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Combined Use of NDT for Evaluation of Concrete Strength in Structures

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***Abstract*—This investigation aims at developing a system of combined use of two different non-destructive tests for evaluation of concrete strength with better precision. Outcomes of an experimental analysis on the effects of concrete materials mix and different curing conditions on the Rebound Number and Ultrasonic Pulse Velocity of concrete are presented.**

Two different types of cement are used in this research i.e. OPC and PPC under different curing conditions. It has been noticed that Rebound Hammer readings increased with the compressive strength of concrete. Ultrasonic pulse velocity values were also greatly influenced by the cements and aggregate. This reveals the restriction of using UPV tests for estimating compressive strength of concrete. IS: 13311 promotes combined use of Ultrasonic pulse velocity (UPV) and Rebound Hammer tests for evaluation of concrete strength in structures with greater consistency. Though, the analysis of test data is not simple, because the results are significantly influenced by environmental exposure to which structure it is rendering. So, it is needed to establish a correlation between outcomes of these techniques and actual strength of concrete structures before assessing the strength of existing structures. In the present research, a correlation has been recognized between compressive strength of concrete structures and NDT results.

***Index Terms*—NDT techniques, ultrasonic pulse velocity method, rebound hammer, correlation curves.**

I. Introduction

Non-destructive testing in present scenario has gained a great significance in practical and engineering values. In last few years, this subject has received growing attention, particularly the quality depiction of damaged concrete structures using Non-destructive testing (NDT).

There are numerous advantages of Non Destructive testing such as less requirement of labour, negligible effect structure health due to testing, no need of drilling cores and less expensive testing equipment required as compared to Destructive testing. All these advantages are valuable only if the results are reliable, representative and as near as possible to the actual strength of the tested element of the structure.

II. Rebound Hammer and Ultrasonic Pulse Velocity Test

A. Rebound Hammer Test

Rebound hammer is to determine the surface compressive strength of concrete as per IS: 13311 (Part 2) - 1992. The hammer can be used in the horizontal or vertical positions.

The modus operandi of test is described in IS: 13311 Part 2: 1992 and BS1881 202 (1986). It is handy, user-friendly, and low-priced and can speedily cover large areas but it is expensive only as a qualitative tool since it computes the relative surface hardness of the concrete. Compression test ought to be used to find out the real strength of the concrete. The rebound measurement is not only affected by parameters like the size, age, aggregate type, moisture content but also by the finishing of the concrete.

B. Ultrasonic Pulse Velocity Method

Ultrasonic pulse velocity tester is an attractive tool for examining concrete. It is used to assess the suitability and repair condition of concrete and the procedure of test is described in IS: 13311 Part (1). The equipment is moveable so that it can be easily usable in the field for in situ testing conditions. However, there are several fundamental and practical factors that may interfere in the calculation of concrete strength by means of ultrasonic. Concrete is a blend of materials like cement, coarse aggregate, fine aggregate and water. This complexity makes the behavior of ultrasonic waves in concrete highly unbalanced, which in turn obstructs non-destructive testing. These complexities make it overly optimistic effort to formulate an ultrasonic test method for the computation of concrete strength. Nevertheless, considering the seriousness of the infrastructure problem and the degree of the cost of treatment, major improvement is greatly required to get better the current condition. It has been found that the standard ultrasonic method using longitudinal waves for testing concrete can guess the concrete strength only with ± twenty percent accurateness under laboratory conditions (Popovics 1998). Lorenzi (2009) induced voids in the concrete sample and investigated by means of UPV and rebound hammer, found that the NDT data can be used to make reliable guess about concrete condition without damaging structural elements. The outcome of admixture, different water cement ratio, its composition and ages of concrete can make suspicions in the strength of concrete by Non- destructive Testing.

III. Literature Review

Several researchers used different NDT equipments in order

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to assess the condition of RC structures.

Villain et al. (2018) addresses the utilization of non-destructive testing methods to evaluate indicators for both the concrete durability and mechanical properties of RC structures. NDT results are achieved by means of ultrasonic or electromagnetic techniques and then showed a relationship with these durability and mechanical indicators. The obtained conversion model are utilized to transform observables into indicators, depends on the authentic concrete design mix. If this conversion model is not available for the RC structure under study, then the assessment may be not enough due to high indecision on the results. This paper suggests a calibration method to develop a conversion model suitable for the structure by use of a least number of cores in order to perk up the on-site assessment. Results found by analyzing more than 1600 data fully validate the tested calibration method.

According to Neves et al. (2018), by measuring cover depths and carbonation of drilled cores of carbonated reinforced concrete structures residual service life of structures can be assessed. The “square root law” for the progress of the carbonation has been assumed by the researchers.

