Determining In-Place Concrete Compressive Strength

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There are numerous situations in bridge construction where it is necessary to determine the in-place compressive strength of the concrete. These include removal of formwork, application of post-tensioning, transfer of force from pretensioned strands, termination of cold weather protection, and opening a bridge to traffic. Failure to achieve the specified compressive strength using the standard-cured cylindrical specimens is an unplanned situation that occasionally occurs. This article is part of a series of articles that provide brief descriptions of methods to determine the in-place compressive strength and resources for more information. A more detailed description of these and other methods is provided in *In-Place Methods to Estimate Concrete Strength (ACI 228.1R-03)*.[1]

Field-Cured Cylinders

In this method, standard concrete cylinders are left at the job site for curing in, as nearly as practicable, the same manner as the concrete in the structure.[2] In practice, this usually means placing the concrete cylinders on or near the member or under the sheet-curing material, if used. This method may be used for cast-in-place concrete as well as precast concrete. For cast-in-place concrete, it is the simplest method; however, at best, the cylinders only represent the concrete near the surface of the member. For precast heat-cured concrete, the cylinders are generally placed under an insulated cover and receive curing more similar to that of the member.

Concrete Cores

This method is usually used when the standard-cured cylinders fail to achieve the specified compressive strength and no more cylinders are available for later age tests. It is the most direct method to determine the compressive strength of concrete in a structure because the test is made on the actual concrete that has been subjected to the in-place curing environment. Nevertheless, the core locations must be carefully selected because all parts of the member may not have been subjected to the same curing conditions. The core locations must avoid reinforcement, other embedments, and highly stressed areas.

The strength measured on the cores must also be carefully evaluated. For example, according to the American Concrete Institute's (ACI's) *Building Code Requirements for Structural Concrete (ACI 318-14) and Commentary (ACI 318R-14)*,[3] concrete in an area represented by core tests shall be considered structurally adequate if the average strength of three cores is equal to at least 85% of the specified strength and if no single core strength is less than 75% of the specified strength. No similar provision is included in the American Association of State Highway and Transportation Officials (AASHTO) specifications,[4] although individual project specifications may address it.

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Match Curing

Match curing is a system for curing standard concrete cylinders—usually 4 × 8 in.—at the same temperature as that measured in a concrete member.[5,6] Commercial systems include a temperature sensor in the member, a controller, special insulated cylinder molds with built-in heating systems, and a temperature sensor in the mold. The controller is used to control the heating systems so that the temperature in the cylinder matches the temperatures measured in the member. The system may also include a means to record and read the member temperatures and the cylinder temperatures. Noncommercial systems have also been used with this technique. Some precast concrete plants have used heated cabinets for this purpose rather than individual molds.

The method is particularly useful for determining the concrete compressive strength at early ages in the fabrication of precast concrete members or for determining the compressive strength of concrete at a critical section in a member. The location of the temperature sensor in the member is particularly important because temperatures can vary throughout a member and temperature influences the rate of strength gain.

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Because the match-curing system only provides heat to the cylinders and cannot cool them, the temperature of the cylinders may exceed that of the member if the temperature of the member decreases at a faster rate than that of the cylinders. If this happens, the cylinder strengths may not entirely represent the in-place concrete strength.

Sensors at the Black Ankle Valley Bridge were also used to monitor test cylinders for curing compliance and verification of strengths. Photo: John Gnaedinger, Con-Cure LLC.

Maturity Method

The maturity method involves laboratory tests to determine a strength-maturity relationship for the specific concrete mix that will be used in the structure.[7] The strength-maturity relationship is a mathematical expression that is used to convert the concrete temperature history to a maturity index. The in-place concrete temperature is then measured continuously and the in-place concrete maturity index is calculated from the data. The in-place compressive strength is then estimated from the maturity index and the strength-maturity relationship.

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Several commercial products are available to monitor and record the concrete temperature as a function of time. They include embedded digital devices that store the data and can be accessed remotely for downloading the data in real time. Some devices will calculate the maturity index. This method is the most complex method described in this series of articles, but it has been successfully used on many projects to expedite construction.

References

1. American Concrete Institute (ACI) Committee 228. 2003. *In-Place Methods to Estimate Concrete Strength (ACI 228.1R-03)*. Farmington Hills, MI: ACI.
2. American Association of State Highway and Transportation Officials (AASHTO). 2017. *Standard Method of Test for Making and Curing Concrete Test Specimens in the Field*. AASHTO T 23-17. Washington, DC: AASHTO.
3. ACI Committee 318. 2014. *Building Code Requirements for Structural Concrete (ACI 318-14) and Commentary (ACI 318R-14)*. Farmington Hills, MI: ACI.
4. AASHTO. 2015. *Standard Method of Test for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete*. AASHTO T 24-15. Washington, DC: AASHTO.
5. AASHTO. 2016. *Standard Practice for Match Curing of Concrete Test Specimens*. AASHTO PP 54-16. Washington, DC: AASHTO.
6. Popovics, J. S., S. Ham, and S. Garrett. 2014. *State of Practice for Concrete Cylinder Match Curing and Effect of Test Cylinder Size.* Report No. FHWA-ICT-14-003. Urbana, IL: Illinois Center for Transportation.
7. ASTM Subcommittee C09.64. 2017. *Standard Practice for Estimating Concrete Strength by the Maturity Method*. ASTM C1074-17. West Conshohocken, PA: ASTM International.

Other Resources

1. ACI Committee 214. 2016. *Guide for Obtaining Cores and Interpreting Compressive Strength Results (ACI 214.4R-10)*. Farmington Hills, MI: ACI.
2. ACI Committee 306. 2016. *Guide to Cold Weather Concreting (ACI 306R-16)*. Farmington Hills, MI: ACI.

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