IN-LB	Inch-Pound Units
SI	International System of Units

Obtaining Cores and Interpreting Core Compressive Strength Results—Guide

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Core testing is the most direct method to determine the compressive strength of concrete in a structure. Generally, cores may be obtained to assess whether concrete in a new structure complies with strength-based acceptance criteria or to evaluate structural capacity of an existing structure based on in-place concrete strength. In either case, the process of obtaining core specimens and interpreting strength test results is often confounded by various factors affecting in-place concrete strength or the measured strength of a test specimen. The scatter in strength test data, which is unavoidable given the inherent randomness of in-place concrete strengths and the uncertainty attributable to preparation and testing of the specimen, may further complicate compliance and evaluation decisions.

This guide summarizes practices for obtaining cores and interpreting core compressive strength test results. Factors that affect in-place concrete strength are reviewed so sampling locations that are consistent with objectives of the investigation can be selected. Strength correction factors are presented for converting measured strength of nonstandard core-test specimens to strength of equivalent specimens with standard diameters, length-to-diameter ratios, and moisture conditioning that have been derived using data for normalweight concrete with strengths between 2000 and 13,400 psi (14 and 92 MPa). This guide also provides direction for checking strength compliance of concrete in a structure under construction and methods for determining equivalent specified strength to assess existing structure capacity.

Keywords: compressive strength; core; hardened concrete; sampling; test.

CONTENTS

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CHAPTER 1—INTRODUCTION

1.1—Introduction

Core testing is the most direct method to determine in-place compressive strength of concrete in a structure. Generally, cores for strength assessment are obtained to:

a) Assess, if required, whether concrete in a new structure complies with strength-based acceptance criteria
b) Determine in-place concrete strengths in an existing structure for evaluation of structural capacity

In new construction, cylinder strength tests failing to meet strength-based acceptance criteria can be investigated using provisions given in ACI 301. These criteria specify the circumstances when core tests are permitted, the number of cores to be tested, the conditioning of the cores before testing, the limits on the time interval between coring and testing, and the basis for determining whether the concrete in the area represented by the core strengths is structurally adequate. This guide presents procedures for obtaining and testing cores and interpreting results in accordance with ACI 301.

If strength records are unavailable, the in-place strength of concrete in an existing structure can be evaluated using cores. In-place concrete compressive strength determination is simplified when in-place strength data are converted into equivalent specified concrete compressive strength f_c' values that can be directly substituted into conventional strength equations with customary strength reduction factors. This guide presents procedures for performing this conversion in a manner consistent with the assumptions used to derive strength reduction factors for structural design.

Analysis of core test data can be difficult and lead to uncertain interpretations and conclusions. Based on 10 hypothetical core test results (Hanson 2007), 23 practitioners estimated the concrete compressive strength of in-place concrete between 3000 and 5000 psi (21 and 35 MPa). Strength interpretations should always be made by, or with the assistance of, an investigator experienced in concrete technology. Factors contributing to the scatter of core strength test results include:

a) Systematic variation of in-place strength along a member or throughout the structure
b) Random variation of concrete strength, both within one batch and among batches
c) Low test results attributable to flawed test specimens or improper test procedures
d) Effects of the size, aspect ratio, and moisture condition of the test specimen on the measured strengths
e) Additional uncertainty attributable to testing that is present even for tests performed in strict accordance with standardized testing procedures

1.2—Scope

This guide summarizes current practices for obtaining cores and interpreting core compressive strength test results in light of past and current research findings. Many of these findings are based on older references, as the research has reached a mature state. Distinct procedures are presented for two cases:

1) To assess whether concrete strength in a new structure complies with strength-based acceptance criteria
2) To determine an in-place concrete strength that is equivalent to the specified concrete compressive strength f_c' to be directly substituted into conventional strength

equations with customary strength reduction factors for strength evaluation of an existing structure

It is inappropriate to use procedures in Chapter 9 for determining equivalent specified concrete strength to assess whether suspect concrete in a new structure complies with strength-based acceptance criteria.

