Assessment of Strength of Concrete by Non-Destructive Testing Techniques

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ABSTRACT

In this paper an attempt was made to establish Non Destructive Evaluation (NDE) technique for assessment of compressive strength of in-situ concretes of various types by conducting Ultrasonic Pulse Velocity (UPV) and Rebound Hammer tests. A combined method of Pulse Velocity and Rebound Number as a NDE technique was developed by conducting UPV, Rebound Hammer and destructive tests on concrete cubes of various mixes. It can be used for integrity assessment of concrete structures and also for evaluation of strength of concrete up to 75 MPa. The various concretes like Plain concrete, Recycled aggregate concrete, concrete with replacement of fly ash with 10%, 20%, 30%, of M15, M20, M25, M30, M35 and M40 mixes were designed as per SP23-1982. Concrete cubes of size 150x150x150mm were cast and tested for compressive strength at 7 days, 14 days, 28 days, 56 days and 90 days for all the mixes. Just before conducting destructive test, UPV and Rebound Hammer tests were conducted on the same cubes as per IS 13311 (Part-1&2). A comparative study was made among the compressive strength, Pulse Velocity, and Rebound Number for all types of concrete of various mixes and curves were drawn. Regression analysis was also made for the tests being conducted and kept them ready for assessment of compressive strength of in-situ concrete structures. It is observed that the Pulse velocity and Rebound Number increases with the age of concrete increases. As there are no standard curves for evaluating the compressive strength of in-situ concretes of various types from UPV and Rebound Hammer tests, NDE technique developed here can be used for further course of study. It is concluded that the curves obtained for assessment of compressive strength of concretes from the values of Pulse Velocity and Rebound Number can be incorporated in the IS codes for future reference.

Key words: Non –Destructive Evaluation, Pulse velocity, Rebound Number, Fly ash Concrete, Recycle Aggregate concrete, Regression analysis

I. INTRODUCTION

Non-Destructive Testing (NDT) has been defined as comprising those test methods used to examine an object, material or system without impairing its future usefulness (1). The term is generally applied to non medical investigations of material integrity. Strictly speaking, this definition of nondestructive testing does include noninvasive medical diagnostics. Ultrasound, X-rays and endoscopes are used for both medical testing and industrial testing. In the 1940s, many members of the American Society for Nondestructive Testing (then the Society for Industrial Radiography) were medical X-ray professionals. Medical nondestructive testing, however, has come to be treated by a body of learning so separate from industrial nondestructive testing that today most physicians never use the word nondestructive. Nondestructive testing is used to investigate the material integrity of the test object. A number of other technologies - for instance, radio astronomy, voltage and amperage measurement and rheometry (flow measurement) - are nondestructive but are not used to evaluate material properties specifically. Nondestructive tests in great variety are in worldwide use to detect variations in structure, minute changes in surface finish, the presence of cracks or other physical discontinuities, to measure the thickness of materials and coatings and to determine other characteristics of industrial products.

frequency of future inspections/repairs as they sense damages at micro level(2). However, while assessing the capabilities and limitations of various non-destructive testing (NDT) and evaluation (NDE) techniques that can be applied to concrete structures, it has been found that, in many cases, the data obtained are qualitative rather than quantitative and hence efforts are being made to overcome this limitation.
II. NDE TECHNIQUES FOR ASSESSMENT OF CONCRETE STRUCTURES

Table: 1 gives the capabilities of some of the NDT & NDE techniques for assessment of concrete structures (3). It is clear that ultrasonic methods are superior methods in the sense that they are capable of providing more information on concrete parameters as compared to the other methods (4).

III. EXPERIMENTAL INVESTIGATION

Objective:
The main objective of the present investigation is to study the quality of Plain, Recycled Aggregate and fly ash concretes of various mixes by Non-Destructive testing and to develop a NDE technique.

Experimental Programme:
The experimental work is carried out on Plain concrete, recycled aggregate concrete and fly ash concrete with 10%, 20%, 30% replacement. The materials used for preparation of concrete are as per codal provisions. Cement (43 Grade), Sand (Zone III), Coarse aggregate (crushed granite passes through 20mm and retained on 4.75mm), W/C ratio: 0.5 and Fly ash (Vijayawada Thermal Power Station). Recycled Aggregate from buildings demolished debris, was used and Mixes M15, M20, M25, M30, M35 & M40 were designed as per SP:23-1982. Concrete cubes of size 150x150x150mm were cast and cured and tested for 7, 14, 28, 56, 90 days compressive strength. Before testing for compressive strength, Ultrasonic Pulse Velocity (UPV) and Rebound Hammer tests were conducted on the same cubes for assessment of strength of concrete.

