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Reliability Of Non-Destructive Tests For Hardened Concrete Strength

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Abstract

This work was carried out to study the reliability of non-destructive tests for hardened concrete strength. In this work, two groups of test specimens in the form of 150mmX150mmX150mm cubes were used. The first group of specimens was used for established calibration curves for rebound hammer and ultrasonic pulse velocity instruments used in the test. The second group of test specimens was used for comparing the results obtained from calibration curves of rebound hammer and ultrasonic pulse velocity tester and those obtained from compressive testing machine. All of the test samples were tested at the ages of 28 days. Statistical analysis was done to establish a relationship between CTM test and non-destructive tests. The tests show that difference in results of properly calibrated hammer and CTM lies between ±2 to ±7% and that of properly calibrated USPV and CTM lies between ±7 to ±17%. This interpretation was made by taking samples from the same batch and cured them in the same condition. The findings strongly recommend the use of Non destructive tests by properly calibrating the instrument.

Keywords: *compressive strength; non-destructive tests; reliability; rebound hammer; ultrasonic pulse velocity tests*

1. Introduction

Non-destructive testing of hardened concrete has always been an exigent problem to the civil engineers. The increasing age of concrete structures over the entire world, has led to a growing demand for reliable tools for concrete strength assessment. In order to improve these estimations, a calibration curve is developed for the readings of the pulse velocity and the rebound number and relates them to the compressive strength. However, there is a wide degree of disagreement concerning the increase of the accuracy of the estimation of strength from the combined method. Certain researchers also claimed that the accuracy of compressive strength can be improved by the combined method of pulse velocity and rebound index Tanigawa, Baba and Mori, 1984[19]. A combined pulse velocity and rebound index method for a specific aggregate type and a specific age of concrete had been developed and this had shown a good behaviour Samarin et. al, 1991[18]. But unfortunately, the results obtained were not compared with a calibration from pulse velocity alone or rebound index alone to state the degree of improvement in accuracy. For others, analysis of strength estimated from rebound index made along with pulse velocity contributes little, if any, to the increase of accuracy of the ultrasonic strength estimation Popovics et. al,2004[17].The accuracy of estimation of compressive strength of test specimens cast, cured, and tested under laboratory conditions by the standard calibrated ultrasonic pulse velocity is ±20% . The current way of ensuring reliability of non-destructive testing for hardened concrete strength, is to establish a correlation curve relating non-destructive readings to strength, for a particular mix under investigation. Regression analysis is used in establishing such curve. By consensus, the accuracy of estimation of compressive strength of test specimens cast, cured, and tested under laboratory conditions by a properly calibrated hammer lies between ±15 and ±20%. However, the probable accuracy of estimation of concrete strength in a structure is ±25%. Reliability of non-destructive tests for hardened concrete strength assessment improved by their combination as well as in the SONEB method E.Proverbio & V.Venturi,20056.A relationship was determined and correlated between non-destructive testing named as Schmidt rebound hammer test and concrete destructive compression test Ferhat Aydin & Mehmet saribiyik,20107.The study was to determination of concrete compressive strength using cores from Reinforced structures by combination of destructive and non-destructive methods Cengiz Kurtulus and Ali Bozkurt,2011[5].

Although most of these methods are based on statistics, it is observed that in actual practice much of this testing is done without the use of statistical principles leading to erroneous results. Even IS codes does not offer any guidance on sampling and an acceptance criteria for tests results. Aim of the present work was to evaluate the reliability of non-destructive tests on hardened concrete strength.

The interpretation of the data is the most challenging task of the engineer assessing the structure. The recommendations made based on the interpreted result can be very significant. Decision on whether a structure is adequate or not, the standard and specifications are respected or not, and the exact causes of the deterioration, depends on the outcome of the data's interpretation. It is neither desirable that they lead to the condemnation of a structure safe or economically repairable building, nor it is admissible that they provide a false sense of confidence in an otherwise unsafe structure. Accuracy and reliability of Non-destructive testing depends upon method of sampling, quality of instruments used and proficiency of personnel using it and kind of statistical tools that are used for arriving at results and their interpretation.

The objectives of this project are to investigate the reliability in interpreting Non-Destructive Testing (NDT) results of concrete structures and determine the factors affecting the interpretation of (NDT) results of concrete structures.

2. Test Specimens

40 cubes of 150 mm x150 mm x150 mm were casted. Compaction was carried out by using internal vibrators to ensure uniform castings. The cubes were stripped from moulds and placed in the water one day after casting and put in wet gunnies for curing. Tests were carried out for all tests specimens after 28 days after casting.

3. Methods & Material

3.1 Cement: Locally available Ordinary Portland cement (OPC) 43 grade was used in tests as per IS 8112: 1989[14].

3.2 Aggregate: Aggregate is formed from natural sources by the process of weathering and abrasion, or by artificially crushing a larger parent (rock) mass. Other types of aggregates may be used for plain concrete members (Code Cl. 5.3.1), however, as far as possible, preference shall be given to natural aggregates. Aggregate is generally categorized into fine aggregate (particle size between 0.075 mm and 4.75 mm) and coarse aggregate (particle size larger than 4.75 mm), as described in IS 383: 1970[10].

