Report on Methods for Estimating In-Place Concrete Strength

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Reported by ACI Committee 228

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This report provides methods for estimating the in-place strength of concrete in new and existing construction. These methods include: rebound number, penetration resistance, pullout, pull-off, ultrasonic pulse velocity, maturity, and cast-in-place cylinders. The principle, inherent limitations, and repeatability of each method are reviewed. Procedures are presented for developing the relationship needed to estimate compressive strength from in-place results. Factors to consider in planning in-place tests are discussed, and statistical techniques to interpret test results are presented. The use of in-place tests for acceptance of concrete is introduced. The Appendix A provides information on the number of strength levels that should be used to develop the strength relationship and explains a regression analysis procedure that accounts for error in both dependent and independent variables.

Keywords: coefficient of variation; compressive strength; construction safety; in-place tests; nondestructive tests; sampling; statistical analysis.

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CHAPTER 1—INTRODUCTION

1.1—Scope

In-place tests are performed typically on concrete within a structure, in contrast to tests performed on molded specimens made from the concrete to be used in the structure. Historically, they have been called nondestructive tests because some of the early tests, such as rebound number and ultrasonic pulse velocity, were noninvasive and did not damage the concrete. Over the years, however, new methods have developed that result in superficial local damage. Therefore, the terminology "in-place tests" is used as a general name for these test methods, which includes those that do not damage the concrete and those that result in some near-surface damage. In this report, the principal application of in-place tests is to estimate the compressive strength of the concrete. The pull-off test can be used to estimate the tensile strength of concrete or evaluate bond strength between layers. The significant characteristic of most of these tests is that they do not directly measure the compressive strength of the concrete in a structure. Instead, they measure some other property that can be correlated to compressive strength (Popovics 1998). The strength is then estimated from a previously established relationship between the measured property and concrete strength. The uncertainty of the estimated compressive strength depends on the variability of in-place test results and the uncertainty of the relationship between these two parameters. These sources of uncertainty are discussed in this report. An alternative approach for correlation between tests results and concrete strength is presented in EN 13791 (2007) and BS 6089 (2010).

In-place tests can be used to estimate concrete strength during construction so that operations requiring a specific strength can be performed safely or curing procedures terminated. They can also be used to estimate concrete strength during the evaluation of existing structures. These two applications require slightly different approaches, so parts of this report are separated into sections dealing with new and existing construction.

A variety of techniques are available for estimating the in-place strength of concrete (Malhotra 1976; Bungey et al. 2006; Malhotra and Carino 2004). No attempt is made to review all methods in this report; only those methods that have been standardized by ASTM International are discussed. Examples of methods not covered include internal fracture tests (Chabowski and Bryden-Smith 1980; Domone and Castro 1987) and torque tests (Stoll 1985).

1.2—Need for in-place tests during construction

In North American practice, the most widely used test for concrete is the compressive strength test of standard cylinders (ASTM C39/39M). This test procedure is relatively easy to perform in terms of sampling, specimen preparation (ASTM C31/C31M), and strength measurement. When properly performed, this test has low single-operator variation and low interlaboratory variation and, therefore, the method lends itself to use as a standardized testing procedure. The compressive strength so obtained is used to verify that the specified strength (f_c') used to calculate the nominal strengths of structural members has been achieved. Therefore, the compressive strength of standard cylinders is an essential parameter in design codes and project specifications.

When carried out according to standard procedures, however, the results of the cylinder compression test represent the potential strength of the concrete as delivered to a site. The test is used mainly as a basis for quality assurance of the concrete to ensure that contract requirements are met. It is not intended for determining the in-place strength of the concrete because it makes no allowance for the effects