

Misconceptions about Shotcrete—True Stories from ASA Technical Inquiries

By Charles Hanskat

As Executive Director and Technical Director for ASA, I get the unique opportunity to tackle a number of technical inquiries every month about shotcrete. Over the last couple of years, we've seen a sharp increase in inquiries from engineers, architects, and owners about pool and water feature installations. Likely part of this increase is the publication on our website of pool position statements (www.shotcrete.org/pages/products-services/shotcrete-resources.htm).

A few of these inquiries were simply questions about best practices, but many have resulted from issues during or after construction. These are true stories. Believe me, I couldn't make some of these up.

Inquiry: A pool owner called and asked, "My shotcrete contractor had some delays while shooting our pool. The concrete got too hard to pump through the machine, so they took the concrete out of the truck in wheelbarrows, and then hand packed the concrete into the remaining open spots in the floor, steps, and benches. The contractor said they do this all the time. Is this OK?"

Misconception: Concrete intended to be shotcreted doesn't need to be physically shot.

Fact: Shotcrete by its definition is concrete pneumatically placed at high velocity. These velocities average from 50 to 80 mph (80 to 125 kmh). The energy released by impact of this high-velocity material provides compaction and consolidation of the concrete. Without the velocity and impact of shooting the concrete, alternative methods of consolidation must be used to eliminate voids and densify the concrete. Hand packing of very stiff, unpumpable material does not provide the compaction effort needed, so likely the concrete in-place has random voids and poor bond to adjacent concrete. Overall, these hand-packed sections will have less strength, reduced durability, and because this is a pool—greater permeability.

Inquiry: A pool owner in Arizona called after cracks formed in their new pool shell. The contractor had told them they needed to "water" the

pool twice a day to prevent cracks, which they did, but cracks still formed.

Misconception: Adequate curing of shotcreted concrete surfaces is just dampening the surface occasionally.

Fact: Proper curing means keeping the concrete surface continuously damp. Curing for 7 days is recommended for shotcrete. Wet curing with water is preferred to using spray-on curing membranes. ACI 308R-01, "Guide to Curing Concrete," states "The objectives of curing are to prevent the loss of moisture from concrete and, when needed, supply additional moisture and maintain a favorable concrete temperature for a sufficient period of time." Curing is essential to allow the cement in the concrete to continue to hydrate. Hydration of the cement is how concrete builds strength, reduces permeability, and improves durability. Because shotcrete has a relatively low water-cementitious materials ratio (w/cm) compared to most placed concrete in floors with w/cm of 0.50 or greater, it would benefit greatly from supplying additional curing water. ACI 308.1-11, "Specification for Curing Concrete," requires for wet curing: "Keep the concrete surfaces continuously wet. Do not allow alternate wetting and drying of concrete surfaces." One would expect that the hot, dry, and potentially windy conditions prevalent in Arizona would create high evaporation rates and wetting the pool surface once or twice a day would not provide a continuous supply of supplemental water.

Inquiry: Another pool owner called about cracking in the coves, benches, and steps in their new pool. Investigating further, they found substantial delaminations and voids below the surface in many of these areas. I asked, "Did you watch the shotcreting procedure?" They answered "Yes." I then asked, "Did you ever see any concrete or material shoveled out of the pool?" Answer: "...No."

Misconception: Some shotcrete contractors feel shotcrete rebound and overspray is able to be left in the floor and coves, or shoveled up into the

benches because it will be covered up by a layer of “good” shotcrete and won’t affect the structural integrity or watertightness of the pool shell.

Fact: When shotcrete impacts a surface, the material that bounces off is called “rebound.” This rebound material is mostly aggregate (sand and rock) and much less paste than in the shotcrete mixture design. Thus, rebound material is substantially weaker and more porous than the shotcrete mixture supplied. When rebound is incorporated in any final shotcreted section, one is introducing a layer of weakness within the concrete section. The section will then not act monolithically, as the designer intended; plus, it gives a weak plane in the shell that will encourage cracking and delaminations when the pool is exposed to wetting/drying and seasonal temperature variations. Rebound and overspray must always be removed and not incorporated in any of the structural pool shell.

Inquiry: An engineer working on a large free-form concrete fountain basin called and asked, “Our shotcrete contractor said we needed to use wet-mix shotcrete because dry-mix is porous and needs extra coatings or plastering to make the fountain basin watertight. Is this true?”

Misconception: Dry-mix is more porous than wet-mix, and not acceptable for liquid-containing pools or structures because it would require additional coating to provide the desired serviceability.

