

Concrete in Practice

What, why & how?



CIP 9 - Low Concrete Cylinder Strength

WHAT Constitutes Low Cylinder Strength

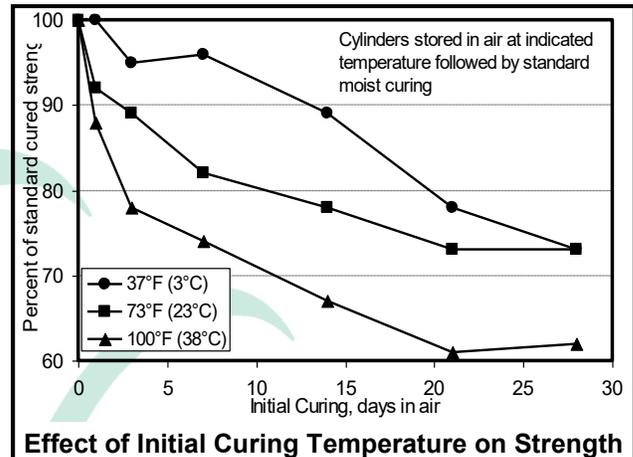
Strength test results of concrete cylinders are used as the basis of acceptance of ready mixed concrete when a strength requirement is specified. Cylinders are molded from a sample of fresh concrete, cured in standard conditions and tested at an age indicated in the specification, usually at 28 days. For strength test results to be reliable, procedures must be in accordance with ASTM standards. The average strength of a set of two 6×12 in. (150×300 mm) or three 4×8 in. (100×200 mm) cylinders made from the same concrete sample constitutes one test result. In some cases cylinders are tested at 7 days to get an early indication of the potential strength, but these test results are not to be used to determine the acceptability of the concrete. Cylinders used for acceptance of concrete should not be confused with field-cured cylinders. Tests of field-cured cylinders are used to evaluate whether the in-place concrete has been properly cured and protected, to estimate the early-age strength in the structure to strip forms or for post-tensioning, and to continue construction activity. The ACI Building Code, ACI 318, and the Specification for Structural Concrete, ACI 301, recognize that when mixtures are proportioned to meet the requirements of the standards, strength test results will fail to comply with acceptance criteria about one time in 100 tests due to normal variability.

The strength acceptance criteria used are:

- The average of three consecutive tests equals or exceeds the specified strength, and
- No single test is lower than the specified strength by more than 500 psi (3.5 MPa) when the specified strength is less than or equal to 5000 psi (35 MPa), or

No single test is lower than $(0.9 \times \text{specified strength})$ when the specified strength is greater than 5000 psi (35 MPa)

An example of these strength acceptance criteria is provided in the table. If the strength test results fail either condition (a) or (b), steps must be taken to increase the strength of the concrete. If the results fail condition (b), an investigation should be made to



ensure structural adequacy of that portion of the structure.

WHY are Compressive Tests Low?

The major reasons for low compressive strength tests are:

- Improper cylinder handling, curing and testing - this is typically the reason in most cases;
- The addition of excessive water to the concrete mixture at the jobsite due to delays in placement or requests for a higher slump to facilitate placement and finishing;

Acceptance of Concrete on Compressive Strength

4000 psi Specified Strength

Test No.	Individual Cyl. No. 1	Individual Cyl. No. 2	Average (Test)	Average of 3 Consecutive
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Acceptable Example

1	4110	4260	4185	---
2	3840	4080	3960	---
3	4420	4450	4435	4193
4	3670	3820	3745	4047
5	4620	4570	4595	4258

Low Strength Example

1	3620	3550	3585	---
2	3970	4060	4015	---
3	4080	4000	4040	3880*
4	4860	4700	4780	4278
5	3390	3110	3250†	4023

* Average of three consecutive low.

† One test more than 500 psi low.

3. High air content in the concrete (and test specimens); and
4. Errors in production and unanticipated factors during delivery

When low compressive strength test results are reported:

1. Collect all test reports and analyze the results before taking action. Labs should not provide reports of only failing tests.
2. Look at the pattern and numbers of reported strength results.
 - Considering the sequence of results—is there a violation on compliance with the strength acceptance criteria discussed above
 - The strength range of two or three cylinders prepared from the same sample should rarely exceed 8.0% or 9.5% of the strength average, respectively.
 - Do the results indicate that the cylinders are being loaded to complete failure
3. Do the test reports provide any causal reasons?
 - Review the dates and times of batching, sampling, pick up from jobsite and delivery to the lab
 - Review concrete and ambient temperatures, number of days cylinders were left in the field, procedures used for initial curing in the field, duration of transportation, and subsequent curing in the lab
 - Review the slump, air content, and density, if measured
 - Review for any reported cylinder defects.

It is important that procedures are conducted in accordance with ASTM standards. Almost all deficiencies in handling and testing cylinders will result in a lower measured strength. All violations add up to cause significant reductions in measured strength. The more significant factors are improperly finished surfaces, initial curing over 80° F (27°C); frozen cylinders; extra days in the field; damage during transportation; delay in stripping molds and curing at the lab; improper capping; and insufficient care in breaking cylinders.

The laboratory should be held responsible for deficiencies in its procedures. Field-testing technicians and laboratory personnel should be certified; construction workers untrained in concrete testing must not make and handle cylinders. ACI 318 requires laboratories to conform to ASTM C1077 for their quality system and

personnel qualifications. Laboratories should be inspected by the Cement and Concrete Reference Laboratory (CCRL) laboratory inspection or an equivalent program. Field testing personnel must have a current ACI Grade I Field Testing Technician certification, or equivalent. Laboratory personnel should have the ACI Grade I and II Laboratory Testing Technician and/or the ACI Strength Testing Certification, or equivalent.

If the deficiency justifies investigation, first verify testing accuracy and then compare the structural requirements with the measured strength. If testing is deficient or if strength is greater than actually needed in that portion of the structure, there is little point in investigating the in-place strength. However, if procedures conform to the standards and the strength as specified is required for the structural capacity of the member in question, further investigation of the in-place concrete may be required. (CIP 10).

HOW to Reduce Low Strength Tests?

1. Ensure that sample of concrete at the jobsite is obtained in accordance with ASTM C172
2. Ensure that the cylinders are made and cured in accordance with the standard curing requirements in ASTM C31.
3. Ensure that cylinders are handled with care at the jobsite and during transportation.
4. Ensure the cylinders are tested in the laboratory in accordance with ASTM C39.

References

1. ASTM Standards C31, C39, C172, C1077, ASTM Book of Standards, Volume 04.02, American Society for Testing and Materials, West Conshohocken, PA. www.astm.org
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4. *In-Place Concrete Strength Evaluation-A Recommended Practice*. NRMCA Publication 133, NRMCA, Alexandria, VA., www.nrmca.org
5. *Effect of Curing Condition on Compressive Strength of Concrete Test Specimens*, NRMCA Publication 53, NRMCA Alexandria, VA.
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8. *Why Low Cylinder Tests in Hot Weather?* E.O. Goeb, Concrete Construction, Jan. 1986.
9. *CIP 10 – Strength of In-Place Concrete; CIP 34—Making Concrete Cylinders in the Field*, CIP Series, NRMCA, Alexandria, VA

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