3.2.1 Fine aggregate: Commercial, locally available sand was used.

3.2.2 Coarse aggregate: Gravel and crushed rock were used as coarse aggregate. The maximum size of coarse aggregate used was 20 mm. locally available crushed coarse aggregate with a nominal maximum aggregate size was used.

3.3 Water: Water has a significant role to play in the making of concrete in mixing of fresh concrete and in curing of hardened concrete. In order to ensure proper strength development and durability of concrete, Water used for mixing and curing was free from impurities such as oils, acids, alkalis, salts, sugar and organic materials.

3.4 Casting Details: M 25 mixes was mixed in a concrete mixer. All the specimens were vibrated with a pocket vibrator in the same conditions. After that they were cured under site condition.

4. Testing Equipment

The equipments used were those available in the structural laboratory of NITTTR, CHANDIGARH.

4.1 Rebound Hammer: Rebound Hammer used in the test was Concrete Test Hammer Type N generating an energy impact of 2.207 Nm. Shown in Fig.4.1.

Figure 4.1: Concrete Test Hammer Type N

4.2 Pulse Velocity Tester: Pulse velocity tester used in the test was Pundit 6 Model PC 1000 generating a low frequency ultrasound pulse of 54 kHz, shown in Figure 4.2.

Figure 4.2: Pundit 6 Model PC 1000

4.3 Compression Testing Machine:

Compressive Testing Machine used in the test is shown in fig.4.3

Figure 3.4: Compression Machine

5. Testing Procedures

40 Numbers 150 mm x 150 mm x 150 mm cubes specimens were casted. After 28 days from casting, the concrete cube was tested with non-destructive tests include ultrasonic pulse velocity test as described in ASTM Standard C 597 (2002a) [1] & IS: 13311 (Part-1)-1992 [15]

Figure 5.1: UPV Testing

And rebound hammer test as per ASTM Standard C 805 (2002b) [2] & IS: 13311, (Part-2)-1992 [16]

Figure 5.2: Rebound Hammer Testing

And followed by compression test as per IS: 516-1959 [12] & IS: 1199-1959 [13]

Figure 5.3: Compressive strength Testing

The main reason to carry out ultrasonic pulse velocity test, rebound hammer test and compression test at the same concrete cube was to create a correlation between the compressive strength of the concrete with ultrasonic pulse velocity test and rebound hammer test. The reliability of interpreting NDT results of the uniformity of concrete was investigated by comparing the results obtained from direct test and calibration curve with CTM.

Table 5.1: Cube Calibration Data

No.	Pulse Velocity (m/sec)	Rebound Number (nos.)	Compressive Strength (N/mm^2)
1.	4600	32.30	32.00
2.	4530	31.33	30.10
3.	4500	31.67	30.20
4.	4450	31.00	30.00
5.	4680	34.00	32.60
6.	4500	31.50	30.00
7.	4590	32.30	31.00
8.	4610	32.30	31.50
9.	4500	31.20	30.00
10.	4600	32.20	32.50

