

This article is a continuation of the “What’s This Report For?” series, based on a technical session sponsored by ACI Committee E702, Designing Concrete Structures. In keeping with ACI’s mission to provide knowledge and information for the best use of concrete, the articles will be posted on the ACI Web site (www.concrete.org/education/edu_online_CEU.htm) and, along with sample reports and multiple-choice questions, be used for educational materials.

The Concrete Test Report

What the designer needs to know

BY LUKE M. SNELL

Probably the most common report in the concrete industry is the concrete test report. Typically, a report is sent when a 7-day break is completed. Later, the same report is updated and resent with the 28-day test results. On a large project, these reports will quickly accumulate. So, what information can be determined from these reports?

The concrete test report serves one basic purpose: to assure those involved with a project that the right concrete was delivered to the job site. While the format of test reports can vary from one testing laboratory to the next, each will contain the information needed to determine whether the concrete meets the job-site requirements. In the U.S., a concrete test report provides documentation that random samples of fresh concrete have been taken as required in the project specifications and ASTM C172 and that a prescribed series of tests has been conducted in accordance with ASTM C31 and C39. Some of the key things that need to be reviewed in a report include:

- Identifying data, including the job-site name and location, the name and location of the laboratory, and the identification numbers of the test specimens;
- Ambient temperature at the job site;
- Location where the concrete represented by the samples has been placed in the structure;
- Date and time of sampling, as well as the identity of the individual who took the sample;
- Test results on fresh concrete (generally slump, air content, and concrete temperature);
- Curing method for the concrete samples, as well as high and low temperatures that the concrete samples underwent while in the field;
- Compressive strength of each test specimen (reported to the nearest 10 psi [0.1 MPa]);
- Type of fracture pattern; and
- Ages of the specimens when tested.

Some test report forms include space for optional comments. Useful comments might include whether

water or admixtures were added at the site. A sample should be taken only after all of the water has been added to the mixture. Technicians should always note when they observe any deviations from test standards. For example, visible defects in a test specimen or cap should be noted in the test report; however, laboratories should avoid making judgments based on incomplete data. For example, some laboratories make it a practice to indicate, based on a 7-day break, that the anticipated 28-day strength will be too low. As noted in the following discussion, such a practice may not be warranted.

INTERPRETING THE RESULTS

If you are the Engineer of Record, you'll normally receive an initial set of reports after the 7-day breaks. These can be used as an early indication of the official 28-day strength. For a typical portland cement concrete, the 7-day strength is about two-thirds to three-fourths of the 28-day strength. Be careful, though! If your concrete mixture contains fly ash, for example, the strength gain may be considerably slower than for a concrete mixture with portland cement only (Fig. 1).¹ Comparing the two may cause unnecessary distress and even panic. You'll have a much better basis for comparison if your concrete supplier has strength-gain data for the particular concrete mixture being evaluated.

Another thing to keep in mind is that an official compressive strength test in accordance with ACI 318-08, Section 5.6.2.4,² is the average of two 6 x 12 in. cylinders or three 4 x 8 in. cylinders, not a single cylinder break. A single, apparently low break could be significant, but it's almost impossible to know exactly what it means. If you need a reliable indication of the 7-day strength, break enough cylinders to provide an official test.

