STRUCTURAL HEALTH ASSESSMENT BY NON DESTRUCTIVE TESTING

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***ABSTRACT*: Structures are assemblies of load carrying members capable of safely transferring the superimposed loads to the foundations. Their main and most looked after property is the strength of the material that they are made of Concrete, as we all know, is an integral material used for construction purposes. Thus, strength of concrete used, is required to be 'known' before starting with any kind of analysis.**

In the recent past, various methods and techniques, called as Non-Destructive Evaluation (NDE) techniques, are being used for Structural Health Monitoring (SHM).The concept of Non-destructive testing (NDT) is to obtain material properties of in place specimens without the destruction of the 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 degree of 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 larger structural elements. The energy absorbed by the concrete is related to its strength. There is no unique relation between hardness and strength of concrete but experimental data relationships can be obtained from a given concrete. However, this relationship is dependent upon factors affecting the concrete surface such as degree of saturation, carbonation, temperature, surface preparation and location, and type of surface finish.Unfortunately, test specimens are not an exact representation of in-situ concrete, and may be affected by variations in specimen type, size, and curing procedures.The aim of the project was to obtain the Calibration Graphs for Non Destructive Testing Equipments viz., the Rebound Hammer and Ultrasonic pulse Velocity Tester and to study the effect of reinforcement on the obtained results. These Non Destructive Instruments were then used to test the columns, beams and slabs of two double storied new buildings at Rai Industrial Area, Sonepat.

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.

***Keywords*: Non-Destructive Evaluation, Structural Health Monitoring, Columns, Steel, Composite Sections of concrete & compressive Strength, stress-strain relations,strength determination, Concrete damage detection.**

Introduction:

The direct determination of the strength of concrete implies that concrete specimens must be loaded to failure. Therefore, the determination of concrete strength requires special specimens to be taken, shipped, and tested at laboratories. This procedure may result in the actual strength of concrete, but may cause trouble and delay in evaluating existing structures. Because of that, special techniques have been developed in which attempts were made to measure some concrete properties other than strength, and then relate them to strength, durability, or any other property. Some of these properties are hardness, resistance to penetration or projectiles, rebound number, resonance frequency, and ability to allow ultrasonic pulses to propagate through concrete. Concrete electrical properties, its ability to absorb, scatter, and transmit X-rays and gamma rays, its response to nuclear activation, and its acoustic emission allow us to estimate its moisture content, density, thickness, and its cement content. However, the term "non-destructive" is given to any test that does not damage or affect the structural behaviour of the elements and also leaves the structure in an acceptable condition for the client.

Columns are considered critical elements in structures. Reinforced concrete columns are the main load bearing elements of any structure. They support the beams and slabs and transfer the loads to the foundations. Hence they have to be designed and detailed adequately toresist both gravity and lateral loads. To keep a high level of structural safety, durability and performance of the infrastructure in each country, an efficient system for early and regular structural assessment is urgently required. The quality assurance during and after the construction of new structures and after reconstruction processes and the characterisation of material properties and damage as a function of time and environmental influences is more and more becoming a serious concern. Non-destructive testing (NDT) methods have a large potential to be part of such a system. NDT methods in general are widely used in several industry branches. Aircrafts, nuclear facilities, chemical plants, electronic devices and other safety critical installations are tested regularly with fast and reliable testing technologies. A variety of advanced NDT methods are available for metallic or composite materials.

Structural Health Monitoring

Structural health monitoring is at the forefront of structural and materials research. Structural health monitoring systems enable inspectors and engineers to gather material data of structures and structural elements used for analysis. Ultrasonics can be applied to structural monitoring programs to obtain such data, which would be especially valuable since the wave properties could be used to obtain material properties. This testing approach may be used to assess the uniformity and relative quality of the concrete, to indicate the presence of voids and cracks, and to evaluate the effectiveness of crack repairs. It may also be used to indicate changes in the properties of concrete, and in the survey of structures, to estimate the severity of deterioration or cracking. Decreases in ultrasonic waves speeds over time can reveal the onset of damage before visible deficiencies become evident. This allows inspectors and engineers to implement repair recommendations before minor deficiencies become safety hazards.

Structural Health Assessment by Non-Destructive Testing

The quality of new concrete structures is dependent on many factors such as type of cement, type of aggregates, water cement ratio, curing, environmental conditions etc. Besides this, the control exercised during construction also contributes a lot to achieve the desired quality. The present system of checking slump and testing cubes, to assess the strength of concrete, in structure under construction, are not sufficient as the actual strength of the structure depend on many other factors such as proper compaction, effective curing also. Considering the above requirements, need of testing of hardened concrete in new structures as well as old structures, is there to assess the actual condition of structures. Non-Destructive Testing (NDT) techniques can be used effectively for investigation and evaluating the actual condition of the structures. These techniques are relatively quick, easy to use, and cheap and give a general indication of the required property of the concrete. This approach will enable us to find suspected zones, thereby reducing the time and cost of examining a large mass of concrete. The choice of a particular NDT method depends upon the property of concrete to be observed such as strength, corrosion, crack monitoring etc.

