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Curing Test Cylinders in Hot Weather

Don't let the sun catch you crying about low cylinder breaks

BY FRANK A. KOZELISKI

Several studies have shown that improper first-day curing of test cylinders during hot weather can cause laboratory-measured compressive strengths to be up to 15% lower than those for properly cured cylnders.[1,2] This apparent strength deficiency can trigger a specification requirement for needless and costly additional testing, including tests of cores or, in the worst case, load tests of the structure itself. Avoiding this problem requires careful attention to treatment of cylinders at the job site.

ASTM CURING REQUIREMENTS

Standard initial curing for test cylinders requires them to be stored immediately after molding, for a period up to 48 h, in a temperature range from 60 to 80 °F (16 to 27 °C) and in an environment preventing moisture loss.[3] The cylinders must also be shielded from direct sunlight.

The environment preventing moisture loss can be maintained by one or more of the following procedures:

- Immediately immersing molded specimens with plastic lids in water saturated with calcium hydroxide;
- Storing in properly constructed wooden boxes or structures;
- Placing in damp sand pits;
- Covering with removable plastic lids; and
- Covering with plastic sheets or nonabsorbent plates, if provisions are made to avoid drying and damp burlap is used inside the enclosure but prevented from contacting the concrete surfaces.

The temperature during initial curing can be controlled by:

- Using ventilation;
- Using ice; and
- Using thermostatically controlled heating or cooling devices.

Other suitable means may be used, provided the requirements limiting specimen storage temperature and moisture loss are met. For example, immersion in water saturated with calcium hydroxide may be the easiest way to maintain the required storage temperature, especially for concretes with specified strengths of 6000 psi (40 MPa) or greater. Cardboard molds shouldn't be used if cylinders are immersed in water.

On two recent hot-weather projects, my company produced the concrete and supplied a commercially produced, thermostatically controlled curing box so

Fig. 1: A thermostatically controlled heating and cooling box can be used to maintain the 60 to 80 °F (16 to 27 °C) initial curing temperature required by ASTM C 31

cylinders would be properly cured during the first 24 h (Fig. 1). The box was also used to store the cylinders until they were transferred to the laboratory of record, which was 140 mi (225 km) from the job site. Test results for the project had a coefficient of variation less than 10%, and no individual tests fell below the specified strength. Cement efficiency was higher than 10 psi/lb (150 kPa/kg) of cementitious material.

WHEN TO USE STANDARD CURING

Test data from standard-cured cylinders are used for:

- Acceptance testing for specified strength;
- Checking adequacy of mixture proportions for strength; and
- Quality control.

If the cylinders aren't cured in the standard manner, low test results caused by curing variations can be incorrectly attributed to quality control deficiencies in concrete production (see sidebar). The low test results may also delay acceptance of the concrete until further testing confirms an adequate strength level. The additional testing and the delay both drive up construction costs needlessly. Proper standard curing is therefore essential when the test results will be used to show that the producer delivered concrete of the specified strength.

NEW MEXICO CURING LESSONS

Tests conducted by the New Mexico Ready Mix Concrete & Aggregate Association in August 1994[2] showed that cylinders exposed to direct sunlight had significantly lower strengths, even when the cylinders were kept moist with wet burlap (Fig. 2). Further, cylinders stored in plastic molds with lids on them, but on the floor of an air-conditioned laboratory, also had significantly

LAB-CURED VERSUS FIELD-CURED CYLINDERS

Have you heard this statement? "If the concrete structure is in the sun, the concrete test cylinders should also be in the sun, so they better represent the strength of the in-place concrete."

The statement seems logical, but isn't true for acceptance testing. Acceptance-test results represent the potential strength of the concrete that's discharged from the truck. The test is not intended for determining the in-place strength of the concrete because it makes no allowance for the effects of placing, compaction, or curing.[1] When cylinder tests are used to indicate whether or not the producer delivered concrete of the specified strength, standard curing is mandatory.

Cylinders cured in the same manner as the concrete structure serve a different purpose. The results from testing these field-cured cylinders can be used to determine when a structure can be put into service, to determine adequacy of curing and protection of the structure, and to determine when forms or shores can be removed. They may also be used for comparison with test results from in-place testing methods. They should not, however, be used as a basis for acceptance of concrete. A corollary to this statement is that results from the testing of laboratory-cured cylinders should not be used to estimate in-place strength.[2]

Finally, test results may not be reliable indicators of concrete strength. ACI Committee 228 states that:

"Measured strengths of field-cured cylinders may be significantly different from in-place strengths because it is difficult, and often impossible, to have identical bleeding, consolidation, and curing conditions for concrete in cylinders and concrete in structures."