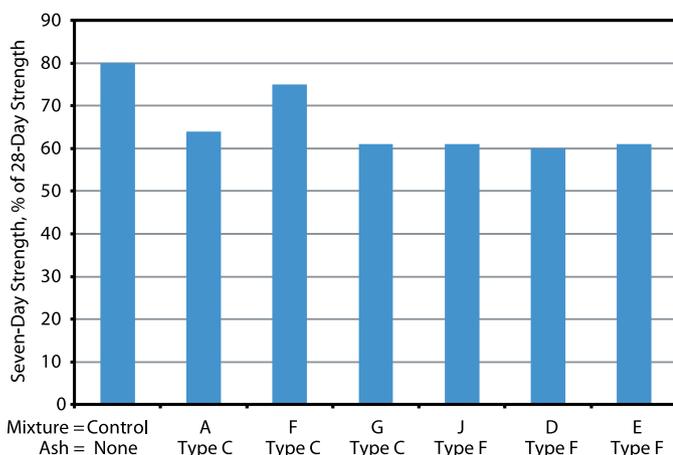


Fig. 1: The rate of strength gain is a function of the mixture proportions, so there is no single ratio that can be used for predicting the 28-day strength. In this test series, a control mixture comprising portland cement achieved about 80% of its 28-day strength in 7 days. Other mixtures with 25% fly ash replacement achieved from 60 to 75% of their 28-day strengths in 7 days (data from Reference 1)

It's helpful to track the measured strength of the concrete using a simple quality control chart of strength versus test date.³ That way, you can see any patterns that develop. Another plot that could provide a useful indication of what should be expected for 7-day results is a chart of the ratios of the 7- and 28-day strength results.

WHAT IF A TEST RESULT ISN'T ACCEPTABLE?

ACI 318-08, Section 5.6.3.3, gives two criteria for accepting the strength of the concrete:

- The average of any three consecutive strength tests equals or exceeds f'_c ; and
- No individual strength test falls below f'_c by more than 500 psi when f'_c is 5000 psi or less or by more than 10% of f'_c when f'_c is greater than 5000 psi.

If the test result fails to meet either of these criteria, you'll need to take appropriate measures for the concrete represented by the failed test(s) and for any concrete yet to be placed on the job. Details of how to apply these procedures are given in ACI's Concrete Knowledge Center.⁴ But what measures are appropriate?

Checking the procedures

It's helpful to keep in mind that almost any deviations from the procedures specified by ASTM C31, "Standard Practice for Making and Curing Concrete Test Specimens in the Field," or ASTM C39, "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens," will result in artificially low-strength test results. The first thing to do is to check that everything was done according to the standards. A good report will leave plenty of tracks to follow, and you should check them all, preferably with the cooperation of the testing laboratory.

Ideally, the laboratory will have done some checking before issuing the report. They may also have internal records of additional data they don't include in their written reports but that could provide additional clues. Although not all laboratories do so, it's good practice to retain all specimens that fail to meet the specified strength to aid in the investigation. Some specific items to look for include:

- Mishandling of the specimens either directly after casting or when moving them from the field to the laboratory. Gripping freshly cast specimens from the top can distort them. At 24 hours, specimens are relatively fragile and must be protected from jarring and excessive vibration;
- Curing temperature in the field. ASTM C31 requires that the temperature of field-cured cylinders be maintained between 60 and 80°F (16 and 27°C) or 68 and 78°F (20 and 26°C) for concrete with a specified strength of 6000 psi (40 MPa) or greater. If the temperatures were lower, the early-age strength

tests will tend to be low, but the later-age strength tests will recover; higher temperatures tend to have the opposite effect. Freezing the specimens at early ages can cause permanent damage;

- Excessive relief of the finished surface of the cylinder. The tolerances are slightly different depending on whether bonded or unbonded caps are used. If the relief exceeds the tolerance, the surface of the specimen needs to be cut or ground;
- Asymmetric loading of specimens (that is, specimens not properly centered in the testing machine). The test report should make a note of asymmetric failure modes; and
- If the concrete contains a significant quantity of fly ash or slag, do not expect the 7-day breaks to reach two-thirds or three-fourths of the 28-day strength values. Also, be aware that these concretes will be more sensitive to low curing temperatures.

If you find any errors in the testing procedures, make sure they're corrected and note any test results that are suspect. If you can't find errors in the testing procedures, then there is likely something wrong with the concrete itself—probably stemming from an error that will be harder to determine. Some detective measures are described in the following, but your first step is to examine the concrete delivery ticket and verify that the right concrete was sent to the site. You should also check the batch weights against the concrete submittal to make sure that there are no significant errors in batching.

