

Shotcrete Placed in Multiple Layers does NOT Create Cold Joints

By Charles S. Hanskat

Designers and inspectors often confuse placement of multiple layers of shotcrete in building out a section with cold joints experienced in cast-in-place concrete construction. The American Concrete Institute's (ACI's) Concrete Terminology defines cold joint as:

“Cold joint—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 use 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. It is well proven in laboratory testing that properly placed shotcrete is very well consolidated, and provides excellent strength and durability. 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 an immediate exposure of that hardened surface to fresh cement paste. As a result, 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, rough broom finish). Table 1 shows the results from Beaupré's (1999) report. The report concluded that “it can be seen 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.”

Table 1: Multi-layer bond strength in MPa (psi) (Beaupré 1999)

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

Note: NA is not available

Technical Tip

Specified shotcrete bond strength for shotcrete to properly prepared concrete substrates generally ranges from 100 to 150 psi (0.69 to 1.00 MPa). 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 full 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 actually more stringent than ACI 318-11, Section 6.4, on construction joints, because it 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 cast-in-place work where the difference between lifts is readily apparent.

References

ACI Committee 309, 2005, "Guide for Consolidation of Concrete (ACI 309R-05)," American Concrete Institute, Farmington Hills, MI, 36 pp.

ACI Committee 506, 2013, "Specification for Shotcrete (ACI 506.2-13)," American Concrete Institute, Farmington Hills, MI, 40 pp.

ACI Committee 318, 2011, "Building Code Requirements for Structural Concrete and Commentary (ACI 318-11)," American Concrete Institute, Farmington Hills, MI, 503 pp.

Beaupré, D., 1999, "Bond Strength of Shotcrete Repair," *Shotcrete*, V. 1, No. 2, Spring, pp. 12-15.



Sawed side of shotcrete test panel shot with multiple layers



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