Position Statement #7
ASA Pool and Recreational Shotcrete Committee

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Curing of Shotcrete for Swimming Pools

Shotcrete for swimming pools and other water containment structures such as aquatic parks and lazy rivers present unique complexities in curing and protection. As with all concrete, proper curing improves the overall gain of strength-related properties and reduces the overall amount and size of concrete cracking near the surface. However, for swimming pools, proper curing influences watertightness, long-term durability, and facilitates the bond and finishing ability of subsequent-applied cementitious finish coatings.

'Curing' is a method of maintaining adequate moisture within the concrete material nearest to the surface to ensure ongoing hydration of the cementitious binder. ACI 308R-16, "Guide to External Curing of Concrete," notes that surface exposure to 90% or less relative humidity can suspend hydration of cement at early ages. Thus, unless relative humidity is maintained above 90%, deliberate action must be taken, such as misting, soaking, or covering of the surface to maintain high humidity levels and conditions that allow the surface to hydrate at a similar rate to that of the inner matrix of the shotcrete.

Refer to ACI 506R, "Guide to Shotcrete," for additional curing methods. Typically, the effective zone for curing of concrete can reach depths between 1/4 and 3/4 in. (6 and 19 mm) from the outer surface depending on the finish texture and the permeability of the material. Although external curing does not penetrate deep enough to supply moisture to the inner matrix, maintaining a high humidity at the surface reduces the rate at which the inner-matrix water exits the system. Maintaining a similar moisture content and temperature between the outer surface and the inner matrix of the material promotes uniform hydration and lessens cracking associated with moisture and temperature gradients.

'Hydration' is the chemical reaction that converts the cementitious powder materials and water into a rigid structural material, or binder. In general, with sufficient moisture present, approximately 70% of cement hydration takes place in the first 7 days, and approximately 85% of cement hydration takes place in the first 28 days. The remaining unhydrated cement will continue to hydrate for many years after placement if moisture is present.

MINIMIZING MOISTURE AND TEMPERATURE GRADIENTS

The primary goal of curing is to maintain the moisture and temperature of the surface to levels that are similar to the interior of the shotcrete. Significant temperature or moisture gradients between the outer surface and the interior of shotcrete can result in cracking and a weaker, less-durable surface. Maintaining the temperature and sufficient moisture at the surface allows for a similar development of hydration and strength-gain properties to that of the interior of the shotcrete. A unique aspect of shotcrete in a water-submersion environment is that often, any shortfall in physical strength is quickly recovered subsequent to submersion, assuming sufficient cementitious material is present.

When a shotcrete cylinder or core meets or exceeds its required compressive strength (f_c'), a sufficient amount of cement has hydrated to achieve this strength. However, such testing may not adequately qualify the condition, strength, or durability of the outer surface. The quality of the outer surface can be weak or compromised, yet have little effect on strength test results based on cylinders or cores. Adherence to a proven curing method ensures the development of necessary outer-surface properties that directly impact the overall watertightness of shotcrete and the application and performance of a subsequently-applied cementitious finish coating.

CURING CONSIDERATIONS

ACI and ASA typically require that curing remains in place for a minimum of 7 days, or until at least 70% of the specified 28-day compressive strength (f_c') is achieved. It has been shown that extending wet curing from 3 days to 7 days can result in a 10 to 20% reduction in shrinkage cracking at the outer surface (the curing-affected zone). Prolonged wet curing significantly increases abrasion resistance (increases upper-surface strength) and significantly reduces surface permeability and absorption capacity.

For shotcrete swimming pool structures that are to receive a cementitious finish coating, ACI Committee 524, Plastering, and the National Plasterers Council (NPC) recommend that moist curing be continued for 28 days.

Ideally, the first 7 days should be soaked more frequently. It is recommended to soak the surface from three to five times per day (the more the better) initially, dependent upon the climate or region of the country. This is typically done by spraying water onto the shotcrete surface with a garden hose. Thereafter, it is recommended to wet all exposed surfaces at least once per day.

Wet curing for 28 days drastically reduces shotcrete's absorptive capacity. This is due to discontinued capillaries and carbonation of the surface. In some cases, well over a 50% reduction in absorptive capacity of the substrate is reported. Reducing shotcrete-absorptive capacity (capillary suction) also reduces shrinkage cracking. Reducing absorptive capacity also allows increased control of the subsequently-applied finish coating application by: creating a more uniform absorption rate across the surface of the shotcrete; extending the period of time available to physically force the finish coating material into the rough darby-cut shotcrete with minor surface depressions to achieve a good bond; and extending the time that mix water remains within the coating, enhancing overall finishability.

RECOMMENDED CURING

Immediately after finishing, keep shotcrete continuously moist for at least 7 days by soaking the surface three to five times daily or more. Thereafter, continue water curing at least once a day from day 7 to day 28. Wet periodically thereafter, one to two times per week, until the interior finish coating has been applied, and the swimming pool is filled with water.

Alternative curing methods have been employed to maintain surface moisture, such as covering the shotcrete with absorptive mat or fabric, sand or other covering, and keeping continuously wet; or covering the shotcrete with polyethylene sheeting of at least 4 mil thickness to prevent moisture loss. Curing compounds, if used, must be removed prior to applying subsequent coatings to ensure that an adequate bond can be achieved between the coating and the shotcrete.

The shotcrete should not be allowed to freeze until it has reached a minimum compressive strength. Generally, shotcrete that has reached 500 psi (3.5 MPa) before freezing takes place will not be damaged by freezing. When the temperature of shotcrete rises above 40°F (4°C), the hydration reaction will resume, and further develop strength. In general, shotcreting operations should be stopped when the anticipated 24-hour (daily) average ambient temperature falls below 40°F unless cold weather concrete measures are taken such as those mentioned in ACI 306R. In a hot-weather environment, the problems encountered with wet-mix shotcrete are the same as for form-and-pour concrete: increased water demand, increased rate of slump loss, rapid setting, and difficulty in regulating the entrained air content. For dry-mix and wet-mix shotcrete, the finishing operations, if any, should proceed as rapidly as the shotcrete condition allows. Curing should also start as soon as possible.

References

1. Hall, C., and Hoff, W.D., *Water Transport in Brick, Stone and Concrete*, first edition, Spon Press, 2002, pp. 224-227.

2. ACI Committee 524, "Guide to Portland Cement-Based Plaster (ACI 524R-16)," American Concrete Institute, Farmington Hills, MI, 2016, 40 pp.

3. Schallom, R. III, "Curing Pneumatically Applied Concrete," *Shotcrete*, V. 8, No. 2, Spring 2006, pp. 40-42.

4. ACI Committee 506, "Guide for Specifying Underground Shotcrete (ACI 506.5R-09)," American Concrete Institute, Farmington Hills, MI, 2009, 52 pp.

5. ACI Committee 308, "Guide to External Curing of Concrete (ACI 308R-16)," American Concrete Institute, Farmington Hills, MI, 2016, 38 pp.

6. National Plasterers Council, *The National Plasterers Council Technical Manual*, ninth edition, Wauconda, IL, 2016.

7. The Association of Pool & Spa Professionals, *APSP Builders Manual*, third edition, Alexandria, VA, V. 3.3, 2013, pp. 7-18 to 7-23.

Position Statements

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

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