Dont tear out that concrete yet. Just because a cylinder breaks low doesn't mean that you have bad concrete. Occasionally, cylinders aren't properly made or tested. Cores removed from the structure also can be used for acceptance. Contractors must know about coring to protect their in-place concrete investment. Cores can get you out of trouble.

Cores for acceptance

ACI 318 “Building Code Requirements for Reinforced Concrete” (Ref. 1) requires three cores removed from the concrete area in question. If the average of the three cores is equal to at least 85% of the 28-day compressive strength and no core is less than 75% of the 28-day compressive strength, then the concrete is considered to be structurally adequate.

These concrete acceptance criteria based on core testing are quite common. However, be careful; some owners require the average core strength results to be equal to the required 28-day compressive strength.

ASTM requirements

Never let a testing laboratory obtain and test a core that isn’t in conformance with ASTM C 42, Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete (Ref. 2). If the core doesn’t meet this ASTM standard, the engineer or owner could question the validity of the test and make the contractor pay for another test. If for some reason a core is taken that violates the ASTM standard, check with the engineer and the owner to make sure they will consider the core a satisfactory test.

Core diameter. The core diameter must be at least twice the maximum nominal size of the coarse aggregate. However, it is preferable for the core diameter to be three times the maximum nominal size of the coarse aggregate. For 1½-inch coarse aggregate the minimum core diameter would be 3 inches and preferably 4⅛ inches.

Be careful — a 3-inch-diameter core barrel will provide a core with a smaller diameter. Core barrels are sized by outside diameter, not inside diameter. Select a core barrel greater than 3 inches to obtain a minimum 3-inch-diameter core.

Core length. The length of the core, when capped, should be about twice the diameter. If after capping
the core height is less than the core diameter, then the core shouldn’t be tested. ASTM permits a core length from about equal size to a maximum of twice the size of the core diameter.

**Moisture conditioning.**
The core should be submerged in lime-saturated water at 73.4° F ± 3.0° F for at least 40 hours. Test the core promptly after removing it from the lime-water. If necessary, protect the core with a wet burlap cover until the test.

If directed by the engineer or owner of the project, a core can be preconditioned in another manner (dry), under ASTM C 42. ACI 301 (Ref. 3) and ACI 318 (Ref. 1) both provide guidance for conditioning cores.

**Length-to-diameter ratio.**
The length of the capped core and the core diameter must be measured to the nearest 0.01 inch. Use the average of two core diameter measurements at mid-height. These measurements are used to compute the length-to-diameter ratio.

ASTM provides length-to-diameter correction factors that are used to reduce the compression strength measured by the testing machine.

These correction factors are applicable for concrete strengths ranging from 2000 to 6000 psi, lightweight (100 to 120 pounds per cubic foot [pcf]) and normal-weight concrete, and cores tested wet or dry. A core with a length-to-diameter ratio from 1.94 to 2.10 requires no correction factor. Correction factors not provided by Table 1 can be determined by interpolation.

### Table 1. Length-to-diameter Strength Correction Factor (Ref. 2)

<table>
<thead>
<tr>
<th>Length/Diameter Ratio</th>
<th>Strength Correction Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.75</td>
<td>0.98</td>
</tr>
<tr>
<td>1.50</td>
<td>0.96</td>
</tr>
<tr>
<td>1.25</td>
<td>0.93</td>
</tr>
<tr>
<td>1.00</td>
<td>0.87</td>
</tr>
</tbody>
</table>

**End preparation and capping.**
Don’t forget end preparation and capping. Sloppy capping and unplaned or misaligned ends can affect core strength. Cores, like cylinders, must be properly prepared and capped. The provisions for capping a core are the same as for a cylinder.

### Practical considerations
**When to core?** For new construction, a low 7-day or 28-day compressive strength break usually initiates the coring process. Don’t core too early; bond strength develops slower than compressive strength. ASTM C 42 recommends waiting 14 days until coring to avoid disturbing the bond between the coarse aggregate and mortar. For new concrete cured in cold weather the time period before coring may be longer.

