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Report on Nondestructive Test Methods for Evaluation of Concrete in Structures

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A review is presented of nondestructive test (NDT) methods for evaluating the condition of concrete and steel reinforcement in structures. Methods discussed include visual inspection, stress-wave, nuclear, measurement of fluid transport properties, magnetic and electrical, infrared thermography, and ground-penetrating radar. The principle of each method is discussed and the typical instrumentation described. Testing procedures are summarized and the data analysis methods explained. The advantages and limitations of the methods are highlighted. This report concludes with a discussion of planning a NDT program. General information is provided for those faced with the task of evaluating the condition of a concrete structure and who are considering the applicability of NDT methods to aid in that evaluation.

Keywords: covermeter; deep foundations; half-cell potential; infrared thermography; nondestructive testing; polarization resistance; radar; radiography; radiometry; stress-wave methods; transport properties; visual inspection.

CONTENTS

ACI 228.2R-13 supersedes ACI 228.2R-98(04) and was adopted and published June 2013.

CHAPTER 1—INTRODUCTION

1.1—Scope

Nondestructive testing (NDT) methods are used to determine concrete properties and to evaluate the condition of concrete in deep foundations, bridges, buildings, pavements, dams, and other concrete construction. For this report, NDT is defined as generally noninvasive, with the exception of transport property tests, which may cause easily-repaired surface damage. While coring and load testing may be considered nondestructive, they are excluded from this report. Refer to ACI 437R for more information about strength evaluation of existing concrete buildings.

NDT methods are applied to concrete construction for four primary reasons:

1. Quality control of new construction
2. Troubleshooting problems with new and old construction
3. Condition evaluation of older concrete for rehabilitation purposes
4. Quality assurance of concrete repairs

NDT technologies are evolving and research continues to enhance existing methods and develop new methods. The report is intended to provide an overview of the principles of various NDT methods practiced and to summarize their applications and limitations. Emphasis is placed on methods that have been applied to measure physical properties other than the strength of concrete in structures, to detect flaws or discontinuities, and to provide data for condition evaluation. Methods to estimate in-place compressive strength are presented in ACI 228.1R.

1.2—Needs and applications

Nondestructive testing (NDT) methods are increasingly applied for the investigation of concrete structures. This increase in the application of NDT methods is due to a number of factors:

a) Technological improvements in hardware and software for data collection and analysis

b) The economic advantages in assessing large volumes of concrete compared with other methods

c) Ability to perform rapid, comprehensive assessments of existing construction

d) Specification of NDT methods for quality assurance of deep foundations and concrete repairs

An increased use of NDT methods is occurring despite the lack of testing standards for many of the methods. The development of testing standards is critical for proper application and expanded use of NDT methods for evaluation of concrete construction.

Traditionally, quality assurance of concrete construction has been performed largely by visual inspection of the construction process and by sampling the concrete to perform standard tests on fresh and hardened specimens. This approach does not provide data on the in-place properties of concrete. NDT methods offer the advantage of providing information on the in-place properties of hardened concrete, such as the elastic constants, density, resistivity, moisture content, and fluid transport characteristics.

Condition assessment of concrete for structural evaluation purposes has been performed mostly by visual examination, coring, and surface sounding, which refers to striking the object surface and listening to characteristics of the resulting sound. Condition assessments are used to examine internal concrete conditions and to obtain specimens for testing. This approach limits the areas of concrete that can be investigated effectively. Some coring may be necessary for calibration purposes, particularly if the concrete strength is required. Cores also cause local damage and limit the information to the core location. Condition assessments can be made with NDT methods to provide essential information for the structural performance of the concrete, such as:

a) Member dimensions

b) Location of cracking, delamination, and debonding

c) Degree of consolidation, presence of voids, and honeycomb

d) Steel reinforcement location and size

e) Corrosion activity of reinforcement

f) Extent of damage from freezing and thawing, fire, or chemical exposure

g) Strength of concrete

1.3—Objective

This report reviews the state of the practice for nondestructively determining nonstrength physical properties and conditions of hardened concrete. The overall objective is to provide the potential user with a guide to assist in planning, conducting, and interpreting the results of nondestructive tests (NDT) of concrete construction.

Chapter 3 discusses the principles, equipment, testing procedures, and data analysis of the various NDT methods. Typical applications and inherent limitations of the methods are discussed to assist the potential user in selecting the most appropriate method for a particular situation. Chapter 4 discusses the planning and performance of NDT investigations. Included in Chapter 4 are references to in-place tests covered in ACI 228.1R and other applicable methods for evaluating the characteristics of existing concrete.

CHAPTER 2—NOTATION AND DEFINITIONS

2.1—Notation

Because NDT crosses different science and engineering disciplines, the same symbols are used differently by different practitioners. The context of the symbol should be established and related to the body of text.

A = cross-sectional area (3.5.3, 3.6.2); wetted area (3.6.2)