The subsequent testing of structure will largely depend upon the result of preliminary testing done with the appropriate NDT technique. The NDT being fast, easy to use at site and relatively less expensive can be used for

(i) Testing any number of points and locations
(ii) Assessing the structure for various distressed conditions
(iii) Assessing damage due to fire, chemical attack, impact, age etc.
(iv) Detecting cracks, voids, fractures, honeycombs and weak locations
(v) Assessing the actual condition of reinforcement

Variety of NDT methods have been developed and are available for investigation and evaluation of different parameters related to strength, durability and overall quality of concrete. Each method has some strength and some weakness. Therefore prudent approach would be to use more than one method in combination so that the strength of one compensates the weakness of the other. The various NDT methods for testing concrete are listed below –

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

Fig. Testing of a beam by UPV Tester

NON DESTRUCTIVE EVALUATION (NDE) METHODS

Concrete technologists practice NDE methods for

(a) Concrete strength determination

(b) Concrete damage detection

AIM OF THE PROJECT METHODS

The aim of the project was to obtain the Calibration Graphs for Non Destructive Testing Equipments viz., the Rebound Hammer and Ultrasonic pulse Velocity Tester and to study the effect of reinforcement on the obtained results. These Non Destructive Instruments were then used to test the columns, beams and slabs of two double storied buildings.

Fig. UPV Tester used in the Project

PROCEDURE:
The procedure that was followed during experiments consisted of the following steps:
1. Various concrete mixes were used to prepare standard cubes of 150-mm side length.

2. Concrete cubes of unknown history made under site conditions were also brought from various sites for testing.

3. All cubes were immersed under water for a minimum period of 24 h before testing.

4. Just before testing, the cubes were rubbed with a clean dry cloth in order to obtain a saturated surface dry sample.

5. Once drying was complete, each of the two opposite faces of the cube were prepared for the rebound hammer test as described in the specifications.

6. The cubes were positioned in the testing machine and a slight load was applied. The rebound number was obtained by taking three measurements on each of the four faces of the cube. The rebound hammer was horizontal in all measurements.

7. Once the rebound hammer test was complete, each of the two surfaces was prepared for the ultrasonic pulse velocity test as described in the specifications. Care was taken so that there was no effect of the notches produced by the hammer. The time was measured on each of the two opposing surfaces and the average was recorded.

8. Once non-destructive testing on each cube was completed, the cube was loaded to failure and the maximum load was recorded.

Conclusion
Considerable engineering judgment is needed to properly evaluate a measurement. Misinterpretation is possible when poor contact is made. For example, in some cases it may not be possible to identify severely corroded reinforcing bar in poor quality concrete. However, it is possible to identify poor quality concrete which could be the cause of reinforcing bar problems. The poor quality concrete allows the ingress of moisture and oxygen to the reinforcing bars, and hence corrosion occurs. Presently the system is limited to penetration depths of 1 ft. Research is ongoing to develop a system that can penetrate to a depth of 10 ft or more.

When variation in properties of concrete affect the test results, (especially in opposite directions), the use of one method alone would not be sufficient to study and evaluate the required property.
In recent years, innovative NDT methods, which can be used for the assessment of existing structures, have become available for concrete structures, but are still not established for regular inspections. Therefore, the objective of this project is to study the applicability, performance, availability, complexity and restrictions of NDT. In summary, ultrasonic pulse velocity tests have a great potential for concrete control, particularly for establishing uniformity and detecting cracks or defects. Its use for predicting strength is much more limited, owing to the large number of variables affecting the relation between strength and pulse velocity.

The purpose of establishing standard procedures for non-destructive testing (NDT) of concrete structures is to qualify and quantify the material properties of in-situ concrete without intrusively examining the material properties. There are many techniques that are currently being research for the NDT of materials today. This chapter focuses on the NDT methods relevant for the inspection and monitoring of concrete materials.

REFERENCES: RELATED BOOKS, JOURNALS AND ARTICLES
1. V. Malhotra, Editor, Testing Hardened Concrete: Non-destructive Methods, ACI, Detroit, US (1976) monograph No. 9.
2. A. Leshchinsky, Non-destructive methods Instead of specimens and cores, quality control of concrete structures. In: L. Taerwe and H. Lambotte, Editors, Proceedings of the International Symposium held by RILEM, Belgium, E&FN SPON, UK (1991), pp. 377–386.
3. Handbook on Non Destructive Testing of Concrete" (second edition) by V.M. Malhotra and N.J. Carino
4. "Non-destructive testing" by Louis Cartz.
5. "Concrete Technology" by M L Gambhir.
6. "Concrete Technology" by M S Shetty
7. Civil Engineering Construction Review, August 1998 Edition (Non Destructive Testing of Concrete).