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SHOTCRETE: WET PROCESS VERSUS DRY PROCESS

BY DENNIS BITTNER

Shotcrete was invented in the early 1900s by American taxidermist Carl E. Akeley by propelling dry material through a hose with water injected at the nozzle to fill plaster models of animals. Soon after, it was discovered that the same method was an effective way to repair buildings. In 1911, Akeley was granted a patent for his invention, originally called the "cement gun," and the shotcrete industry was born.

ACI 506R[1] defines shotcrete as "mortar or concrete pneumatically projected at high velocity onto a surface." Shotcrete is used in multiple arenas of construction including, but not limited to, repair and restoration, mining, underground and tunneling, refractory, and new construction. The two types of shotcrete processes, dry-mix shotcrete (also known as gunite) and wet-mix shotcrete, have grown steadily in popularity in both concrete repair and new construction. This article will compare and contrast the two shotcrete processes.

Dry-mix shotcrete is defined by ACI 506R as "shotcrete in which most of the mixing water is added at the nozzle." Dry ingredients are placed in a hopper and then pneumatically propelled through a hose to the nozzle. The nozzleman then controls the addition of water manually at the nozzle (Fig. 1). Wet-mix shotcrete is defined by ACI 506R as "shotcrete in which all of the ingredients, including water, are mixed before introduction into the delivery hose and compressed air is introduced to the material flow at the nozzle." In other words, the dry-mix process involves blowing powder through a hose and adding water at the nozzle; wet-mix involves pumping already mixed material to the nozzle (Fig. 2). The main difference between the two processes is the point at which the water is added. Compressed air is introduced at the nozzle during the wet-mix process to enhance the spray characteristics.

PROCESS SELECTION

When selecting a method of placement, the finished product is rarely a determining factor. Other than a few small technical differences, the

Fig. 1: Dry-mix shotcrete being installed on a retaining wall project

Fig. 2: Wet-mix shotcrete installation at dome structure

material is all the same once it hits the substrate regardless of application method. The determining factors are scope of work, availability of materials, availability of equipment, site access, and contractor preferences.

One of the biggest factors in process selection is the scope of work. Each application is unique. Quantity is also a factor. Advances in concrete pumps have allowed for faster placement of wet process material. This higher production rate tends to make the wet process a preference on larger jobs. Many lock and dam, underground, and rail tunnel projects require hundreds, or even thousands, of yards of material placed in large wide open areas. In many of these applications, aesthetics are not a concern and the shotcrete is not given any type of trowel finish, and is left with a natural gun finish. The speed of placement with the wet process is attractive to contractors on these types of projects.

Projects such as bridge pier repairs and parking garage rehabilitation often involve small areas. These areas often require a finish, possibly steel trowel, rubber float, or flash finish. This requires the contractor to stop the shooting portion of the operation to cut and finish the repair. Wet-process shotcrete is not conducive to stop-and-start repairs, as each time the shooting process is stopped, the hose must be cleaned out to remove already mixed shotcrete. In addition, the entire truck must be used at once if using ready mix. Using the dry process, the equipment can be turned off with minimal material waste as the water has yet to be added. This makes the dry process a more popular method for smaller repairs, as well as stop-and-start work.

Mixtures for both processes are compatible with alkali-resistant, polypropylene, macrosynthetic, and steel fibers. Also, both mixtures can be used with a variety of admixtures such as accelerators, integral corrosion inhibitors, and retarders. Therefore, modifying a mixture to job-specific requirements is not generally a determining factor in selection, as both processes provide a large amount of flexibility. Both processes can and generally should be microsilica-enhanced. Microsilica increases the performance of shotcrete in multiple aspects, including enhanced adhesion and improved strengths.

Material availability is another determining factor. The rising cost of trucking has made it important for contractors to source materials as close to the jobsite as possible. Limited numbers of material producers in certain geographic areas may sway a contractor to select a shotcrete method. Also, many projects have green initiatives in place which require contractors to source materials locally whenever possible. In some instances, local available aggregates may be insufficient to meet project specifications. In these cases, contractors are forced to purchase materials from suppliers located greater distances from their location. Advances in mixers have made pre-blended bulk bags of material more popular on remote sites and nightshift work for wet process applications where ready mix is not available or practical.

A contractor's personal preference is also a consideration in selecting wet- or dry-process shotcrete for a project. A contractor who has more experience with one method over the other tends to stick with that method. This allows them to draw on that experience throughout the project. Wet- and dry-process shotcrete requires completely different equipment to install (Fig. 3 and 4). So the type of equipment owned by a contractor obviously plays a major role in the decision making process.

