

Use of Accelerated Strength Testing

Reported by ACI Committee 214

This report describes the three accelerated test methods given in ASTM C684 and gives guidance for the interpretation of the test results with the help of examples.

Keywords: coefficient of variation; **compression tests;** compressive strength; concrete construction; **concretes;** cylinders; **evaluation;** **quality control;** sampling; standard deviation; **statistical analysis;** variations.

Introduction

In concrete construction, the 28-day compressive test is usually used to evaluate the strength of concrete, although ACI 318 permits ages other than 28-days for acceptance purposes. Results of the 28-day tests determine if adjustments are required in the batching and mixing process to satisfy concrete quality parameters. With present methods of rapid construction it is imperative that methods be developed to estimate the 28-day strength of concrete cylinders at an earlier age.

ASTM Standard C684 specifies the following procedures to provide an early indication of the potential strength of concrete and the variability of the production process.²

Procedure A — Warm Water Method

Procedure B — Boiling Water Method

Procedure C — Autogenous Method

Procedures A and B permit testing of the cylinders at 24 and 28½ hr respectively, while Procedure C requires 49 hr (± 15 minutes) of curing before testing. Variations of these tests are used to con-

form with normal working hours. For example, one testing laboratory uses a 72 hr test for cylinders made at jobsites on Friday. This permits boiling, cooling, capping, and testing on Mondays.

All three test procedures listed require equipment to control the temperature of the cylinders during the accelerated curing cycle. Fig. 1 and 2 show schematic drawings for two of the methods. After curing, the cylinders should be tested in accordance with ASTM procedures. When Procedure A is used, the cylinders are cured in a warm water bath at 95 ± 5 F (35 ± 3 C) for $23\frac{1}{2}$ hr; ± 30 min. The warm water acts as an insulator and most of the acceleration in strength is provided by the heat of hydration. Procedure B requires an initial cure of 23 hr at 70 ± 10 F (21 ± 5 C) followed by immersion in boiling water for $3\frac{1}{2}$ hr. A thermally insulated container is used with Procedure C. Cylinders are stored in this container for 48 hr, and the heat generated by hydration of the cement accelerates the strength gain. The most important use of accelerated test data is for quality control to permit rapid adjustment of batching and mixing. To estimate the 28-day strength from the accelerated strength test data, an equation must be established for the specific concrete mix using the same materials. This correlation is presently necessary because of the traditional use of the 28-day strength for design procedures. However, in the future as acceptance criteria change, it may be possible to work directly with accelerated strength tests.

Adequate lead time must be provided to establish basic correlation equations. Among factors that need to be considered are: project size, climatic conditions, properties of concrete mix and material, and physical facilities at a batching plant or jobsite. A minimum of 30 sets of test data covering a wide strength range are needed to establish an adequate correlation equation; for a single strength require-

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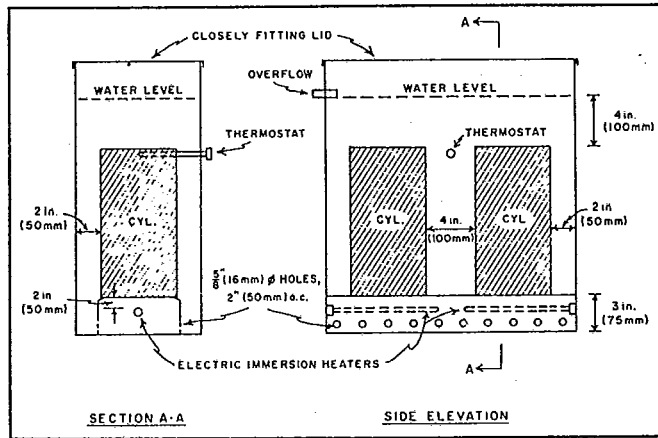


Fig. 1 — Accelerated curing water tank (Procedure A).

ment, the strength range should include the specified strength and should equal at least 75 percent of the specified strength. It should be achieved by the use of not fewer than three water-cement ratios. A correlation coefficient of less than 0.80 should be regarded with suspicion. Fig. 3 shows a typical correlation curve for cylinders tested by the boiling method.⁵ Similar curves can be developed for other methods.