Ultrasonic Methods:
The ultrasonic methods refers to transmission and reflection of mechanical stress waves through a medium in the frequency range of 20kHz to 2 MHz. Ultrasonic Pulse Velocity technique gives relationship between the quality of concrete and the velocity of an ultrasonic pulse that passes through the material. The velocity of the ultrasonic waves in an isotropic medium is a function of the elastic modulli and the density of the material. The ultrasonic pulse velocity method involves measurement of travel time over a known path length of a pulse of ultrasonic waves. Ultrasonic Pulse Velocity is also used to determine the extent of determination of concrete structure. If there are no changes in materials, concrete mix or construction procedure within a concrete structure, any reduction in ultrasonic pulse velocity in a given region indicates defective or deteriorated concrete in that region. A curve between Pulse Velocity and Compressive strength was drawn and regression analysis was also made and shown in Fig. 1.

Rebound Hammer Technique:
The Schmidt Rebound Hammer tests basically a surface hardness measurement with little apparent theoretical relationship between the strength of concrete and the rebound number of the hammer. However within certain constraints, empirical correlations have been established between strength properties and the Rebound Number. The correlation between Rebound Number(N) and Compressive strength (C) was shown in Fig.2 and it will vary from one researcher to another.

\[ C = a + bN \]

Where a and b are constants depends on moisture content of concrete, age of concrete and type of cement also. The accuracy of method varies in the range of ±15% to ±20%, due to many variables that influence the strength of the concrete.

Combination methods have also been developed and was shown in Fig.3, for estimation of the strength of the concrete with improved accuracy by using more than one technique. If moisture content in concrete increases the Pulse Velocity (V) increases but Rebound Number (N) decreases(5). The following empirical relationship has been developed for estimation of concrete compressive strength(C)

\[ C = R_0 + R_1N + R_2V \]

Where \( R_0, R_1, R_2 \) are regression coefficients.

IV. RESULTS

Tests were conducted on Plain concrete, Recycled aggregate concrete and fly ash concrete(6) of mixses M15, M20, M25, M30, M35 & M40 and curves (Figures 4 to 15) are drawn for depicting the values of compressive strength, Pulse velocity and Rebound Number against the Age of concrete for 7, 14, 28, 56, 90 days. Some of the photographs are shown in Fig.s 16 to 19.

V. CONCLUSIONS

1. It is observed that Recycled aggregate concrete has shown 30% less strength than Plain concrete and fly ash concrete has shown about 15% less strength than plain concrete.
2. It is found that Pulse Velocity and Rebound Number increases with the age of concrete.
3. The actual strength of plain concrete obtained from the destructive testing is more than that predicted based on the charts supplied by the manufacturer.
4. NDE (Combined Method of UPV and Rebound Hammer) technique developed here is more effective and can be incorporated in codal provisions for future reference for validating the strength of in-situ concrete structures.

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REFERENCES


Table 1 NDE techniques for assessment of concrete strength

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**Fig. 1** Variation of Compressive Strength of Concrete Mix (MPa) with Pulse Velocity (V)

\[ y = 64.34x - 269.7 \]
\[ R^2 = 0.394 \]

**Fig. 2** Variation of Compressive Strength of Concrete Mix with Rebound Number (N)

\[ y = 1.931x - 28.20 \]
\[ R^2 = 0.929 \]

**Fig. 3** Combined Method of Pulse Velocity (V) and Rebound Number (N)
Fig. 4 Comparison of Compressive Strength of Plain concrete with other concretes for M15 Mix

Fig. 5 Comparison of Compressive Strength of Plain concrete with other concretes for M20 Mix

Fig. 6 Comparison of Compressive Strength of Plain Concrete with other concretes for M25 Mix
Fig. 7 Comparison of Compressive Strength of Plain concrete with other concretes for M30 Mix

Fig. 8 Comparison of Pulse Velocity of Plain concrete with other concretes for M15 Mix

Fig. 9 Comparison of Pulse velocity of Plain concrete with other concretes for M20 Mix
Fig. 10 Comparison of Pulse velocity of Plain concrete with other concretes for M25 Mix

Fig. 11 Comparison of Pulse velocity of Plain concrete with other concretes for M30 mix

Fig. 12 Comparison of Rebound Number of Plain concrete with other concretes for M15 Mix
Fig. 13 Comparison of Rebound Number of Plain concrete with other concretes for M20 Mix

Fig. 14 Comparison of Rebound Number of Plain concrete with other concretes for M25 Mix

Fig. 15 Comparison of Rebound Number of Plain concrete with other concretes for M30 Mix
Fig. 16 UPV test on concrete cubes

Fig. 17 Rebound Hammer test on concrete cubes

Fig. 18 Concrete cubes in curing tank

Fig. 19 Digital Compression tester