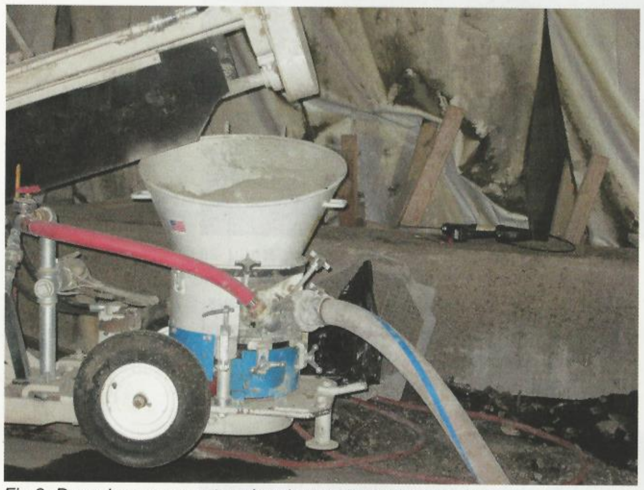

Fig 3: Dry-mix process rotary-bowl type shotcrete machine

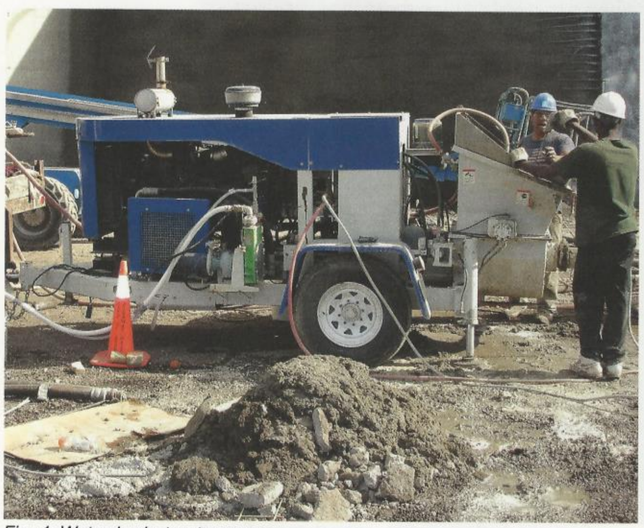

Fig. 4: Wet-mix shotcrete pump

Temperatures will affect curing times of the materials, making it another element in deciding on which shotcrete process is most appropriate for a job. In cold weather, shotcrete does not hang as well, especially in overhead applications. Rebound—material that does not adhere to the substrate at which it is propelled—increases at lower temperatures. In hot weather, the material may require more extensive curing to prevent cracking.

Orientation and depth of shotcrete application are other factors that should be considered. Certain types of overhead locations at particular depths may lend themselves to one process or the other. Some areas are situated in a way that prevents proper nozzeling posture and distance. Sometimes in mining applications, tight conditions require nozzlemen to shoot from their knees, stomachs, and backs at distances either farther away or closer to the substrate than is standard. All of these factors play a part in selecting a process.

SPECIFYING SHOTCRETE

There is an old cliché that says "shotcrete is not a product, it is a process." This is important to remember when specifying shotcrete work. Often, it is best to let projects include both processes at bid time. In an open competitive bid situation, the best method for the application will result in the successful bid. This allows a contractor to use the method that they are most comfortable with, thereby providing the owner and architect/engineer the best opportunity to have a successful project. Some jobs clearly lend themselves toward wet, some clearly to dry. Many jobs do not lend themselves to either method specifically. Some projects have used wet and dry processes simultaneously. Other projects have been phased where one contractor used the dry process while another opted for the wet process, performing the same scope of work with equal success.

As was stated earlier in this article, wet or dry, it's all the same when it hits the substrate. When specifying shotcrete and regardless of the method, it is important that the material supplier is verified that they can meet the performance requirements. For starters, ACI Certified Shotcrete Nozzlemen should be a requirement. In addition, an experience level commensurate to the project on the part of the contractor should be a requirement. On-site material testing must be a part of the project (Fig. 5). Inspectors should have a basic working knowledge of the shotcrete process.

For more information on shotcrete specifications, refer to ACI 506.2[2] and ACI 506.5R,[3] and visit the American Shotcrete Association website at **www.shotcrete.org**. ACI RAP Bulletin 12[4] also provides procedures for shotcrete application.

Fig. 5: Preparation of a shotcrete test panel

CONCLUSIONS

Shotcrete is an excellent repair method when compared to traditional cast-in-place methods. It provides high bond strength, increased compressive and flexural strength, and increased resistance to chemical and alkali attack. It requires little or no formwork, which makes shotcrete traditionally faster than cast-in-place. Shotcrete also offers a myriad of sustainability benefits. Both wet- and dry-mix shotcrete can provide a viable, cost effective, and durable solution for many design requirements.

REFERENCES

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Dennis Bittner *is a Construction Products Representative for The QUIKRETE® Companies. He has been involved in both wet- and dry-mix process projects in multiple arenas of shotcrete construction, with an emphasis on bridge and tunnel projects for State DOTs and the rail industry. Bittner sits on the Board of Direction of the American Shotcrete Association and on the Board of the ICRI Pittsburgh Chapter.*