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 standards 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(08), “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 #1-4: “Compressive Strength Values of Pool Shotcrete,” “Shotcrete Terminology,” “Sustainability of Shotcrete in the Pool Industry,” and “Water-tight Shotcrete for 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 Terminology 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 309R-05, “Guide for Consolidation of Concrete,” indicates that if bond is obtained between cast sections, a cold joint is avoided. ACI 309R-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.

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

<table>
<thead>
<tr>
<th>Time</th>
<th>Type of finish between layers (results with no curing compound)</th>
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<tbody>
<tr>
<td></td>
<td>Type</td>
</tr>
<tr>
<td>4 hours</td>
<td>None</td>
</tr>
<tr>
<td>1 day</td>
<td>NA</td>
</tr>
<tr>
<td>28 days</td>
<td>NA</td>
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Notes: One-layer full thickness used in this project had a bond (tensile) strength of 350 psi (2.4 MPa); NA is not available
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 ranges 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 506.2-13, “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, 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 is more stringent than ACI 318-11, Section 6.4, on construction joints, because it requires removal of all potential bond-breaking materials immediately
Position Statement #5
ASA Pool and Recreational Shotcrete Committee

ASA has produced position statements on the best practices for proper shotcrete placement. To date, five position statements from our Pool & Recreational Shotcrete Committee and one from our Board of Direction have been issued. These statements have also been published in Shotcrete magazine.


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References