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INVESTIGATION OF COMPRESSIVE STRENGTH USING ULTRASONIC PULSE VEOCITY METHOD

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ABSTRACT
There are many methods to access concrete in situ such as non-destructive tests (NDT). These methods consider indirect measure for assessing the strength of concrete to predict in situ strength. In the present study ultrasonic pulse velocity and rebound hammer test were used for assessing compressive strength of concrete at 7, 28 and 56 days.
The rebound hammer test is based on principle that the rebound of an elastic mass depends upon hardness of surface, while the ultrasonic pulse velocity method monitors the internal characteristic of concrete in terms of m/s. These two tests affected by many parameters depends on the nature of production materials in production of concrete, so there is difficulty in determining strength of hardened concrete in situ precisely.
Concrete mixes with w/c ratio of 0.30, 0.35, 0.40, 0.45 and 0.50 were cast in the laboratory. The cubes of 150 mm size were tested for compressive strength using UPV, Rebound Hammer and also by crushing at the age of 7, 28 and 56 days of curing. Regression analysis is carried out to establish relation between compressive strength of concrete and results of UPV and Rebound Hammer test. The relations are validated by verifying the results of compressive strength of concrete with w/c ratio of 0.55.

Keywords— Compressive strength non-destructive testing (NDT); impact rebound hammer (IRH); ultrasonic pulse velocity (UPV) combined method.

INTRODUCTION
Concrete is a composite material composed of coarse granular material embedded in a hard matrix of material (the cement or binder) that fills the space between the aggregate particles and glues them together. We can also consider concrete as a composite material that consists essentially of a binding medium within which are embedded particles or fragments of aggregates. The simplest representation of concrete is:
Concrete = Filler + Binder
These days concrete is being used for wide varieties of purposes to make it suitable in different conditions. Admixtures are used to modify properties of ordinary concrete so as to make it suitable for any conditions. Admixtures are defined as materials other than aggregate (fine and coarse), water, fiber and cement, which are added into concrete batch immediately before or during mixing. The widespread use of admixture is mainly due to the many benefits made possible by their application. For instance, chemical admixtures can modify the setting and hardening characteristic of cement paste by influencing the rate of cement hydration. Water-reducing admixture can plasticize fresh concrete mixtures by reducing surface tension of water, air-entraining admixtures can improve the durability of concrete, and mineral admixtures such as pozzolans (materials containing reactive silica) can reduce thermal cracking.

LITERATURE REVIEW
Brian and Mohamed describe in detail the results of a laboratory investigation where the compressive strength of 150 mm side-length cubes was evaluated. The resulting correlation curve for each test is obtained by changing the level of compaction, water/cement ratio and concrete age of specimens. Unlike other works, the research highlights the significant effect of formwork material on surface hardness of concrete where two different mould materials for specimens were used. Non-destructive testing (NDT) was carried out using

ultrasonic pulse velocity (UPV) and impact rebound hammer (IRH) techniques to establish a correlation with the compressive strengths of compression tests thus pulse velocity tests were used in this study. All charts show the 95% prediction interval, thus enabling professionals to predict concrete strength simply and reliably.

G.F. Kheder discussed the research work using test results of two NDT methods (UPV and Schmidt hammer) the research was in two stage, the first one was to determine the compressive strength in conjugation with concrete mix proportions and density to developed mathematical relationship using multiple linear regression by for dry and wet conditions, where in the second stage determined linear co-relation between the predicted compressive strength made in the first stage and actual strength taking from limited number of core cutting from the same structure. In each part of the work author tested 103 different mixes at ages 7-90 days. After testing both the test be concluded that none of the ultrasonic pulse velocity or rebound hammer separately can predict the concrete compressive strength accurately. This is because each of this methods is affected by certain properties of concrete, and is not sensitive to other properties or variables that affected concrete compressive strength but the combined methods of UPV and rebound hammer use greatly improves the accuracy of the process of assessment of concrete strength especial information about concrete mix proportion and density are available the accuracy can be within $\pm$ 10%.

Mahdi Shariati has performed the experimental work on in situ concrete including column, slab, and beam using ultrasonic pulse method and complaining their results with compressive strength and establishes a correlation between the compressive strengths of compressive tests and NDT values. These two tests have been used to determine concrete quality by applying regression analysis models. He developed the co-relation of author is given by

$fc\ (V) = - 173.04 + 4.07V^2 + 57.96\ V + 1.31R$

V = ultrasonic pulse velocity

R = rebound no

The author also maintained that using combined method the results and co-relation which is shown are more precise and dose to experimental results to those results that were achieved from individual methods.

