american shotcrete association

Monolithic Shotcrete for Swimming Pools (No Cold Joints)

Shotcrete is the preferred construction method and concrete placement process for structural swimming pool installations. The versatility of shotcrete placement allows for a wide variety of sizes or shapes. Applicable stan dards for shotcrete design, specifications, and application can be found in American Concrete Institute (ACI) Committee 506 Guides, Specifications, and Technical Notes. Proper shooting technique and nozzle operation are well-covered in CCS- 04(20), "Shotcrete for the Craftsman." Specific pool shotcrete applications are described by the American Shotcrete Association (ASA) Pool and Recreational Shotcrete Committee Position Statements (currently numbered #1-7: "Compressive Strength Values of Pool Shotcrete," "Shotcrete Terminology," "Sustainability of Shotcrete in the Pool Industry," and "Water-tight Shotcrete for Swimming Pools", "Monolithic Shotcrete for Swimming Pools", "Forming and Substrates in Pool Shotcrete", and "Curing of Shotcrete from Swimming Pools").

Shotcrete contractors and applicators specializing in swimming pool construction are responsible and liable to observe appropriate design standards, use quality materials, establish appropriate quality control testing, and employ application techniques to build a fully functional pool with long-term serviceability and durability. Two important criteria in a pool shell are the concrete must meet the ASA's minimum 28-day compressive strength of 4000 psi (28 MPa) (ASA Pool Position Statement #1) and be essentially watertight prior to final surface applications (paint or plaster). These performance criteria assume a monolithic shotcrete pool shell without any cold joints. With shotcrete, the construction of a monolithic shotcrete pool shell is not constrained by time limits as long as proper techniques are observed from surface preparation to mixture design to the shooting velocity of the concrete itself. Shotcrete can be applied in multiple layers, sections, or phases without producing a single cold joint.

The American Concrete Institute's (ACI's) Concrete Ter- minology defines "cold joint" as "a joint or discontinuity resulting from a delay in placement of sufficient duration to preclude intermingling and bonding of the material, or where mortar or plaster rejoin or meet."

In cast-in-place concrete construction, internal vibration is the most common method for providing adequate consolidation of the placed concrete. In cast-in-place work, a cold joint is formed when an initial lift of concrete becomes too stiff for penetration by the vibrator used to consolidate a subsequent lift. This thus precludes the "intermingling" of material in the definition. However, ACI PRC-309-05, "Guide for Consolidation of Concrete," indicates that if bond is obtained between cast sections, a cold joint is avoided. ACI PRC-309-05, Section 7.2, states: "When the placement consists of several layers, concrete delivery should be scheduled so that each layer is placed while the preceding one is still plastic to avoid cold joints. If the underlying layer has stiffened just beyond the point where it can be penetrated by the vibrator, bond can still be obtained by thoroughly and systematically vibrating the new concrete into contact with the previously placed concrete; however, an unavoidable layer line will show on the surface when the form is removed."

Shotcrete does not require internal vibration for consolidation of concrete. Instead, shotcrete provides thorough consolidation and densification by high-velocity impact of fresh concrete material on the receiving surface. Laboratory testing proves that properly placed shotcrete is very well-consolidated, and provides excellent bond strength and durability (Zhang et al. 2016). The high-velocity impact of shotcrete on a hardened, previously shot layer (or existing concrete surface) provides a strong, abrasive blast to open up the surface, and then provides immediate exposure of that hardened surface to fresh cement paste. As a result, properly placed shotcrete exhibits excellent bond to concrete and previously shot surfaces.

TABLE 1: MULTI-LAYER BOND STRENGTH IN PSI (MPA) (BEAUPRÉ 1999)

	Type of finish between layers (results with no curing compound)			
Time	None	Scratch	Scratch + wood	Roughen with broom
4 hours	300 (2.1)	260 (1.8)	300 (2.1)	275 (1.9)
1 day	NA	300 (2.1)	300 (2.1)	NA
28 days	NA	260 (1.8)	NA	290 (2.0)

Notes: One-layer full thickness used in this project had a bond (tensile) strength of 350 psi (2.4 MPa); NA is not available

