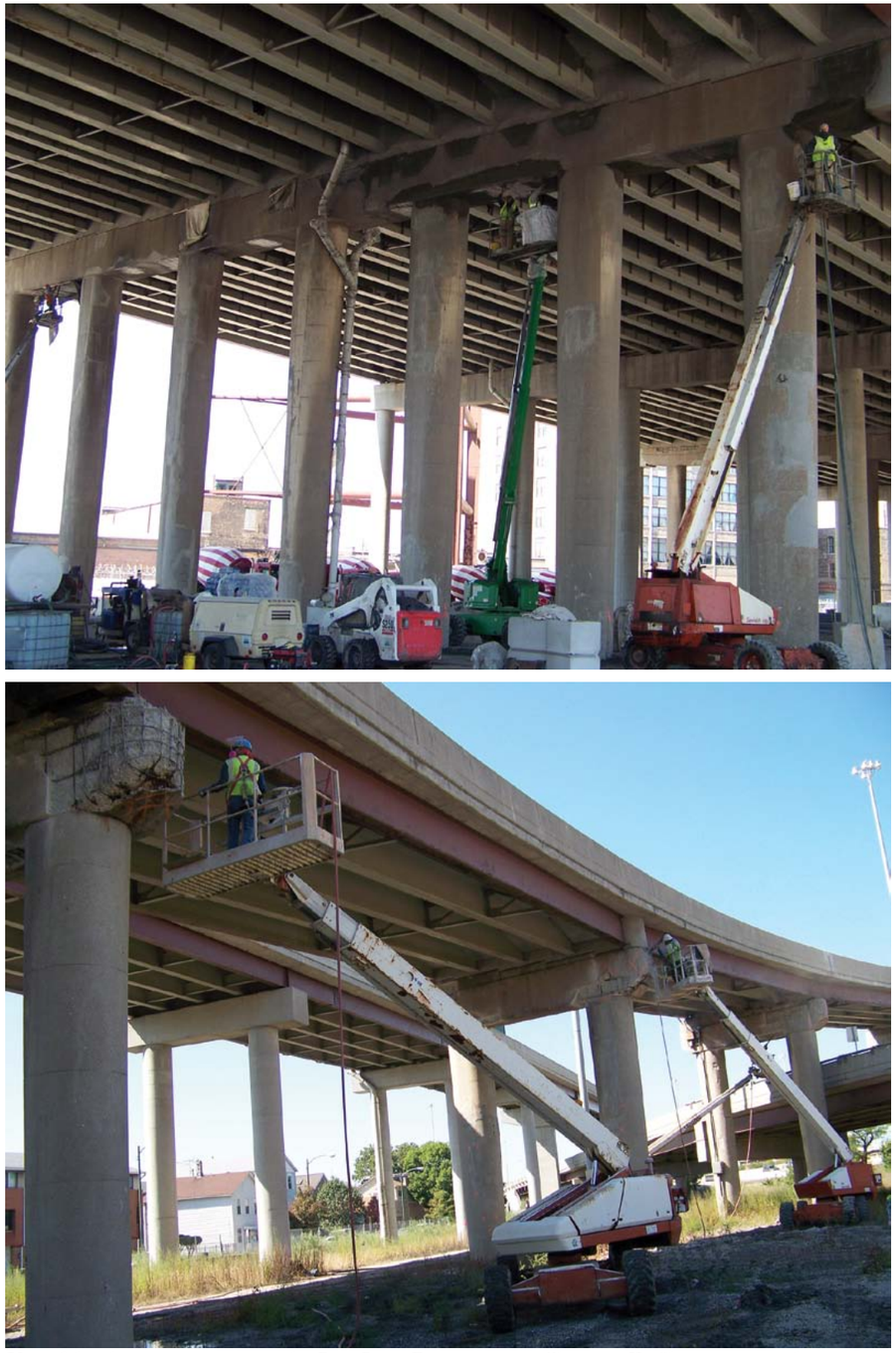
Contractors primarily choose to use the wet-mix shotcrete process over the form-and-pour method for its advantages in green building, safety, and quality. Shotcrete has the inherent ability to minimize or sometimes eliminate the use of formwork, saving lumber or steel and the energy to manufacture, transport, and dispose of the formwork at the end of the project. Shotcrete delivers a freshly mixed concrete material on a consistent basis to properly encase the reinforcing steel. Contractors also have the benefit of touching the receiving surfaces only once and not having to revisit them to strip forms, fill holes, grind, and so on. The energy savings from the use of shotcrete versus the form-and-pour method is significant. For more information on the sustainability of shotcrete, go to the ASA Web site's Sustainability page (**www.shotcrete.org/sustainability.html**).