Lakshmipathy et al. [4] found that SCC is one of the high performance concretes with excellent strength and durability properties. However, its mix proportioning and testing methods for flow characteristics are different from those of the ordinary concrete. SCC has high powder content and a super plasticizer for enabling flow while keeping coarse aggregate in viscous suspension. The powder is usually cement and filler in powder influences the properties of SCC both in fresh and hardened state. An attempt has been made to develop cost –effective SCC with supplementary cementations materials such as fly ash (25%), GGBS (20%) and Silica flume (5%) and examine its strength properties in comparison to the conventional concrete

Razon Domingo and Sohichi Hirose were established the correlations among compressive strength, flexural strength and combined nondestructive testing methods for different design mixes using high early strength cement to predict on site strength of Portland cement concrete (PCC) pavement concrete mix designs of varying water cement ratios were prepared using high early strength cement and specimens were prepared and tested for compressive strength and flexural strength at different ages. Author established correlations between flexural strength of pavement from compressive strength of pavement from compressive strength UPV and rebound number but a better correlation is established using combined UPV and rebound number, authors used multiple regressions to analyze combined NDT methods to predict flexural strength for pavement and the results show good correlations between flexural strength and combined UPV and rebound number. The equation which is developed by authors is given below

Log compressive strength = 1.056 (LogRN) + 1.633 (Log Direct UPV) – 0.097

All the test results were recorded furtherance of this study by validating results of UPV and rebound number in actual tests during pavement construction.

Subramania et al. [5] focused on the workability characteristics and strength parameters of SCC containing fly ash. The cement used for the study was 43 grade ordinary Portland cement and was partially replaced by 0%, 25%, 50%, and 75% of fly ash. Based on the guidelines of European Federation of producers and contractors of specialist products for structures (EFNARC), the mix proportions were chosen and the cement content alone was varied without varying the aggregate content. The water powder ratio was kept at 0.4 throughout the study. Water reducing admixture and VMA used to improve the workability characteristics.

Chang et al. discusses the results concerning the correlation between the compressive strength at early ages of concrete and that hardened under standard conditions. The author utilizes the impact pulse velocity of non destructive method to estimate the compressive strength. The relationship of pulse velocity and strength can be established for concrete but they are controlled under various w/c ratio. It is noted that from experimental programmed, the growth rate of compressive strength in concrete is fate at the ages of 1 day to 7 days. The growth rate of the concrete at early ages is independent of water cement ratio. As the curing time (in days) increase there is increase in pulse velocity in concrete. The relationship between pulse velocity and compressive strength may be developed for a various w/c ratio, specimen, and materials locally available. Author concluded that impact pulse velocity appears to co-relation fairly well with compressive strength at early ages (upto 7 days). Author also concluded that pulse velocity is most incentive to great variation in compressive strength at early ages.

OBJECTIVES OF INVESTIGATION

- To produce co-relation between crushing strength and NDT methods of ultrasonic pulse velocity to predict better compressive strength.
- To study test results of UPV methods on concrete specimen varying with w/c ratio from 0.30 to 0.50 with interval 0.05.

MATERIALS

1. Cement: The cement used in this experimental work is "ACC 43 grade Ordinary Portland Cement". All properties of cement are tested by referring IS 8112 - 1989 Specification for 43 Grade Ordinary Portland Cement.
2. Fine aggregate: Locally available river sand conforming to Grading zone II of IS: 383–1970. Fineness modulus was found to be 2.76, Specific gravity was 2.59.
3. Super Plasticizer: Scelphonated melamine based super plasticizer (supplied by Roff. India Pvt. Ltd. Mumbai) is used as water reducing and self retarding admixture in this experimental work. The properties of SP as reported by manufactured are presented in table. They satisfy the requirement of IS 9103-1999 (Amended 2003) ASTM C 494-type F.
4. Dosage of Super Plasticizer: Workability of concrete mainly depends upon dosage of admixtures such as Super Plasticizer and water cement ratio. The dosage of admixtures required for making concrete are selected after several trials mixes. The required percentage of Super Plasticizer for satisfying the properties of concrete are presented in Table 3.5. Column 2 and 3 of table shows the mixes and water content of concrete. Column 4 represents the percentage of Super Plasticizer required for concrete for appropriate workability.
5. Water: Potable laboratory tab water was used for mixing of concrete.

Table 3.5: Dosages of Super Plasticizer

Sr. No.	Concrete Mix	Water Content (kg/m^3)	Super Plasticizer (%)
1	2	3	4
1	M1	171	0.8
2	M2	171	0.6
3	M3	171	0.5
4	M4	171	0.4
5	M5	171	0.3

METHODOLOGY

Determination of total aggregate content: Find out the total aggregate content. This requires an estimate of the wet density of the fully compacted concrete. This can be found out from fig. 5 in DOE standard code for approximate water content and specific gravity of aggregate. If specific gravity is unknown, the value of 2.6 for uncrushed aggregate and 2.7 for crushed aggregate can be assumed. The aggregate content is obtained by subtracting the weight of cement and water content from weight of fresh concrete.

Fine aggregate proportion is determined in the total aggregate using fig. 6 is for 20 mm size course aggregate. The parameters involve in fig. 6 as per DOE standard are maximum size of course aggregate, the level of workability, w/c ratio and the percentage of fines passing 600 µ sieve. Once the proportion of F.A. is obtained, multiplying the weight of total aggregate gives the weight of fine aggregate. Then the weight of the C.A. can be found out. Course aggregate can be further divided into different fractions depending upon the shape of aggregate.