A model has been presented, based on numerous non-destructive experimental data, through which the carbonation rate can be predictable by means of air-permeability kT.

In this research, non-destructive testing of cementitiously stabilized materials was studied using UPV by Mandal et al. (2016). Flexural strength and flexural modulus tests were carried out on CSMs and their constrained modulus were observed. The influence of compaction, curing time, and binder amount was assessed. The result shows that the P-wave velocity reduces with decrease in density, whereas P-wave velocity enhances with increase in curing time and binder amount.

The compressive strength of several concrete mixes produced using lightweight aggregate has been evaluated using the non-destructive ultrasonic pulse velocity method by Bogas et al. (2013). In this study almost 84 separate compositions have been tested after 3 and 180 days of curing, compressive strengths of these samples is ranging about 30 to 80 MPa.

In an experimental study performed by Jain et al. (2013) evaluated the effects of concrete ingredients, proportion of concrete mix, and variables related to workmanship on the Rebound Number and Ultrasonic Pulse Velocity of concrete. In this study combined use of both the NDT techniques had been determined.

An experimental study has been performed by Rabehi et al. (2013) in order to establish the link among open porosity characterized by the initial absorption, the carbonation depth and compressive strength. Correlation between the quantity of water absorbed in 1 hour, the carbonation depth in 180 days and 28 days compressive strength has been developed.

According to Shi et al. (2012) concrete has been recognized as a compound material which is porous and extremely heterogeneous. The durability of steel reinforced concrete in chloride environments is of high importance to researchers, building owners and maintenance engineers. I this work durability of reinforced concrete structures exposed to chloride environments, and the methods of measuring the chloride ingress into concrete structures have been studied.

IV. Experimental Results

This chapter presents the results obtained by Destructive and Non-destructive.

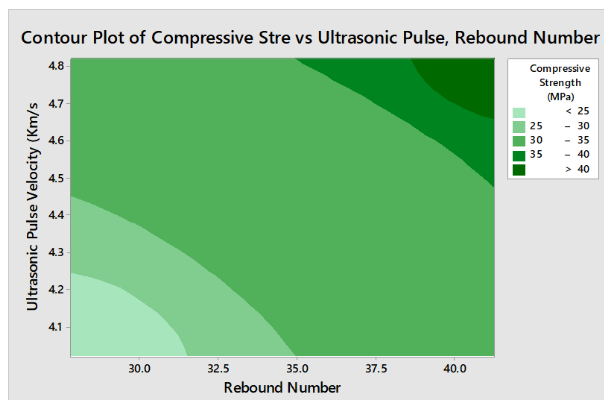

Fig. 1. Contour plot among Rebound Number, UPV and Compressive Strength

TABLE I
OBTAINED RESULTS

Mix	Curing	Age	Ultrasonic Pulse Velocity (Km/sec)		Rebound Number		Compressive Strength (MPa)	
			OPC	PPC	OPC	PPC	OPC	PPC
M 30	**7 Days wet +Air**	**7 Days**	4.02	4.43	27.83	28.71	20.13	21.1
		28 Days	4.51	4.57	35.7	37.85	31.23	32.26
	28 Days wet +Air	**28 Days**	4.53	4.62	36.42	38.65	32.12	33.48
M 40	**7 Day wet +Air**	**7 Days**	4.5	4.65	37.38	38.96	31.83	33.7
		28 Days	4.79	4.8	41.25	41.25	42.53	42.77
	28 Days wet +Air	**28 Days**	4.82	4.89	41.1	43.54	43.23	43.67

TABLE II
EQUATIONS OBTAINED

Cement Type	Relation Between		Equation Obtained	R^2 Value
OPC	UPV	Compressive Strength	$y = 29.25x - 98.95$	0.968
PPC	UPV	Compressive Strength	$y = 48.81x - 192.9$	0.95
OPC	Rebound Number	Compressive Strength	$y = 1.696x - 28.61$	0.948
PPC	Rebound Number	Compressive Strength	$y = 1.561x - 25.08$	0.926

V. Conclusion

From the experimental study, following points of conclusions has been noticed:

1. Small increment in UPV readings with age but the change is very has been noted, because the density of the concrete remains same with the increase in age, so UPV only cannot be employed to detect the compressive strength.
2. Similar phenomenon has been noticed in rebound hammer also, this is because hardness of concrete increases with age. The approximate compressive strength can be determined from the rebound number using the rebound hammer conversion chart.
3. For accurate results, combined use of both the methods is necessary. For which correlation curve between ultrasonic pulse velocity (UPV), rebound number (R) and compressive strength have been developed.
4. If test results of rebound number and ultrasonic pulse velocity are available, then by using correlation curves compressive strength can be determined.
5. The relation between Rebound number, UPV and Compressive Strength for M 30 and M 40 grade using OPC and PPC.

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