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Shotcrete Reborn

(Part II of a III Part Series)

When its originators surrendered control of the shotcrete process in the 1950s, the approach fell on hard times. As the authors discuss here, however, it has since recovered and has resumed its rightful place among the world's key construction technologies

By Lily Samuels and Bill Drakeley

The years after the Second World War were times of opportunity and awkwardness in the shotcrete business.

From 1920 until the early 1950s, the Cement Gun Co. owned the trademark to "gunite" and established an aggressive licensing/franchising system to maintain as much control as it could over the process and profit from it to the greatest possible degree. By 1952, however, the Cement Gun Co. decided to release the trademark.

This enabled the American Concrete Institute (ACI) to dig in and study the process, which by that point had become extremely popular as a construction technology. From that point, the name of the process began to shift to "shotcrete," a nominal change that was most significant because it was a step away from the old "gunite" trademark.

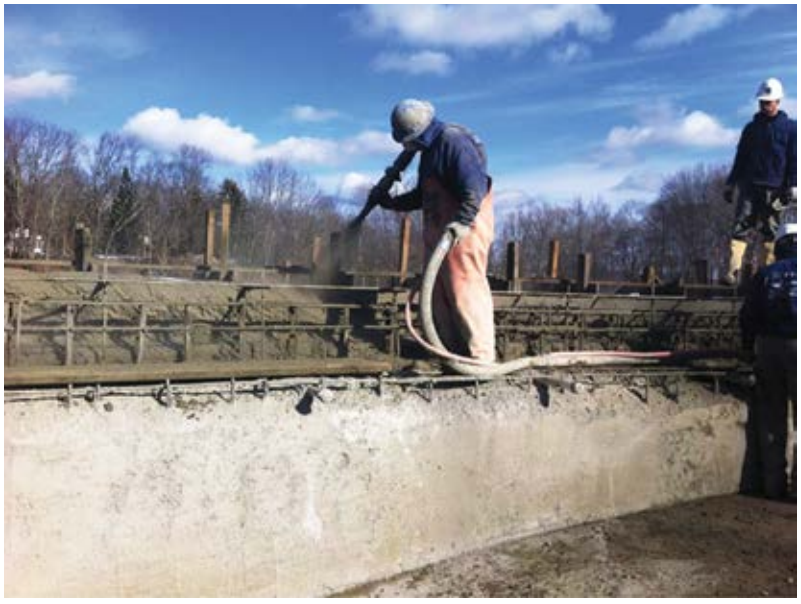

Fig. 1: ACI Certified Nozzleman applying wet-mix shotcrete

In the first installment of this three-part series (*Shotcrete* magazine, Summer 2015, pp. 22-24), we described the genesis of the shotcrete process, starting with Carl Akeley's ingenious invention of a pressurized, double-chamber "gun," and moving on to Samuel Traylor's acquisition of both the gun's patent and of the Cement Gun Co. in Allentown, PA, near the heart of the emerging cement industry. We then described the explosive growth of the use of the company's proprietary dry-mix "gunite" and its ongoing, tight control over technologies and techniques.

The end of the Second World War was the turning point. As we'll see in this installment, changes in America and the industry had lasting effects on shotcrete—for better and worse—that continue to be played out today.

Trying Times

As it turned out, the Cement Gun Co.'s release of the trademark also facilitated the proliferation of contractors attempting the shotcrete process without any in-depth knowledge of how it should be done.

In essence, any contractor with a hose and a cement gun could market him- or herself and the product as being original "gunite," no matter how extensively they departed from the established standards for the method. The word "cowboy" was often used to describe these lone contractors, a large percentage of whom were using the method to build swimming pools.

As time passed through the 1950s and on until the ’80s, novice (but high-volume) contractors kept entering the field having little or no exposure to the original quality control guidelines enforced by the Cement Gun Co. From the early 1950s on, those rigorous procedures were effectively and increasingly watered down. By the early ’80s, the company’s standards, data, and documentation were little more than a memory among a few old-timers who had managed to stay active. It was not, in sum, a good situation.

In addition, a geographical divide soon emerged as some of the “original” gunite contractors on the East Coast became increasingly suspicious of the newcomers out West, where shotcrete was just beginning to gain traction. The perceived need to preserve a competitive edge created an environment in which knowledge sharing and discussion of best practices in the American shotcrete industry effectively ceased.

Without standards or guidance, much began to slip: Quality was sorely lacking in many installations, and the former field workers who’d risen in the business and were now owners of their own companies rarely understood what went into “good” shotcrete application.

Even today there are contractors who still have not embraced proper practices. As we’ll see in the following, a whole range of substandard methods emerged in these difficult years that threatened the reputation of the shotcrete process as the 20th century entered its last years. To this day, in fact, directly addressing and effectively contradicting poor shotcrete application is one of the primary purposes of both the American Shotcrete Association (ASA) and ACI.

