Top Ten Sustainability Benefits of Shotcrete

The United States Green Concrete Council's (USGCC) book, *The Sustainable Concrete Guide—Applications*, includes a list of the top 10 sustainability benefits of shotcrete in its chapter on shotcrete. Over the next 10 issues of *Shotcrete* magazine, this Sustainability column will elaborate on each one of the listed advantages. Previous discussion of advantages from past issues can be viewed on the ASA Web site at **www.shotcrete.org/sustainability**.

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1. Formwork savings of 50 to 100% over conventional cast-in-place construction.
2. Formwork does not have to be designed for internal pressures.
3. **Complex shapes require very little—if any—formwork** (see below).
4. Crane and other equipment savings or elimination.
5. Labor savings of at least 50% in repair applications.
6. New construction speed savings of 33 to 50%.
7. Speed of repair reduces or eliminates downtime.
8. Better bonding to the substrate, which enhances durability.
9. Adaptability to repair surfaces that are not cost-effective with other processes.
10. Ability to access restricted space and difficult-to-reach areas, including overhead and underground.

Complex Shapes Require Very Little—If Any—Formwork

One of the major benefits of the shotcrete process is that it can be sprayed in place on vertical and overhead surfaces without the need for forming. Most conventional formed and placed concrete uses flat-surfaced shapes, as these are by far the easiest to form. Curved or even just tapered sections may be used in form and cast work, but the formwork is much more expensive to construct in terms of time, labor, and materials.

Using shotcrete allows total flexibility in the finished shape and surface treatment. Variable thicknesses, curves, or virtually any combination of shapes are readily available to the designer to produce the most efficient structure possible with the least amount of materials. Shotcrete construction of structurally efficient, yet complex shapes often provides the added benefits of reduced formwork, quicker completion, and reduced project costs. This is a primary reason shotcrete is routinely used for free-form pools, faux-rock surfaces for fountains and zoo enclosures, and continuously tapered walls for liquid storage concrete tanks. Also, as the finished shotcrete surface is evident immediately when placed, there is no question what the final finish will look like. The finish is limited only by the creativity of the architect or engineer and the talents of the shotcrete contractor.

In dry-process shotcreting, the material is conveyed through the hose in a dry or damp state and water is added at the nozzle. The resulting water content is much lower than one would find in normal conventionally placed concrete. The dry-process shotcrete is gunned in place in what is essentially a zero-slump, pneumatically placed concrete. The shotcrete adheres to both the vertical and overhead surfaces, and because of this, it can be easily gunned in place to conform to complex shapes. The same is true for the wet process, where the shotcrete is pumped and air is added at the nozzle to accelerate the concrete mixture with a high velocity into place. With the wet process, you will have a somewhat higher water content because the material must be of a flowable consistency to be pumped, so accelerators are commonly used. Nonetheless, it conforms to the shapes where it is spray-applied. Both methods place material without the need to form or hold the material in place. This in itself is a tremendous benefit because it eliminates the additional time, labor, lumber, and other forming materials necessary in casting, containing, and supporting conventionally placed concrete.

Shotcrete allows for the quick and efficient placement of large quantities of material. In past years in the steel industry, Treadwell ladles—commonly referred to as "torpedo" or "submarine" ladles—were gunned a few times a week. These are long, tapered, football-shaped ladles mounted on railcars that are used to convey molten iron from blast furnaces to BOF shops. The Treadwell ladles required approximately 20 tons (18 metric tons) of refractory to line and were typically gunned in less than 5 hours. No forming or forming materials were necessary for the shotcrete installation, and the refractory material was gunned in place to conform to the unusual internal shape.

Because shotcrete is sprayed in place, it can easily be placed over irregular shapes and surfaces to simulate natural rock formations. In pool and spa construction, shotcrete is often placed in rounded or kidney shapes. As long as there is a solid surface to shoot against, shotcrete can easily conform to any shape. Building forms for irregular shapes is inordinately labor-intensive and time-consuming and requires a great deal of custom, highly skilled handwork. Lumber, bracing, and support systems also become necessary in forming-and-pouring operations with conventionally placed concrete. Shotcrete is routinely used in concrete repair applications to gun round- or oval-shaped bridge piers for overhead arches, in tunnels and sewers, in domes, and on irregular rock surfaces in slope stabilization or mining operations.

In industrial applications, shotcrete is used for gunning refractory linings in vessels, steel ladles, round electric furnaces, smokestacks, ductwork, and in cylindrically shaped cyclones. There are tube penetration areas in power plants where it isn't feasible to form and pour and where shotcrete provides the only viable method of installing refractory materials. Imagine the additional labor and material costs involved in trying to form and pour 36 cone-shaped burners inside a power plant boiler. With shotcrete, there is no need to custom-cut, -fit, and -form each burner; there is no need to purchase the lumber and build the forms. The shotcrete can be sprayed and contoured to fit the receiving surface; an additional benefit is that any variance in the burners and burner tube spacing can be adjusted with a little more or a little less material.

Sustainability is about conserving resources and eliminating waste in materials, transportation, and labor. When you can remove the forming of complex shapes from the project, many additional benefits go with it. If complex shapes require triple or quadruple the labor to form and cast, then being able to shotcrete the material in place without having to build forms becomes even more important. Reduction of transportation is another sustainability benefit. Eliminating forming materials removes the costs and carbon footprint in the production of the lumber—from tree-cutting and transporting to the lumber mill and distributors and, ultimately, to the job site, not to mention the waste and disposal of the forming materials after the project is completed. There are greater demands for sustainability than ever before and we need to make the most of our available resources. The phrase "time is money" is as relevant today as it ever was, and innovative designs and construction methods that improve efficiency are becoming more and more important to explore.