**Where to core?** A low cylinder break usually leads to drilling a core, but where? The National Ready Mixed Concrete Association (Ref. 4) says to avoid coring the top layers of columns, walls, or footings. These top layers will be 10% to 20% weaker than cores from the middle or lower portion (see Figure 1). For vertical structures, ASTM C 42 recommends taking the core from the middle of the deposit.

### Table 2. Dry Versus Wet Compressive Strength

<table>
<thead>
<tr>
<th>Tested Wet</th>
<th>Tested Dry</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Compressive Strength (psi)</strong></td>
<td><strong>Unit Weight (pcf)</strong></td>
</tr>
<tr>
<td>3380</td>
<td>142.4</td>
</tr>
<tr>
<td>2820</td>
<td>138.8</td>
</tr>
<tr>
<td>2970</td>
<td>143.8</td>
</tr>
<tr>
<td>3280</td>
<td>141.9</td>
</tr>
<tr>
<td>2530</td>
<td>140.8</td>
</tr>
<tr>
<td><strong>Avg.</strong></td>
<td><strong>3000</strong></td>
</tr>
</tbody>
</table>
and away from formed joints or edges of the concrete placement.

Cores should be removed from the location in the concrete structure that is considered to have low strength. Most testing laboratories use a rebound hammer for a relative comparison of concrete strength to locate the potentially weak concrete. ACI 301 (Ref. 3) requires the engineer/architect to determine the location of the cores to minimize damage to the structure. If possible, avoid coring through reinforcement. It decreases the life of the core barrel, makes core interpretation difficult, and may decrease the strength of the member.

**Test wet or dry?** ASTM C 42 requires the core to be submerged in lime-saturated water for a minimum of 40 hours prior to testing, and only the project engineer or owner can alter the conditioning requirements of the core. Both ACI 301 and ACI 318 allow the core to be air-dried before testing if the concrete in the structure will be dry under service conditions.

Most engineers consider the difference between dry versus wet compressive strength to be around 10%. However, this may not always be true. Reference 5 reports that air-dried specimens can show a 20% to 25% higher strength than corresponding specimens tested in a saturated condition. On one project in Colorado, the compressive strength of air-dried cores was 1100 psi higher than the compressive strength of saturated cores (Table 2). The average unit weight of the cores for both test conditions was the same, 142.0pcf.

If the concrete will be dry in service, contractors must make sure that their cores will be tested dry in accordance with ACI 301 and ACI 318. Testing wet, when not appropriate, could provide strength results leading to the rejection of good quality concrete.

**Low-strength cores**

Cores drilled through cracks or other defects shouldn’t be tested for compressive strength and neither should a core that breaks during drilling. Also, ACI 318 (Ref. 1) permits the testing of additional cores extracted from a location represented by an erratic core strength result.

Occasionally, be prepared for low-strength cores. However, this doesn’t automatically require the concrete to be removed and replaced. Ask the engineer to review his calculations to consider the effect of low-strength concrete. The load capacity of many reinforced concrete members isn’t controlled by concrete but rather by the reinforcement. Quite often, the concrete can stay in place.

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**The cost of coring**

Cores aren’t free. The cost of a two-man drilling crew runs about $65 an hour. Don’t forget travel time, core barrel wear, and finally testing. Besides compressive strength, most test laboratories also check the density and absorption of the core. Don’t be surprised if the cost of obtaining and testing three cores hits $500.

Who pays for the cores? This varies from region to region. In some areas the contractor always pays for the cores. In other areas, who pays depends upon the strength results. If the strength results indicate good concrete, then the owner pays. If the strength results indicate bad or marginal concrete, then the contractor pays.

Coring questionable concrete usually is a good business practice. Most specifications automatically require cores if the cylinders break low. Following ASTM C 42 and knowing when, where, and what to test, usually provides strength results that make contractors happy. Don’t have good quality concrete rejected—take cores to prove your point.

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**References**

1. ACI 318, “Building Code Requirements for Reinforced Concrete and Commentary,” American Concrete Institute (ACI), P.O. Box 19150, Detroit, MI 48219.
3. ACI 301, “Specifications for Structural Concrete for Buildings.”

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