Improving future test results

As previously indicated, the testing procedures themselves can be significant sources of unacceptably low strengths. The testing laboratory should go over all of the procedures point by point to make sure that they are in full compliance with the relevant standards (ASTM C31, C39, and either C617 or C1231 for bonded or unbonded caps, respectively). You can also verify that all technicians

have the appropriate certifications for laboratory or field testing (from ACI or other organizations) and that the laboratory maintains certification from the Cement and Concrete Reference Laboratory or another relevant agency.

Your test reports should include the air content of the fresh concrete, and they should note any water or admixture additions made on site. It may be possible

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to correlate lower-strength tests (not necessarily unacceptable strength tests) with high air contents or late additions of water.

The times when the concrete was batched and sampled are noted on the batch ticket and should also be noted on the test report. Particularly in hot weather, long delivery times can adversely affect the concrete. On large jobs, your plot of strength versus test date will provide an indication that a low test result could stem from seasonal or weather-related causes. You may see lower strengths in August, for example, due to the adverse conditions imposed by hot weather.

Investigating suspect concrete in place

The question of what to do with suspect concrete is complicated. Removing concrete is costly and causes delays in the project, especially when a lot of time has passed since the concrete was placed. For starters, it's critical to locate the suspect concrete placement within the structure for a possible investigation of the concrete properties.

ACI 318-08, Section 5.6.5.2, states, "If the likelihood of low-strength concrete is confirmed and calculations indicate that load-carrying capacity is significantly reduced, tests of cores drilled from the area in question in accordance with ASTM C42 shall be permitted. In such cases, three cores shall be taken for each strength test that falls below the values given in 5.6.3.3(b)." If you are the engineer on the project, the locations of the cores should be selected in consultation with you because you need to determine which areas of the structure are critical.

It can be extremely useful to employ nondestructive testing techniques to detect areas of relatively high or low strength within the portion of the structure in question. Most specifications don't require testing for every truckload of concrete, so there could be considerable variation within the portion of the structure being investigated. A cover meter or ground-penetrating radar should be used to locate reinforcing steel and prestressing strand so it can be avoided during coring. It may be useful to take additional cores for additional strength tests or for petrographic examination to determine the cause(s) of the low strength, either to aid in improving future performance or to assign responsibility for the costs of remedying the problem. Depending on the dimensions, it may be possible to remove a portion of a core for petrographic examination and use the rest for a strength test.

ACI 318-08, Section 5.6.5.4, states, "Concrete in an area represented by core tests shall be considered structurally adequate if the average of three cores is equal to at least 85% of f'_c and if no single core is less than 75% of f'_c ." If the strength is determined to be unacceptably low, you (the engineer) will need to determine whether to remove and

replace the deficient concrete or to take some other remedial measure. In this situation, nondestructive test methods may be helpful in determining where to take additional cores to pinpoint the locations where concrete must be removed. In the specific case where it is known or suspected that excessive quantities of fly ash or slag cement were batched, however, it may be that the strength will eventually reach satisfactory levels. In that case, it may be helpful to take extra cores to cure at elevated temperatures as an indication of the later-age strength.

References

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2. ACI Committee 318, "Building Code Requirements for Structural Concrete (ACI 318-08) and Commentary," American Concrete Institute, Farmington Hills, MI, 2008, 473 pp.
3. ACI Committee 311, "ACI Manual of Concrete Inspection (SP-2(07))," American Concrete Institute, Farmington Hills, MI, 2007, pp. 16-17.
4. Snell, L.M., "Acceptance of Concrete Test Results," ACI Committee E702 Example Problems, Concrete Knowledge Center—Designing Concrete Structures, accessed at www.concrete.org/Technical/CKC/Designing_Concrete_Structures.htm, accessed Oct. 1, 2010.

Note: Additional information on the ASTM standards discussed in this article can be found at www.astm.org.

Selected for reader interest by the editors.



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