Comparison of Various Samples of Concrete Using Non-Destructive Testing: A Review of Methods

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ABSTRAT

This paper reviews the most common non-destructive testing (NDT) methods of concrete structures as utilized by the structural engineering industry. The fundamentals of NDT methods are explored in regards to their potential, limitations, inspection techniques and interpretations. The factors that influence the success of NDT methods are discussed and the ways to mediate their influence are recommended. Reference is made to standard guidelines for the applications and interpretation of the discussed NDT methods. NDT of concrete was found to be gaining increasing acceptance as a means of evaluating the strength, uniformity, durability and other properties of existing concrete structures. Perceptions of NDT in adequacy were attributable to lack of understanding construction materials and NDT methods themselves. The intent of this paper is to address these concerns by identifying and describing the most common successful methods of NDT as applied to concrete structures.

The concept of nondestructive testing (NDT) is to obtain material properties of in place specimens without the destruction of specimen nor the structure from which it is taken. However, one problem that has been prevalent within the concrete industry for years is that the true properties of an in-place specimen have never been tested without leaving a certain damage on the structure. For most cast-in-place concrete structures, construction specifications require that test cylinders be cast for 28-day strength determination. Usually, representative test specimens are cast from the same concrete mix as the structural elements. Unfortunately test specimen are not an exact representation of in-situ concrete, and may be affected by variations in specimen type, size and curing procedures. The use of the combined methods produces results that lie close to the true values when compared with other methods. The method can be extended to test existing structures by taking direct measurements on concrete elements.

Index Terms: Non-destructive testing, Overview of methods, ND methods in practice

INTRODUCTION

Non-destructive testing is define as the course of inspecting, testing or evaluating materials, components or assemblies without destroying the serviceability of the part or system (Workman& O. Moore, 2012). The purpose of NDT is to determine the quality and integrity of materials, components or assemblies without affecting the ability to perform their intended functions. Non-destructiveness ought not to be confused with non-invasiveness. Testing methods that do not affect the future usefulness of a part or system are considered to be non-destructive even if they consist of invasive actions. For example, coring is a common NDT method that is employed to extract and test specimens from concrete components in orde3r to determine the properties of in-situ concrete. Coring alters the appearance of the component and marginally affects its structural integrity.

Destructive testing explores failure mechanisms to determine the mechanical properties of material such as yield strength, compressive strength, tensile strength, ductility and fracture toughness. NDT methods explore indications of properties without reaching component or assembly failures. Extensive attempts and advancements have been made to develop NDT methods capable of indicating mechanical, acoustical, chemical, electrical, magnetic and physical properties of materials. One of the earliest documented attempts of NDT dates to the 19th century where cracks were detected in railroad wheels by means of acoustic tap testing (Stanley, 1995). More sensitive, reliable and quantifiable NDT methods have expansively emerged in recent years. NDT methods have materialized as a response to the need for structural damage detection and prevention. The steps for choosing an adequate NDT method are (Shull):

- Understanding the physical nature of the material property or discontinuity to be inspected;
- Understanding the underlying physical processes that govern the NDT method.

OVERVIEW OF THE NDT METHODS

- **Introduction to NDE Methods**

A. For strength estimation of concrete

(i) Rebound hammer test

(ii) Ultrasonic Pulse Velocity Tester

(iii) Combined use of Ultrasonic Pulse Velocity tester and rebound hammer test

(iv) Pull off test

(v) Pull out test

(vi) Break off test

B. For assessment of corrosion condition of reinforcement and to determine reinforcement diameter and cover

(i) Half-cell potentiometer

(ii) Resistively meter test

(iii) Test for carbonation of concrete

(iv) Test for chloride content of concrete

(v) Profometer

(vi) Micro covermeter

C. For detection of cracks/voids/ delamination etc.

(i) Infrared thermographic technique

(ii) Acoustic Emission techniques

(iii) Short Pulse Radar methods

(iv) Stress wave propagation methods

- pulse echo method

- impact echo method

- response method

Concrete technologists practice NDE methods for

(a) Concrete strength determination (b) Concrete damage detection

(a) Strength determination by NDE methods:

Strength determination of concrete is important because its elastic behavior & service behavior can be predicted from its strength characteristics. The conventional NDE methods typically measure certain properties of concrete from which an estimate of its strength and other characteristics can be made. Hence, they do not directly give the absolute values of strength.