Best Practices

What are those standards? Why are they so important?

Water-Cement Ratio

Let’s start with proper mixture design and its key component: the water-cement ratio. In a good mixture design, you’ll typically find a water-cement ratio of 0.35 to 0.45 (0.30 is a good lower boundary for dry-mix shotcrete). The binder in this mixture—that is, cement paste—is portland cement. If a contractor wants to cut costs and carries no claims to pursuing quality, he or she will increase the water content of the mixture while reducing the volume of portland cement. The use of this “water of convenience” and reduction in cement leads to substandard results and a cheaper product in more ways than one.

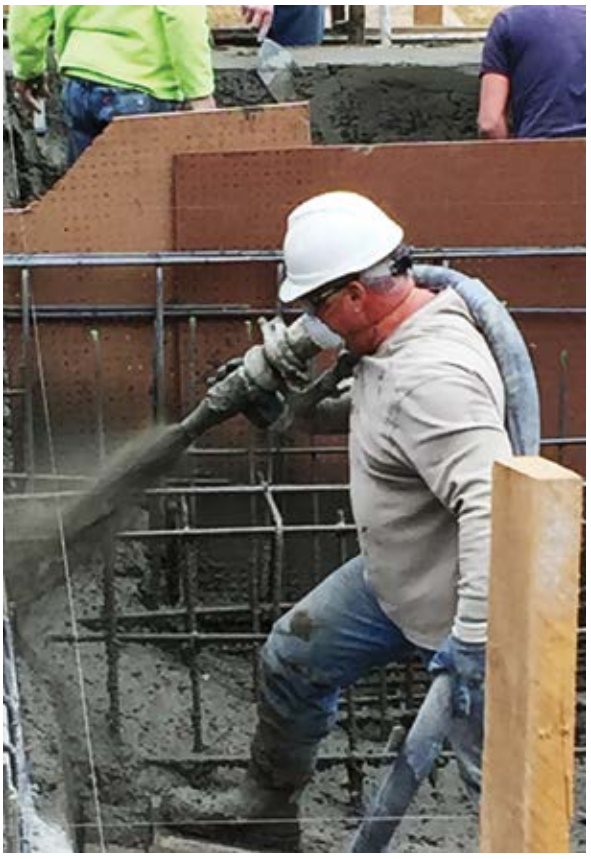

Fig. 2: Nozzleman works in tandem with other trained crewmembers to ensure a successful application

Use of Aggregate

As another example, let’s consider the ratio of aggregate (sand, gravel) to the cement paste/binder: minimally, there should be four parts of aggregate to one part cement—and, ideally, a three-to-one ratio. Cost-cutting contractors (and sometimes even engineers) will alter that ratio to five to one or even six to one, using lots of aggregate and minimal cement paste. Using this questionable cost-cutting model, the production of rebound and overspray inevitably increases—and these jobs are executed well below the specifier’s original expectation for material composition and strength.

Rebound and Overspray

Many of these substandard operators also use the rebound and overspray as “filler” in the concrete structure. Rebound and overspray are worthless—binder-free material that has bounced off the receiving substrate. Using this material in any way fundamentally weakens the concrete wherever it is used.

Fig. 3: Shotcrete sprayed at proper velocities results in compacted material with well-encapsulated steel reinforcing bar

