Concrete in Practice
What, why & how?
NRMCA

CIP 10 - Strength of In-Place Concrete

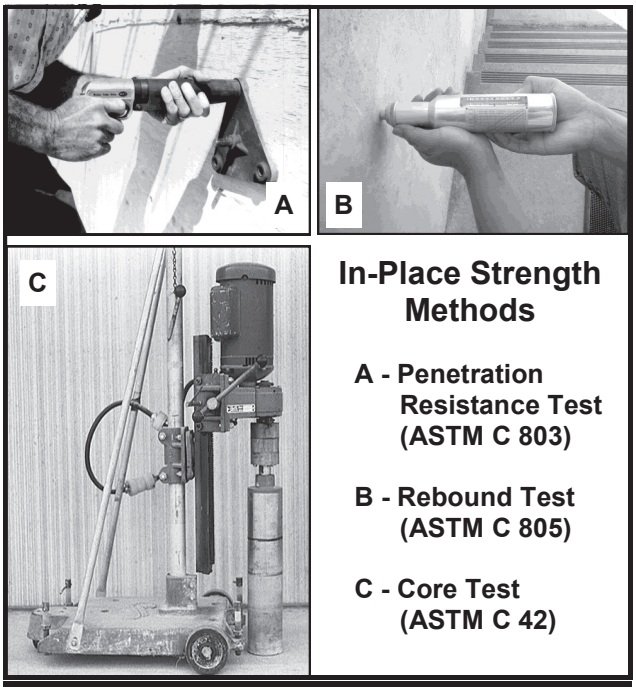
WHAT is the Strength of In-Place Concrete?

Concrete structures are designed to carry dead and live loads during construction and in service. Samples of concrete are obtained during construction and standard ASTM procedures are used to measure the potential strength of the concrete as delivered. Cylinders are molded and cured at 60 to 80°F (17 to 27°C) for one day and then moist cured in the laboratory until broken in compression, normally at an age of 7 and 28 days or at an alternative specified age.

The in-place strength of concrete will not be equivalent to that measured on standard cylinders and will generally be lower. Job practices for handling, placing, consolidation, and curing concrete in structures are relied upon to provide an adequate percentage of that potential strength, measured on cylinders, in the structure. Structural design principles recognize this and the ACI Building Code, ACI 318, has a process of assuring the structural safety during construction. In cold weather a slower rate of in-place strength gain can be expected.

Means of measuring, estimating, or comparing the strength of in-place concrete include: rebound hammer, penetration probe, pullouts, maturity, cast-in-place cylinders, tests of drilled cores, and load tests of the structural member or system.

Cores drilled from the structure is one of the methods of evaluating whether the structural capacity of a concrete member is adequate. Drilled cores generally test lower than standard-cured cylinders. The ACI Building Code (ACI 318) recognizes that concrete construction can be considered structurally adequate if the average of three cores from a region represented by non-compliant concrete strength tests is equal to or exceeds 85 percent of specified strength, f'_c with no single core less than 75 percent of f'_c. Measured core strengths are not corrected for age. TIP 11 discusses core testing for acceptance of concrete. ACI 214.4R provides detailed guidance on core testing, evaluating existing structure capacity using in-place strengths, and determining an equivalent f'_c value for evaluating the structural capacity of an existing structure. The latter process should not be used to determine the acceptability of concrete furnished to a project.



WHY Measure In-Place Strength?

Tests of in-place concrete may be needed when standard cylinder strengths are low and do not comply with strength acceptance criteria outlined in ACI 318. However, do not investigate in-place without first checking to be sure that: the concrete strengths actually failed to meet the specification provisions, low strengths are not attributable to faulty testing practices, or the specified strength is really needed. (See CIP 9 and TIP 11) In many cases, the concrete can be accepted for the intended use without in-place strength testing.

There are many other situations that may require the investigation of in-place strength. These include: shore and form removal, post-tensioning, or early load application; investigation of damage due to freezing, fire, or adverse curing exposure; evaluation of older structures; and when a lower strength concrete is placed in a member by mistake. When cores or other in-place tests fail to assure structural adequacy, additional curing of the structure may provide the necessary strength. This is particularly possible with concrete containing fly ash, slag cement or some blended cements.