Fact: Dry-mix shotcrete produced with quality materials, good mixture design, proper equipment, and experienced nozzle men will produce concrete in-place equal to concrete produced using a wet-mix process. Dry-mix will actually tend to have a lower w/cm . The perception that dry-mix is more porous may occur because dry-mix water content is controlled by the nozzle man. An inattentive nozzle man or inadequate water pressure may allow dry spots in the work. These areas are definitely more porous, but should not be present in quality shotcrete.

Inquiry: Here’s an interesting inquiry: “The plaster color installed in my pool was the wrong color. The plaster has been chipped out. My concern is damage to the shotcrete shell in the process. There are deep holes, gouges, and there was water seepage in a few areas behind the shotcrete. There is also evidence of honey-combed areas in the shotcrete as well as some other shotcrete concerns since reading up on the shotcrete process. I’m being told that they will just plaster over these concerns. However, the plasterer says that plaster thickness should not exceed 7/8 in. (178 mm) thickness, but can be a little thicker around plumbing fixtures (refer to Fig. 1 and 2).

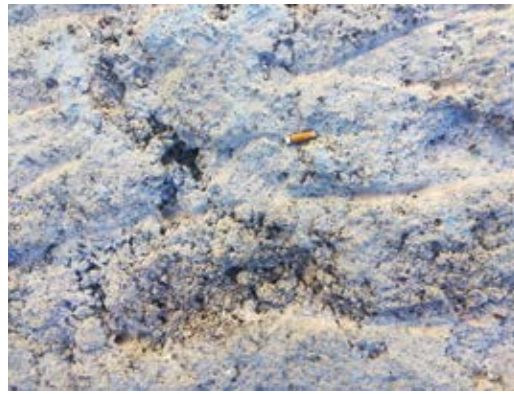


Fig. 1



Fig. 2

Misconception: Shotcrete can be shot rough and without close attention to full compaction because the surface will be covered with plaster and provide the final surface finish.

Fact: ASA has published a position statement, “Watertight Shotcrete for Swimming Pools.” The position statement stresses that shotcrete can and should be built as an essentially watertight structural shell. Further, shotcrete can be finished to very uniform surface tolerances and finishes. A relatively thin, consistent layer of plaster is desired. Properly shotcreted sections should not have any significant voids or sandy, porous, or low-strength sections. From the images, it appears the contractor did not properly place the shotcrete for the pool. Plaster should not be used to fill substantial voids because it has significantly different mechanical properties (strength, thermal expansion/contraction, and shrinkage), and will not provide significant supplemental strength if the shotcreted shell has low strength or porous areas.

Inquiry: “Our pool sat over the winter, and we noticed many areas where the concrete looked sandy or porous. We had cores taken and tested and strengths resulted in 2500 psi (17 MPa). The contract indicated the shotcrete should be 4000 psi (28 MPa). We asked the contractor about the discrepancy, and he said that’s normal. Concrete loses strength over time. Is that correct?”

Misconception: Concrete loses strength over time.

Fact: Concrete usually has a significant amount of unhydrated cement that will hydrate over time. Continuing exposure to moisture and ongoing hydration increases strength, reduces permeability, and thus improves long-term durability. Concrete over 100 years old will still be strengthening. The contractor was wrong in stating concrete loses strength. Also, 2500 psi (17 MPa) is a very low compressive strength and indicates the use of improper materials, equipment, or poor nozzling techniques. ASA maintains that all shotcrete should have a minimum compressive strength of 4000 psi (28 MPa) at 28 days.

Inquiry: I am a structural engineer and we have recently begun work with a shoring contractor. We have been designing soil nails, micropiles, soldier piles, and so on with temporary and permanent shotcrete facings. The contractor has requested that some of our future designs use chain link mesh in lieu of welded wire mesh, particularly in temporary situations with walls under 10 ft (3 m). I understand that chain link is a cost-effective alternative and, according to the contractor, handles the shotcrete great. Is it acceptable reinforcing for shotcrete?

Misconception: Chain link fencing material is adequate for reinforcing shotcrete in underground applications.

Fact: Some mines have used chain link mesh in shotcrete in severely deforming ground and claim that it is better in holding the ground than mesh after large deformations, in which the shotcrete sustains major cracking with deformations. Other than for such unusual applications, we do not recommend the use of chain link mesh in shotcrete. It cannot be fixed “tight” and as such is susceptible to vibration and movement during shooting, resulting in shotcrete sloughing and formation of voids in the shotcrete. Also, the mesh interconnections are conducive to the formation of voids during shooting. Additionally, there doesn’t appear to be any consistent material standards on the strength, flexibility, or brittleness of the steel (or other materials) used in the fencing material, so a designer has no way to establish the tensile or flexural strength of the concrete sections. In brief, don’t use chain link mesh if you want to produce quality, durable shotcrete.