Alternative methods for evaluating concrete strength during construction include tests of cast-in-place cylinders, penetration resistance, or pullout strength, or maturity factor measurements.[3]

References

1. ACI Committee 228, "In-Place Methods to Estimate Concrete Strength (ACI 228.1R-03)," American Concrete Institute, Farmington Hills, MI, 2003, pp. 2-3.

2. "Cylinder Strength and IQ," *Concrete Technology Today*, Portland Cement Association, Skokie, IL, 1996, p. 3.

3. ACI Committee 318, "Building Code Requirements for Structural Concrete (ACI 318-05) and Commentary (318R-05)," American Concrete Institute, Farmington Hills, MI, 2005, pp. 73-74.

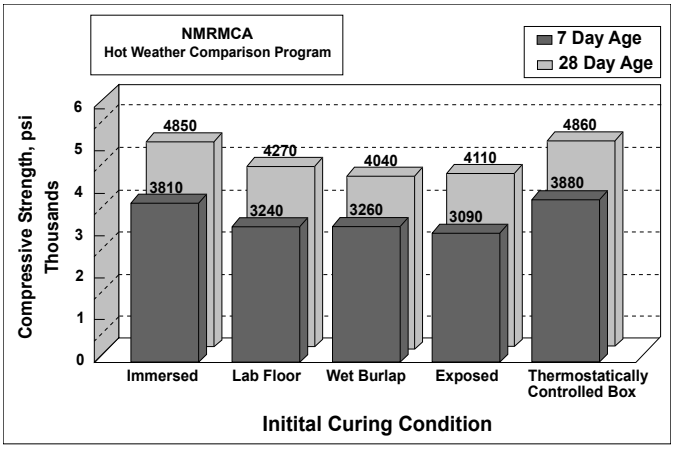

Fig. 2: Tests by the New Mexico Ready Mix Concrete & Aggregates Association show that initial curing by immersing test cylinders in water or using a thermostatically controlled curing box results in significantly higher 7- and 28-day strengths

lower strengths than cylinders immersed in water saturated with calcium hydroxide. These results demonstrate the need for control of both moisture loss and temperature during initial curing.

Moisture loss can be prevented by using homemade or manufactured curing boxes or tanks. Sometimes the requirements for standard initial curing can be met simply by storing cylinders in a 55-gal. drum that is cut in half, filled with water, and kept in the shade. If 4 x 8 in. (100 x 200 mm) cylinders are used, four of them can be totally immersed in a 5-gal. pail, although it is important to control temperature when this is done.

In the summer of 2004, I noticed that cylinders on one job site were being cured in 5-gal. pails (with varying colors) that were exposed to direct sunlight (Fig. 3(a)). I checked the water temperatures and found the water in a white pail was 85 °F (29 °C). This was too high, but it was 12 to 15 °F (7 To 9 °C) cooler than the water in black, red, and yellow pails. To maintain the 60 to 80 °F (16 to 27 °C) initial temperatures required by ASTM C 31, buckets can be buried full depth in the soil at the job site, or shaded by temporary structures built with plywood and sawhorses. Temperatures should be recorded by using a maximum-minimum thermometer as required by Section 10.1.2 of ASTM C 31 (Fig. 3(b)).

Erroneously low strength-test results can be avoided in hot weather if test cylinders are properly protected during the critical 48 h period before they are taken to the testing laboratory. The results are well worth the small cost of protection.

Fig. 3: Pail color affects the water temperature if the pails are left in direct sunlight: (a) water in the black pail was 12 to 15 °F (7 to 9 °C) hotter than water in the white pail; and (b) use a maximum-minimum thermometer to verify that the required 60 to 80 °F (16 to 27 °C) initial curing temperature is maintained

References

1. Bloem, D.L., "Effect of Curing Conditions on the Compressive Strength of Concrete Test Specimens," *Publication* 53, National Ready Mixed Concrete Association, Silver Spring, MD, 1969.

2. Montoya, A., "Hot Weather Comparison Program," New Mexico Ready Mix Concrete & Aggregate Association, 1995.

3. ASTM C 31/C 31M-03a, "Standard Practice for Making and Curing Concrete Test Specimens in the Field," ASTM International, West Conshohocken, PA, 2003, 5 pp.

Selected for reader interest by the editors.

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