HOW to Investigate In-Place Strength?

If only one set of cylinders is low, often the question can be settled by comparing rebound hammer or penetration probe results on concrete in areas represented by acceptable cylinder results. Where the possibility of low strength is such that large portions need to be investigated, a well-organized study will be needed. Establish a grid and obtain systematic readings including good and questionable areas. Tabulate the hammer or probe readings. If areas appear to be low, drill cores from both low and high areas. If the cores confirm the hammer or probe results, the need for extensive core tests is greatly reduced.

Core Strength, ASTM C 42 - If core drilling is necessary observe the following:

a. Test a minimum of 3 cores for each location in the structure represented by low strength tests;
b. Obtain cores with a minimum diameter of 3.7 in. (85 mm) or at least twice the nominal maximum aggregate size. Smaller diameter cores are permitted when it is not feasible to obtain the required size;
c. The length to diameter ratio (L/D) should be around 2, but try to obtain cores with L/D of at least 1½;
d. Avoid drilling cores from the top layers of columns, slabs, walls, or footings, which will be 10 to 20 percent weaker than cores from the mid or lower portions; and
e. Store the cores in sealed watertight bags or containers and transport to the laboratory. Test the cores in accordance with ASTM C42. Saw or grind core ends within 2 days after drilling. Keep cores in a sealed conditionfor at least 5 days after last wetted. Review the requirements for conditioning cores in current versions of ACI 318 and ASTM C42.

Probe Penetration Resistance, ASTM C 803 - Probes or pins driven into concrete can be used to study relative strength of in-place concrete:

a. Different size probes or pins, or a change in driving force may be necessary for large differences in strength or concrete density;
b. Accurate measurement of the exposed length of the probe is required;
c. Probes should be spaced at least 7 in. apart and not be close to the edge of the concrete;
d. Probes not firmly embedded in the concrete should be rejected;
e. Develop a strength calibration curve for the materials and conditions under investigation; and
f. Surface conditions, moisture conditions, and aggregate characteristics can affect the results.

Rebound Hammer, ASTM C 805 - This method is also used to evaluate the relative in-place strength:

a. Wet all surfaces for several hours or overnight because drying affects rebound number;
b. Don't compare readings on concrete cast against different form materials, concrete of varying moisture content, readings from different impact directions, on members of different mass, or results using different hammers;
c. Don't grind off the surface unless it is soft, finished or textured;
d. Test structural slabs from the bottom; and
e. Do not test frozen concrete.
f. Surface conditions, moisture conditions, and aggregate characteristics can affect the results

Maturity, ASTM C1074 – If concrete maturity is used to estimate the in-place strength please refer to CIP 39

Advance Planning - When it is known in advance that in-place testing is required, such as for shore and form removal, other methods can be considered such as: cast-in-place, push-out cylinders and pullout strength measuring techniques covered by ASTM C873 and C900.

References

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2. ACI 228.1R, *In-Place Methods to Estimate Concrete Strength*, ACI, Farmington Hills, MI.
3. ACI 214.4R, *Guide for Obtaining Cores and Interpreting Compressive Strength Results*, ACI, Farmington Hills, MI.
4. ASTM C 31, C 39, C 42, C 805, C 803, C 873, C 900, ASTM Book of Standards, Vol. 04.02, American Society for Testing and Materials, West Conshohocken, PA
5. *Guide to Nondestructive Testing of Concrete*, G.I. Crawford, Report FHWA-SA-97-105, Sept. 1997, Federal Highway Administration, Washington, DC.
6. *CIP 9, 39, Concrete in Practice Series*, NRMCA, Silver Spring, MD, www.nrmca.org.
7. TIP 11, Testing Concrete Cores, *Technology in Practice Series*, NRMCA, Silver Spring, MD,
8. *In-Place Strength Evaluation - A Recommended Practice*, NRMCA Publication 133, NRMCA, Silver Spring, MD.
9. *Understanding Concrete Core Testing*, Bruce A. Suprenant, NRMCA Publication 185, NRMCA, Silver Spring, MD.

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