

# **Center for By-Products Utilization**

## **VARIATION IN CONCRETE CORE STRENGTH**

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## "Variation in Concrete Core Strength"<sup>1</sup>

by  
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Core tests are widely accepted for determining in-situ strength of concrete. However, strength results obtained from core tests are also widely misinterpreted. Typically, core test results are revised only for the L/D ratio other than two. In fact, there are many more factors that affect the core test results. For example, cores obtained from the same concrete having different diameters but the same L/D ratio will yield different strength results.

Factors affecting core test results should be considered in evaluating strength of concrete. Some or all of the following factors should be considered: (1) L/D ratio; (2) diameter; (3) strength level of concrete; (4) aggregate type; (5) moisture condition at the time of testing; (6) direction of core drilling; (7) presence of reinforcing bar; (8) location of core; (9) strength relationship between cylinder and core; etc.

Interpretation of core test results requires experience, judgment and proper accounting of many of these factors that affect the core test results. Unless core test results are properly interpreted, they do not provide the "true" strength of concrete.

In many regulations that govern the design of reinforced concrete, the permissible compressive strength of the concrete is determined from tests on cylinders<sup>3</sup> and cubes. These cylinders are required to be made and cured in accordance with the ASTM Test C39. (<sup>1</sup>) The most frequently used test is the standard 28-day test.

Some specifications (<sup>2</sup>) recognize the normal variability of concrete strength and allow some percentage of the test results to measure below the specified strength level. For instance, ACI 318(2) considers the strength level of the concrete to be satisfactory if the average of three test results are within the specified strength level and no individual test falls more than 500 psi below the specified strength. It is when these test specimen fail to meet the requirements of specifications and there is a concern about the strength of the structure, that tests of cores taken from the structure may be required.

There has been controversy, however, about interpreting the results of core tests. There is a wide disagreement as to:

- (1) at what age the core should be drilled and tested;
- (2) What level of core strength in relation to the specified strength is acceptable;
- (3) What is the relationship between the drilled care and the molded cylinder strength; and,
- (4) What are the important parameters (see p.1) which affect the core strength and what are their effects.

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<sup>3</sup> 6 x 12-in. standard cylinders are used in North America, while in England and several European countries 6 x 6-in. cubes are used.

As an illustration, consider the disparities in interpreting the core strength results. Mattimore<sup>(3)</sup> and U.S.B.R.<sup>(4)</sup> believe that cores give higher strength than control cylinders. On the other hand Petersons<sup>(5)</sup>, Wagner<sup>(6)</sup>, Lapinas<sup>(7)</sup>, Campbell and Tobin<sup>(8)</sup>, Bloem<sup>(9)</sup> and Naik et al.<sup>(10,11)</sup> have shown that cores give lower strength than control cylinders. It is interesting to note that the cores for the U.S.B.R. project were tested at ages greater than 23 months and compared with the 28-day cylinder strength. Bloem and others, however, compared cylinders and cores of about the same age.

The above contradictory conclusions reached regarding core strength results calls for closer study in evaluating the "true" core strength. This formed the basis of a study undertaken at the University of Wisconsin-Milwaukee (UWM), in 1976. The project involved laboratory and literature study to evolve appropriate criteria for evaluating core results. The study involved drilling of 2, 3, 4 and 6-in. diameter cores from several 31 x 31 x 12-in. concrete slabs of nominal 4,000 and 6,000 psi compressive strength. Corresponding control cylinders were also made and tested at about the same age. Core tests were performed at the age beginning 7 days and continued up to the age greater than one year. Other variables that affect the core strength were also investigated<sup>(10)</sup>. Based upon the data collected, and other published information in this country and abroad, a systematic approach is developed for testing and evaluating core strength results. Preliminary results were presented<sup>(11)</sup> earlier at workshops.

Normally compressive strength of concrete is determined from tests conducted on standard cylinders. When these standard cylinders fail to meet the requirements of the specifications, test of cores taken from the suspect concrete may be required. The standard cylinder has a length to diameter ratio (L/D) of 2. In practice, however, it is not always possible to obtain cores with L/D ratio of 2 because the structural unit may not be thick enough to yield a core whose length is twice the diameter. The standard cylinder has a diameter of 6 in. The cores, however, are usually 4 in. in diameter or smaller for a typical building or bridge structure. For 3/4 in. maximum size coarse aggregates, ASTM C-42 allows cores as small as 1.5 in. in diameter. Cores having L/D of 2, with diameters of 6, 4 or 1.5 in., will give different indicated compressive strength values.

Correction factors are given by the ASTM C-42 for L/D ratio other than 2. These correction factors apply either for cores tested wet (after 40 hours of soaking in lime saturated water). ACI 318 requires that cores be tested dry, after drying them at room temperature for 7 days, "if the concrete in the structure will be dry under service conditions." Furthermore, ASTM C-42 has not given any correction factors for different diameter cores having the same L/D ratio.

The foregoing indicates a need for studying dimensional effects on concrete cores tested dry. Kesler in 1959 reported on ASTM cooperative investigation in which he concluded, "dried and autoclaved specimens require greater corrections than do specimen . . . tested wet." A paper published by Meininger et al. (NRMCA-USA, 1977), after the work on a similar project had been started at UW-Milwaukee, UWM, has given correction factors for the L/D ratio for 4 in. diameter cores. These cores were taken perpendicular to the direction of casting, simulating cores drilled from walls and columns.

The UWM investigation was to find correction factors for cores tested dry by coring in the direction of casting, simulating cores drilled from slabs and pavements. Dimensional effects

was studied for the concrete age beginning 7 days up to one year or more, for core diameters 2, 3, 4 and 6 in., and for L/D ratios 0.5, 1.0, 1.25, 1.50, 1.75 and 2.00. A nominal 5-1/2 bags and 7-1/2 bags concrete mixes, 3/4 in. maximum size coarse aggregates, was used. Corresponding standard cylinders of diameters 2, 3, 4 and 6 in. were also made for comparison.

The results show that:

- (1) The 7-day air drying period required by the ACI 318 is arbitrary, time consuming and not necessary. The 3 in. diameter cores lost 3.4 percent weight during the first 3 days of air drying and lost only an additional 0.4 percent weight after additional 4 days of drying. Similarly, 6 in. diameter cores lost only 0.1 percent additional weight after the first 3 days of drying.
- (2) ASTM C-42 and ACI 318 do not recognize that for the same L/D ratio, different diameter cores could yield different strength results. Considerable data were collected to study this parameter. The study is continuing to establish results to show the effect of diameter on the core strength. Lewis (NRMCA-Australia, 1971) also has shown this dimensional effect to be important.

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