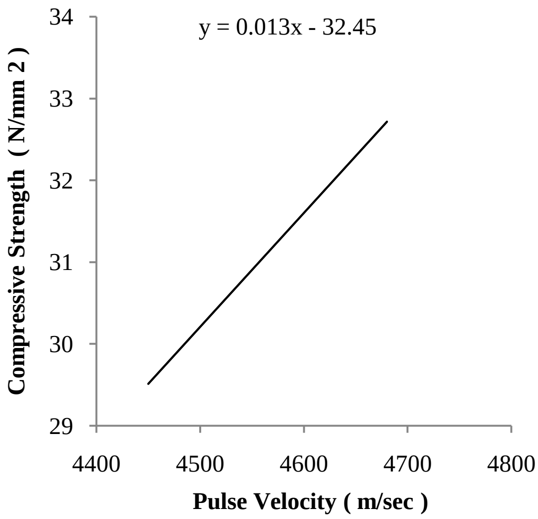

Figure 5.4 Compressive Strength V/S Pulse Velocity

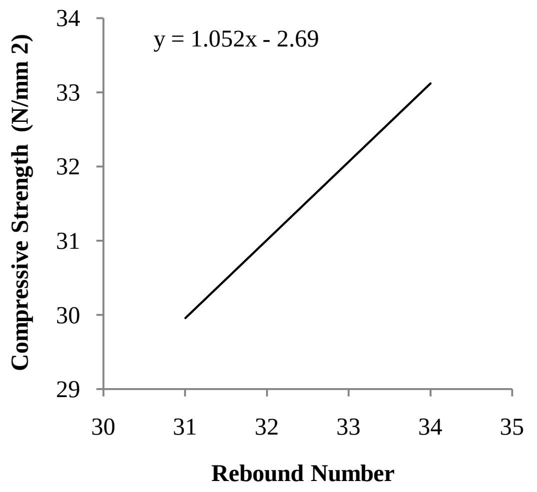

Figure 5.5: Compressive strength vs. Rebound hammer

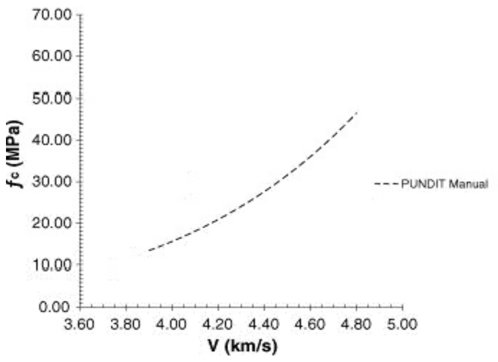

Figure 5.6 Manufacturer's Curve of Pundit Manual

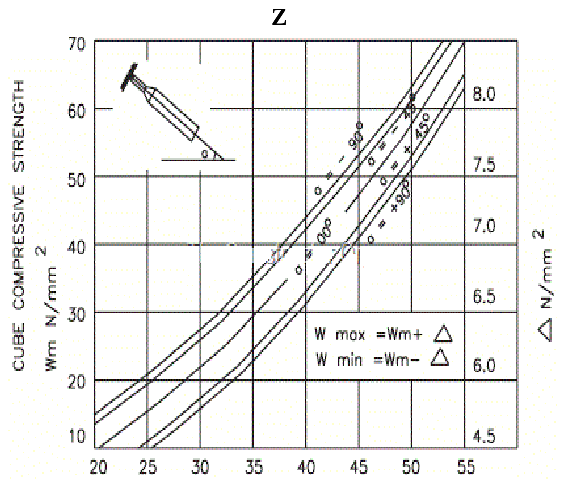

Figure 5.7 Manufacturer's Curve of Rebound Hammer

Table 5.2: Cube Testing Data

No.	Pulse Velocity (m/sec)	Rebound Number	Compressive Strength(N/mm^2) from				
			CTM	Calibration chart of UPV	Manufacturer's curve of UPV	Calibration chart of R.H.	Manufacturer's curve of R.H
1	4640	31.00	31.10	27.87	38.00	29.93	32.00
2	4590	30.67	31.30	27.22	36.00	29.58	31.75
3	4700	31.50	31.20	28.65	41.00	30.45	33.00
4	4730	31.67	31.00	29.04	42.00	30.63	34.00
5	4570	30.50	31.67	26.96	34.00	29.40	32.00
6	4500	30.00	30.80	26.05	31.00	28.87	31.00
7	4520	30.33	31.50	26.31	32.00	29.22	32.00
8	4710	31.33	30.67	28.78	41.00	30.27	34.00
9	4690	31.50	30.85	28.52	40.00	30.45	33.00
10	4650	31.00	31.70	28.00	39.00	29.93	32.00

6. Result & Discussion

6.1 Rebound Hammer Test

The equation that derived from the experimental correlation curve was,

$$y = 1.052x - 2.69 \qquad (1)$$

Where, y = compressive strength (N/mm2)

x = rebound number

For compressive strength obtained by using rebound hammer test and according to experimental calibration equation (1) against CTM test results, the highest difference percentages was 7.24 % and average difference percentages was 4.18 %. For comparison of compressive strength that obtained by using rebound hammer test according to calibration equation that provided by manufacturer against CTM results, the highest difference percentages was 10.86% and the average difference percentages was 4.18 %.

6.2 Ultrasonic Pulse Velocity Test

The equation that derived from the experimental correlation curve was,

$$y = 0.013x - 32.45 \quad (2)$$

Where, y = compressive strength (N/mm2)

x = pulse velocity (m/s)

Compressive strength obtained by using UPV test and according to experimental calibration equation (2) against CTM test results, the highest difference percentages were 16.48% and the average difference percentages were 11.03%. For comparison of compressive strength that obtained by UPV test according to calibration equation that provided by manufacturer against CTM test results, the highest difference percentages was 35.48% and the average difference percentages was 20.01%.

From the comparison results, the results obtained from UPV test according to experimental calibration equation was more accurate than the results that obtained from UPV test according to calibration equation that provided by manufacturer.

From the comparison results, the results obtained from rebound hammer test & UPV tests according to experimental calibration equation were more accurate than the results that obtained from rebound hammer test & UPV tests according to calibration equation that provided by manufacturer.

From the results, we found that the compressive strength that measured by using rebound hammer test were showed more accurate results than compressive strength that measured by UPV test. From the experimental results, rebound hammer test was more reliable than ultrasonic pulse velocity test.

As conclusion, the investigation technique available in this work was still considered adequate and reliable enough for an assessment of the hardened concrete strength. Anyway, did not applied the non-destructive tests' apparatus directly by using the manufacturer calibration chart but a more reliable calibration chart needs to be established. NDT can play an importance role in ensuring product quality, reliably and safety, minimize cost and avoid the loss of human life. It is proposed to incorporate the use of NDT in early stage of construction. This however, requires a close cooperation between structural or civil engineer and NDT inspectors.

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