Contractors also use shotcrete for safety reasons because the air and water hoses used in shotcreting offer considerably less risk than manhandling formwork and scaffolding at different elevations. In addition, if concrete placement is interrupted in the middle of casting a patch area, instead of having to remove the form and prepare the green concrete for subsequent casting, the use of shotcrete placement merely requires a light water- or sand-blasting of the area. The shotcrete process also allows for a visual inspection of the encapsulation of the reinforcing bar, whereas pumping blind into a closed form can easily result in honeycombed concrete or concrete with voids.

The following are a few of the significant changes the state of Illinois has made to their concrete repair specification to ensure a high-quality repair.

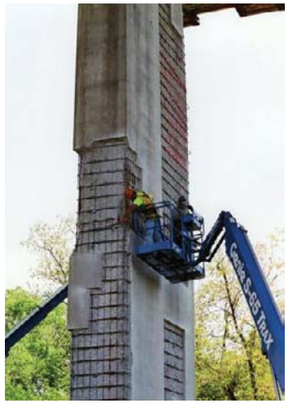
Contractor/Nozzleman Qualifications

The American Concrete Institute (ACI) and its primary sponsoring group, ASA, established the Shotcrete Nozzleman Certification program in 2000. The current "Structural Repair of Concrete" specification only requires the shotcrete personnel performing the work to have a current ACI nozzleman certification for vertical and overhead wet-mix applications. The previous specification, "High Performance Shotcrete," did not require the nozzleman to be ACI-certified for any work—instead, the shotcrete contractor and the shotcrete nozzleman had to have a minimum of 3 years of experience and were required to submit a list of five projects similar to the work being performed.



Use of the shotcrete process on the Dan Ryan Expressway in Chicago, IL. Shotcrete was chosen over the form-and-pour method for its advantages in green building





Use of the shotcrete process on the Abraham Memorial Bridge in LaSalle, IL. The contractors chose the shotcrete process following the IDOT "Structural Repair of Concrete" specification

The project experience submittal required the nozzleman to provide a list of project names, owners, the general contractor's name, the name of the owner's representative, addresses and telephone numbers, a brief description of the work, the total cost of the shotcreting portion of the project, the date of completion, and the equipment used. In the interest of quality, the state should have adopted the proof of contractor experience in addition to nozzleman certification because shotcrete is a specialized construction process and requires years of experience and, as we are all aware, a nozzleman is only one person on a trained crew.

Material

The "Structural Repair of Concrete" specifies a prepackaged, preblended, IDOT-approved dry combination of materials, in which the contractor adds only water on site. The prebagged shotcrete mixture provides a more regulated process, delivering material with consistent mixture proportions. The old "High Performance Shotcrete" specification only required a 3.5:1 (sand:cement) mixture, with a prepackaged dry combination of enhancer/admixture to be combined on site with the water used to hydrate the shotcrete. The difference can be compared to making a cake. Instead of making a homemade cake, where you add your own flour, sugar, baking soda, and so on, now contractors just purchase a "pre-boxed" mixture. Although the expense can be higher, they are more certain to get the appropriate amount of each ingredient.