Interpretation of test results

ACI 214, "Recommended Practice for Evaluation of Strength Test Results of Concrete," can be used in interpreting both standard and accelerated test results. The following formula and table of t values can be used for the application of statistical procedures to quality control of concrete:

$$f_{cr} = f_c' + t\sigma \quad (1)$$

where

f_{cr} = required average strength,

f_c' = design strength specified

t = a constant depending on the proportion of tests that may fall below f_c' . (Table 1)

σ = forecast value of the standard deviation.

The value of f_{cr} obtained from this equation can be either the usual 28-day strength or the actual accelerated strength, depending upon the corresponding value of f_c' .

The probability value, t , (Table 1) estimates the percentage of cylinders that do not achieve the mix proportion strength f_c' . For example, a value of t equal to 1.28 indicates that 10 percent of the cylinders will test lower than f_c' .

The standard deviation, σ , is based on the variability of test results. For concrete batch plants that have a capability of supplying a consistent strength in their product, the value of σ will be low. References 1, 3, and 4 present methods for computing the standard deviation.

Other statistical methods for comparing test data for different projects and the variation within tests are also presented in ACI 214.¹ However, the above formula is all that is needed to establish the target

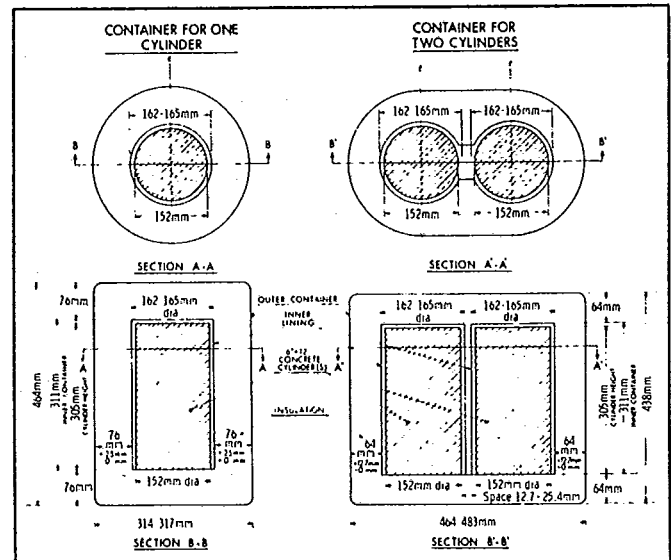


Fig. 2 — Autogenous curing container (Procedure C).

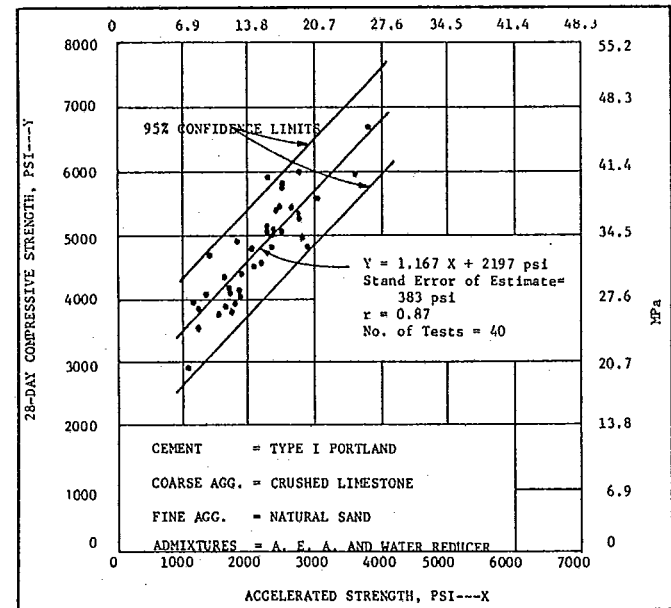


Fig. 3 — Relationship between accelerated and 28-day compressive strength of concrete. Data obtained by the boiling method (Procedure B).

TABLE 1 — Values of t for the equation: $f_{cr} = f_c' + t\sigma$

Number	Likelihood of low test results	t
	Percentage	
1 in 1000	0.1	3.09
1 in 500	0.2	2.88
1 in 100	1.0	2.33
1 in 50	2.0	2.06
1 in 25	4.0	1.75
1 in 20	5.0	1.65
1 in 10	10.0	1.28
1 in 5	20.0	0.84
1 in 2	50.0	0.00