Fig. 1: Floor cast with installed keyway

Fig. 2(a) and (b): Shotcrete on top of cast floor

A study on shotcrete bond to concrete repair surfaces that included work on multi-layer shotcrete bond was conducted at Laval University (Beaupré 1999). The study looked at bond with multiple layers of shotcrete shot 4 hours, 1 day, and 28 days apart with four levels of surface finishing (no surface finishing, scratched with steel trowel, scratched and finished with wood trowel, and rough broom finish). Table 1 shows the results from Beaupré's report. The report concluded that "for the waiting period and the types of finish studied, there is no significant influence of these parameters on bond strength" and "With respect to the multi-layer bond strength of shotcrete, the presence of shotcrete/shotcrete interfaces does not seem to create a large reduction in shotcrete quality in terms of mechanical bond if no curing compound is used." Specified shotcrete bond strength for shotcrete to properly prepared concrete substrates generally range from 100 to 150 psi (0.69 to 1.00 MPa). These levels of bond strength were easily reached by any of the combinations found in Table 1. If a curing compound is used on a layer, it should be completely removed before shooting subsequent layers of shotcrete. In shotcrete construction, surface preparation between layers to provide adequate bond is important. ACI SPEC-506.2-13 (18), "Specification for Shotcrete," specifically addresses this in the requirements of Sections 3.4.2.1 and 3.4.2.2 that:

"3.4.2.1 When applying more than one layer of shotcrete, use a cutting rod, brush with a stiff bristle, or other suitable equipment to remove all loose material, overspray, laitance, or other material that may compromise the bond of the subsequent layer of shotcrete.

Conduct removal immediately after shotcrete reaches initial set."

"3.4.2.2 Allow shotcrete to stiffen sufficiently before applying subsequent layers. If shotcrete has hardened,

Fig. 3: Watertight tank test

clean the surface of all loose material, laitance, overspray, or other material that may compromise the bond of subsequent layers. Bring the surface to a saturated surface-dry (SSD) condition at the time of application of the next layer of shotcrete."

The shotcrete specification requires removal of all potential bond-breaking materials immediately after initial set, as well as the cleaning and SSD conditions provided for in 3.4.2.2. Thus, shotcrete placed in layers does not produce a "cold joint" as defined by ACI because it produces excellent bond between the layers. This has been confirmed by visual inspection of numerous cores taken through multiple layers of shotcrete, where it is often impossible to identify where one layer stops and the other starts, unlike cold joints in form-and-pour work where the difference between lifts is readily apparent.

The connection point between two or more layers of shotcrete or between days of placement is considered to be a "construction joint." This joint is still considered to be monolithic based on the shotcrete application methods. Swimming pool shotcrete performance, durability, water-tightness, and compressive values depend greatly on the proper application and preparation of the construction joint. Preparation includes shaping the joint to a 45-degree angle, cleaning overspray from adjacent reinforcement not yet embedded, and roughening the surface of the joint with a stiff broom, brush, or tool. The joint can then stand for as long as needed before the next placement. When it is time to complete the area, the joint must be cleaned and predampened to a saturated surface-dry damp condition. When properly shooting and curing the subsequently placed shotcrete, the concrete will act as a monolithic section, just as if there were never a joint there to begin with. The secret in making this a joint that acts monolithically with perfect bond is the combination of the proper surface preparation of the joint and high-impact velocity of the shotcrete stream. Shotcrete is a paste-rich concrete that is pneumatically driven by impact into the rough surface left by the joint preparation. No bonding agents are needed, and indeed no bonding agents should be used because they may interfere with the bond of the fresh paste to the rough substrate.

To reiterate, shotcrete swimming pool construction using quality materials, proper equipment, surface preparation, and placement techniques will not have cold joints and will behave monolithically. Also, with high-velocity impact on a receiving surface, the cement paste penetrates the existing three-dimensional bond plane and requires no bonding agents for proper adhesion between shotcrete layers or applications.

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Position Statements

The American Shotcrete Association (ASA) is a non-profit organization of contractors, suppliers, manufacturers, designers, engineers, owners, and others with a common interest in advancing the use of shotcrete. ASA's position statements reflect the best practices for proper shotcrete placement. These statements were developed by industry leaders via a consensus-based process to provide resources to their respective markets. A complete set of statements can be found at **www.shotcrete.org/Resources.**