Surface Preparation, Product Placement, and Curing

While both specifications required the removal of all loose and unsound concrete, followed by sandblasting of the exposed area and reinforcing bar, the new specification further requires a saw-cut edge and strict time limits for placement. Additionally, the "Structural Repair of Concrete" specification clearly states that "formed concrete repair shall not be used for overhead applications." Thus, only shotcrete is allowed when overhead repairs are needed. Both specifications discuss the necessary requirements for placement during hot and cold temperatures, but the new specification now mandates the use of wet curing with cotton mats, except on overhead applications, where the use of a curing compound is permitted. The old "High Performance Shotcrete" specification simply required curing to be done according to the manufacturer's recommendation. The new specification also references ACI 506R, "Guide to Shotcrete," which provides a great deal of additional information on the materials, properties, and application of shotcrete. As the guide states, "the best method for curing is to keep the shotcrete wet continuously for 7 days" to fully develop its potential strength and durability. The current "Structural Repair of Concrete" specification requires coverage of the freshly placed shotcrete with cotton mats or application of a curing compound within 10 minutes. The old "High Performance Shotcrete" specification suggests that, if the use of wet curing is chosen, "The Contractor shall begin curing operations as soon as the Shotcrete has hardened sufficiently to prevent marring the surface."

A time limit is necessary, but it seems impractical to shoot a large-sized patch and finish the patch within 10 minutes. Ideally, the specification should be revised to address the need to prevent plastic shrinkage cracking with either an evaporation retarder or misting within a short time frame (10 minutes may still be too short), and then allowing the 7-day wet curing (used to delay drying shrinkage) to proceed once a later section is ready.

Testing

Although both specifications require an 18 x 18 x 3.5 in. (450 x 450 x 90 mm) test panel to be shot daily, the compressive strength requirements have changed from being tested and producing minimum compressive strengths at 3, 7, and 28 days (3000, 4000, and 5000 psi [21, 28, and 35 MPa]), respectively, to a 14-day test result (4000 psi [28 MPa]). Requiring 4000 psi (28 MPa) at 14 days will generally produce a compressive strength of 5000 psi (35 MPa) at 28 days with most properly designed shotcrete mixtures. In addition, the new "Structural Repair of Concrete" specifies that an air content test be taken from the end of the nozzle tip prior to placement with a measurement of between 4 and 8%. This helps verify the actual air content in the shotcrete being applied to the structure and is called the "as-shot" air content. The as-shot air content can be tested either by shooting and filling up the air content meter or by scraping shotcrete off the freshly shotcreted surface. The as-shot air content generally drops to a level of 3 to 5%, regardless of the air content before the concrete enters the shotcrete pump. This even occurs when an air-entrained agent is used in the shotcrete with as-batched air contents as high as 10%. It should be noted, however, that this test can only be used for nonaccelerated shotcrete.

Conclusion

As new information and technology on shotcrete becomes available from both ACI and ASA, the state of Illinois has revised its concrete repair specification as needed. As a shotcrete contractor, we have successfully placed shotcrete following the new "Structural Repair of Concrete" specification on numerous structures throughout the state of Illinois. In 2008, we repaired over 24,000 ft^2 (2230 m^2) on the Abraham Lincoln Memorial Bridge in LaSalle, IL, and received the 2008 ASA Award for Infrastructure Project of the Year and the IDOT Bridge Rehabilitation Contract of the Year. In 2009, we repaired over 21,000 ft^2 (1951 m^2) of shotcrete on the Dan Ryan Expressway and received the 2009 ASA Award for Infrastructure Project of the Year. The shotcrete solution resulted in a long-term, affordable repair.

While IDOT's specification for "High Performance Shotcrete" is obsolete and should no longer be referenced, the current "Structural Repair of Concrete" specification can be found on IDOT's Web site at **www.dot.state.il.us/bridges/GBSP53.pdf**.

Cathy Burkert *received her bachelor's degree in business management and thereafter started working at American Concrete Restorations, a Chicago-based shotcrete contractor. She joined the laborers' apprenticeship program to learn the intricate details of the trade. After 2 years in the program, she began running her own shotcrete crews and shortly after earned the title of Field Office Coordinator. In March 2009, Burkert became the first female ACI-certified nozzleman for the wet-mix, vertical, and overhead processes. Burkert has been involved with two ASA infrastructure award-winning projects: the Abraham Lincoln Memorial Bridge in 2008 and the Dan Ryan Expressway in 2009.*