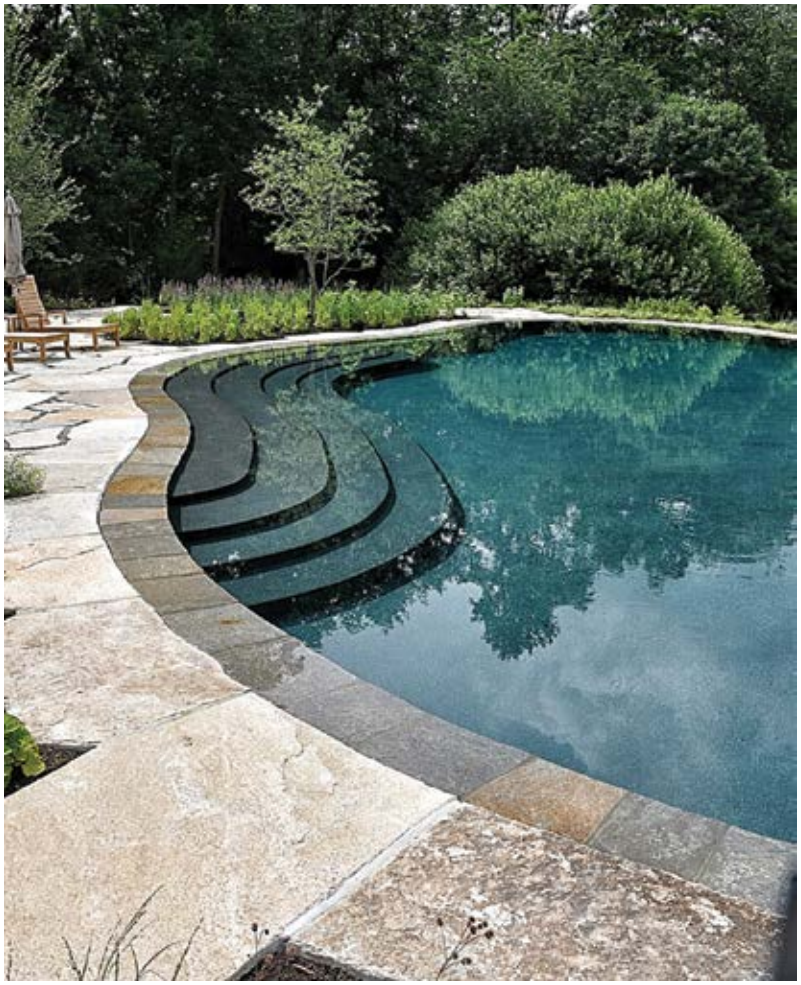

Fig. 4: A free-form pool with a perimeter overflow edge and complex step detail is executed with the shotcrete process

When proper practices are pursued in the dry-mix process, one member of the crew will pre-dampen the dry material when using pre-bagged concrete mixtures to reduce dust and waste while another is normally stationed alongside the nozzle operator to gather and shovel away any rebound or overspray. This clears the way for application of high-quality, paste-rich concrete material to build out the structure.

The fact is, however, that the ignorant or unscrupulous contractor will save a great deal in labor and materials by skipping these crucial steps. The in-place material may incorrectly be said to conform to the norm or the standard, despite the fact that best practice would definitively classify the end product as substandard.

Curing

Another prime example of broad-scale deviation from good practice that cropped up on the 1950s (and persists in some quarters to this day) is the ill-advised tendency some contractors have to skip the curing step. Even in today's shotcrete industry, there are contractors who have apparently never been introduced to this concept or have an imperfect understanding of its importance.

Beyond question, curing is among the most important factors involved in ensuring proper strength gain in concrete. The key is maintaining an adequate level of surface moisture: This prevents evaporation of the mix water from within the hydrating concrete, allowing the chemical processes that are taking place between the water and the cement to continue and increase strength gain.

Without a wet cure or the use of a curing agent, the hydration process will halt early, and the concrete will often not reach its target strength. A properly cured structure with proper concrete mixture proportions, for example, will easily attain compressive strength values of 5000 to 6000 psi (35 to 41 MPa). The same structure, uncured, may not reach half that level.

A Troubled Process

The result of this ongoing lack of proper material selection and application standards was the development of an industry that performed poorly and had a worsening reputation into the 1970s and even into the '80s.

The strange outcome here was the creation of another subtrade of contractors who compensated for the poor performance of shotcrete crews by applying waterproofing materials to concrete

pool shells. In fact, such applications became a new "norm." But those applications should be unnecessary: as we will discuss in the final part of this series, good shotcrete materials, properly mixed, placed, and cured, will be watertight on their own.

Through it all, however, those fortunate engineers who managed to have positive experiences with reputable, knowledgeable shotcrete contractors continued to specify shotcrete as a method of concrete placement and effectively kept it alive. But many more engineers had negative experiences and studiously specified other methods and materials or—and this became the rule rather than the exception—demanded provision of an encapsulating waterproofing membrane over the often-substandard shotcrete material.

Shotcrete Rebirth

Fortunately—and at the same time as the reputation of the shotcrete industry was being profoundly compromised (largely by the misdeeds of pool contractors)—key developments in other areas of the industry were paving the way for redemption.

The emergence of the wet-mix process and development of new pumps and nozzles developed to support the wet-mix approach made shotcrete the ideal method for working in underground environments. In fact, the use of shotcrete in tunnels, mines, and underground infrastructure exploded in the 1970s, giving engineers a different and beneficial set of exposures to the method and lending the process a level of credibility it hadn't seen since the early 1950s.

Test data and documentation began to emerge, and ACI, along with ASA (formed in 1998), began taking the steps needed to produce standards on what it takes to make good shotcrete. This reinvention of the process laid the foundation for the current reputable state of the shotcrete industry—and in the nick of time.

In our next and final article in this series, we'll discuss the current state of the shotcrete industry, some of the challenges it faces, and its future as one of the most versatile construction methods currently available.

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