Damage detection by NDE methods:

Global techniques: These techniques rely on global structural response for damage identification. Their main drawback is that since they rely on global response, they are not sensitive to localized damages. Thus, it is possible that some damages which may be present at various locations remain un-noticed.

Local techniques: These techniques employ localized structural analysis, for damage detection. Their main drawback is that accessories like probes and fixtures are required to be physically carried around the test structure for data recording. Thus, it no longer remains autonomous application of the technique. These techniques are often applied at few selected locations, by the instincts/experience of the engineer coupled with visual inspection. Hence, randomness creeps into the resulting data.

NDE Methods in Practice

Visual inspection: The first stage in the evaluation of a concrete structure is to study the condition of concrete, to note any defects in the concrete, to note the presence of cracking and the cracking type (crack width, depth, spacing, density), the presence of rust marks on the surface, the presence of voids and the presence of apparently poorly compacted areas etc. Visual assessment determines whether or not to proceed with detailed investigation.

The Surface hardness method: This is based on the principle that the strength of concrete is proportional to its surface hardness. The calibration chart is valid for a particular type of cement, aggregates used, moisture content, and the age of the specimen.

The penetration technique: This is basically a hardness test, which provides a quick means of determining the relative strength of the concrete. The results of the test are influenced by surface smoothness of concrete and the type and hardness of the aggregate used. Again, the calibration chart is valid for a particular type of cement, aggregates used, moisture content, and age of the specimen. The test may cause damage to the specimen which needs to be repaired.

The pull-out test: A pullout test involves casting the enlarged end of a steel rod after setting of concrete, to be tested and then measuring the force required to pull it out. The test measures the direct shear strength of concrete. This in turn is correlated with the compressive strength; thus a measurement of the in-place compressive strength is made. The test may cause damage to the specimen which needs to be repaired.

The rebound hammer test: The Schmidt rebound hammer is basically a surface hardness test with little apparent theoretical relationship between the strength of concrete and the rebound number of the hammer. Rebound hammers test the surface hardness of concrete, which cannot be converted directly to compressive strength. The method basically measures the modulus of elasticity of the near surface concrete. The principle is based on the absorption of part of the stored elastic energy of the spring through plastic deformation of the rock surface and the mechanical waves propagating through the stone while the remaining elastic energy causes the actual rebound of the hammer. The distance travelled by the mass, expressed as a percentage of the initial extension of the spring, is called the Rebound number. There is a considerable amount of scatter in rebound numbers because of the heterogeneous nature of near surface properties (principally due to near-surface aggregate particles).

There are several factors other than concrete strength that influence rebound hammer test results, including surface smoothness and finish, moisture content, coarse aggregate type, and the presence of carbonation. Although rebound hammers can be used to estimate concrete strength, the rebound numbers must be correlated with the compressive strength of molded specimens or cores taken from the structure.

Ultra-sonic pulse velocity test: This test involves measuring the velocity of sound through concrete for strength determination. Since, concrete is a multi-phase material, speed of sound in concrete depends on the relative concentration of its constituent materials, degree of compacting, moisture content, and the amount of discontinuities present. This technique is applied for measurements of composition (e.g. monitor the mixing materials during construction, to estimate the depth of damage caused by fire), strength estimation, homogeneity, elastic modulus and age, & to check presence of defects, crack depth and thickness measurement. Generally, high pulse velocity readings in concrete are indicative of concrete of good quality. The drawback is that this test requires large and expensive transducers. In addition, ultrasonic waves cannot be induced at right angles to the surface; hence, they cannot detect transverse cracks.

Acoustic emission technique: This technique utilizes the elastic waves generated by plastic deformations, moving dislocations, etc. for the analysis and detection of structural defects. However, there can be multiple travel paths available from the source to the sensors. Also, electrical interference or other mechanical noises hampers the quality of the emission signals.

Impact echo test: In this technique, a stress pulse is introduced at the surface of the structure, and as the pulse propagates through the structure, it is reflected by cracks and dislocations. Through the analysis of the reflected waves, the locations of the defects can be estimated. The main drawback of this technique is that it is insensitive to small sized cracks.

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