The order of contents parallels the logical sequence of activities in a typical core-test investigation. Chapter 3 describes how bleeding, consolidation, curing, and microcracking affect in-place concrete strength in structures so the investigator can account for this strength variation when planning the testing program. Chapter 4 identifies preferred sample locations and provides guidance on the number of specimens that should be obtained. Chapter 5 summarizes coring techniques that should result in high-quality, undamaged, representative test specimens. Chapter 6 describes procedures for testing cores and detecting outliers by inspection of load-machine displacement curves or using statistical tests from ASTM E178. Chapter 7 summarizes the subsequent analysis of strength test data, including use of ASTM C42/C42M precision statements, research findings concerning accuracy of empirically derived core strength correction factors, and statistical analysis techniques. Chapter 8 briefly elaborates on criteria presented in ACI 301 for using core test results to investigate low-strength cylinder test results in new construction. Chapter 9 presents two methods for estimating the lower tenth-percentile value of in-place concrete strength using core test data to quantify in-place strength. This value is equivalent to the specified concrete strength f_c' and can be directly substituted into conventional strength equations with customary strength reduction factors for strength evaluation of an existing structure.

Example calculations are presented in the appendix for:

a) Outlier identification in accordance with ASTM E178 criteria

b) Determining whether a difference in mean strengths of cores from beams and columns is statistically significant

c) Applying minimum strength acceptance criteria for samples with more than three cores

d) Computing the equivalent specified strength using the two approaches presented in Chapter 9

CHAPTER 2—NOTATION AND DEFINITIONS

2.1—Notation

C = constant related number of batches, number of members, and type of construction, alternate method

d = diameter of core, in. (mm)

e = predetermined maximum error expressed as a percentage of the population average

F_d = correction factor for damage

F_{dia} = correction factor for core diameter

$F_{\ell/d}$ = correction factor for length-to-diameter ratio

F_{mc} = correction factor for moisture content

$f_{0.10}$ = compressive strength of concrete at 10 percent fractile, psi (MPa)

f_c = equivalent in-place compressive strength of concrete, psi (MPa)

$\bar{f}_c$ = sample mean of equivalent in-place compressive strength of concrete, psi (MPa)

$(\bar{f}_c)_{CL}$ = lower bound estimate of the sample mean equivalent in-place compressive strength of concrete at confidence limit CL, alternate method, psi (MPa)

f_c' = specified compressive strength of concrete, psi (MPa)

$f_{c,eq}'$ = equivalent design compressive strength of concrete, tolerance factor method, psi (MPa)

f_{ci} = equivalent in-place compressive strength of individual core specimen, psi (MPa)

f_{co} = compressive strength of concrete core, corrected for ℓ/d, in accordance with ASTM C42/C42M psi (MPa)

$\bar{f}_{co}$ = sample mean core compressive strength of concrete, psi (MPa)

f_{core} = core compressive strength of concrete, psi (MPa)

$f_{min,eq}$ = equivalent minimum strength for samples of more than three cores, psi (MPa)

K = correction factor for number of cores, tolerance factor method

K_1 = coefficient used in equivalent minimum-strength criterion computation

K_2 = coefficient used in equivalent minimum-strength criterion computation

ℓ = length of core, in. (mm)

n = number of samples

P_1 = probability used to determine acceptable minimum strength criteria for samples of more than three cores

P_2 = probability computed in equivalent minimum-strength criterion computation

$p_Y(y)$ = probability computed using binomial distribution in determination of equivalent number of low strengths criterion

s_a = standard deviation of strength correction factors, psi (MPa)

s_c = sample standard deviation of equivalent in-place compressive strength of concrete, psi (MPa)

s_{co} = sample standard deviation of core compressive strength of concrete, psi (MPa)

s_o = overall standard deviation, psi (MPa)

T = factor related to the probability of an occurrence, student's t test method

V = coefficient of variation, ratio of standard deviation to arithmetic average, percent

V_d = coefficient of variation associated with F_d, percent

V_{dia} = coefficient of variation associated with F_{dia}, percent

$V_{\ell/d}$ = coefficient of variation associated with $F_{\ell/d}$, percent

V_{mc} = coefficient of variation associated with F_{mc}, percent

V_{WS} = coefficient of variation of in-place strengths

Z = correction factor to adjust for the uncertainty of strength correction factors, tolerance factor method

ϕ = standard normal cumulative distribution function