Inquiry: I’ve heard that dry-mix shotcrete is not acceptable for exposure to freezing-and-thawing conditions because it isn’t air entrained. Is this true?

Misconception: Dry-mix doesn’t have good freezing-and-thawing durability.

Fact: Dry-mix has decades of good performance in freezing-and-thawing environments, and should not be precluded from use in those exposures. Air

entraining is just one aspect contributing to freezing-and-thawing resistance. Good air void spacing in the hardened concrete is the key to good performance of entrained air in concrete. Strength and to some extent permeability also affects performance. Because shotcrete generally has a lower *w/cm* than conventional form-and-place work, we experience faster strength gain and achieve higher strength over time. Shotcrete also often uses silica fume, fly ash, and other supplementary cementitious materials (SCMs) that increase strength and reduce permeability. Finally, air entraining admixtures are available for use in dry-mix.

Inquiry: I have heard for the best performance of shotcrete, you should avoid finishing and leave as a gun finish. Is this true?

Misconception: Shotcrete should not be finished because it reduces strength, serviceability, or durability of the concrete.

Fact: Shotcrete can be finished in a wide variety of ways, and has little if any detrimental effect on the strength and durability. However, proper finishing techniques should be used. Cutting and finishing (floating or brooming) by experienced finishers will help to produce sections with a consistent surface and section thickness. However, overfinishing or wetting the surface of hardening concrete (in shotcrete or cast concrete) can introduce microcracks in the surface layer. Also, requiring a smooth steel trowel finish will by its inherent nature bring extra paste and water to the surface, increasing the effective *w/cm* and thus reducing strength of that surface layer. However, this is the result for any cast concrete, and not limited to only shotcrete.

Inquiry: I have been told that I shouldn’t use shotcrete because it will have more shrinkage cracks than my cast concrete walls.

Misconception: Shotcrete will have greater shrinkage cracking than form-and-place walls.

Fact: Early-age plastic shrinkage and long-term drying shrinkage are aspects of all concrete work. Plastic shrinkage cracking results from early, quick evaporation of water from the surface of the plastic, hardening concrete. With shotcrete placement, we will have our finished surface exposed to the air. Low humidity and hot or windy conditions will substantially increase the rate of evaporation. Good shotcrete contractors will evaluate appropriate methods to keep the surface damp and minimize or eliminate plastic shrinkage cracks. Long-term drying shrinkage is related to the paste content, amount and size of aggregate, and the *w/cm*. Shrinkage cracking is also related to the ability of the concrete to carry tension. The designer of the concrete structure also has a responsibility to design adequate movement joints to accommodate concrete shrinkage. Shotcrete tends to have a

relatively high paste content so may have a slightly higher shrinkage potential. Conversely, shotcrete has a lower w/cm (0.30 to 0.42) as compared to most form-and-place (0.40 to 0.50), so would tend to have a lower shrinkage potential. Also, shotcrete tends to have earlier strength gain, and higher 28-day strengths (both compressive and tensile) than most form-and-place concrete. This reduces the shrinkage potentially causing cracks. Thus, considering the plusses and minuses, shotcrete may balance the shrinkage potential of form-and-place. More importantly, proper attention by the shotcrete contractor to the installation, through early, wet curing and keeping curing in place for at least 7 days will significantly help reduce the potential for cracking. Also, shotcrete mixtures can use shrinkage-reducing admixtures that will help limit drying shrinkage through the critical first year after placement.



Charles Hanskat is the current ASA Executive Director. He received his BS and MS in civil engineering from the University of Florida, Gainesville, FL. Hanskat is a licensed professional engineer in several states. He has been involved in the design, construction, and evaluation of environmental concrete and shotcrete structures for over 35 years. Hanskat is also a member of ACI Committees 301, Specifications for Structural Concrete; 350, Environmental Engineering Concrete Structures; 371, Elevated Tanks with Concrete Pedestals; 372, Tanks Wrapped with Wire or Strand; 376, Concrete Structures for Refrigerated Liquefied Gas Containment; 506, Shotcreting; and Joint ACI-ASCE Committee 334, Concrete Shell Design and Construction. Hanskat's service to the American Society of Civil Engineers (ASCE), the National Society of Professional Engineers (NSPE), and the Florida Engineering Society (FES) in over 50 committee and officer positions at the national, state, and local levels was highlighted when he served as State President of FES and then as National Director of NSPE. He served as a District Director of Tau Beta Pi from 1977 to 2002. He is a Fellow of ACI, ASCE, and FES and a member of ACI, NSPE, ASTM International, and ASCC.