EXPERIMENTAL PROGRAM

Using river sand, 20mm crushed aggregate of 60% and 10mm crushed aggregate of 40% is used with w/c of 0.3, 0.35, 0.40, 0.45 and 0.50 and SP contains 1%, 0.8%, 0.6%, 0.5% and 0.3% respectively for each mix. The cubes of size 150 x 150 x 150 mm were cast.

TESTING PROGRAM

Ultrasonic pulse velocity method

Scope: Ultrasonic pulse velocity shows the quality of concrete in terms of m/s. it is used to determine the inner characteristic of concrete material, homogeneity, crack depths etc. UPV is used in laboratory or in field.

Principle**:** The method is based on the principle that the velocity of an ultrasonic pulse through any material depends upon the density, modulus of elasticity and Poisson's ratio of the material. Comparatively higher velocity is obtained when concrete quality is good in terms of density, uniformity, homogeneity etc. The ultrasonic pulse is generated by an electro acoustical transducer. When the pulse is induced into the concrete from a transducer, it undergoes multiple reflections at the boundaries of the different material phases within the concrete. A complex wave is developed which includes longitudinal (compression), shear (transverse) and surface (Rayleigh) waves. The receiving transducer detects the onset of longitudinal waves which is the fastest.

The velocity of the pulses is almost independent of the geometry of the material through which they pass and depends only on its elastic properties. Pulse velocity method is a convenient technique for investigating structural concrete.

GENERAL

Ultrasonic instrument is a handy, battery operated and portable instrument used for assessing elastic properties or concrete quality. The apparatus for ultrasonic pulse velocity measurement consists of the following

1) Electrical pulse generator
2) Transducer - one pair
3) Amplifier

Ultrasonic pulse velocity device

The equipment should be calibrated before starting the observation and at the end of test to ensure accuracy of the measurement and performance of the equipment. It is done by measuring transit time on a standard

calibration rod supplied along with the equipment. For good quality concrete pulse velocity will be higher and for poor quality it will be less. The actual pulse velocity obtained depends primarily upon the material and mix proportion of concrete.

COMPRESSIVE STRENGTH OF CONCRETE

Compression i.e. crushing test was carried out as per IS 516-1975. Total 45 cubes of 150 mm side were tested. The compression testing machine of 3000 KN capacity was used. Total rate of loading was kept at 1KN/sec. The compressive strength of specimens calculated by following formula

fc = Pc /Ac

Pc = load at failure in kN

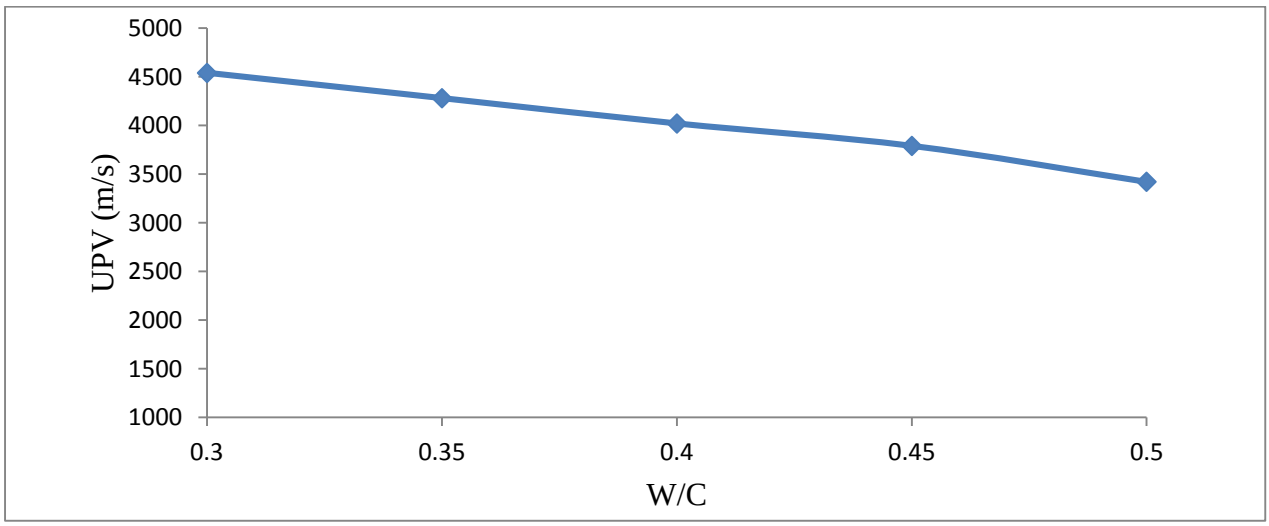
Ac = loaded area in mm^2

Table : Velocity in m/s of UPV Test for M1

Sr. No.	Two apposite faces	UPV (m/s)		
		Sample 1	Sample 2	Sample 3
1	2	3	4	5
1.	1-4	4510	5010	4120
		4580	4960	4220
		4640	4910	4170
2.	2-5	4700	4770	4130
		4680	4690	4090
		4660	4730	4058
3.	3-6	4590	4890	4080
		4670	4830	4200
		4630	4950	4140

Table : Average Velocity in m/s of UPV Test

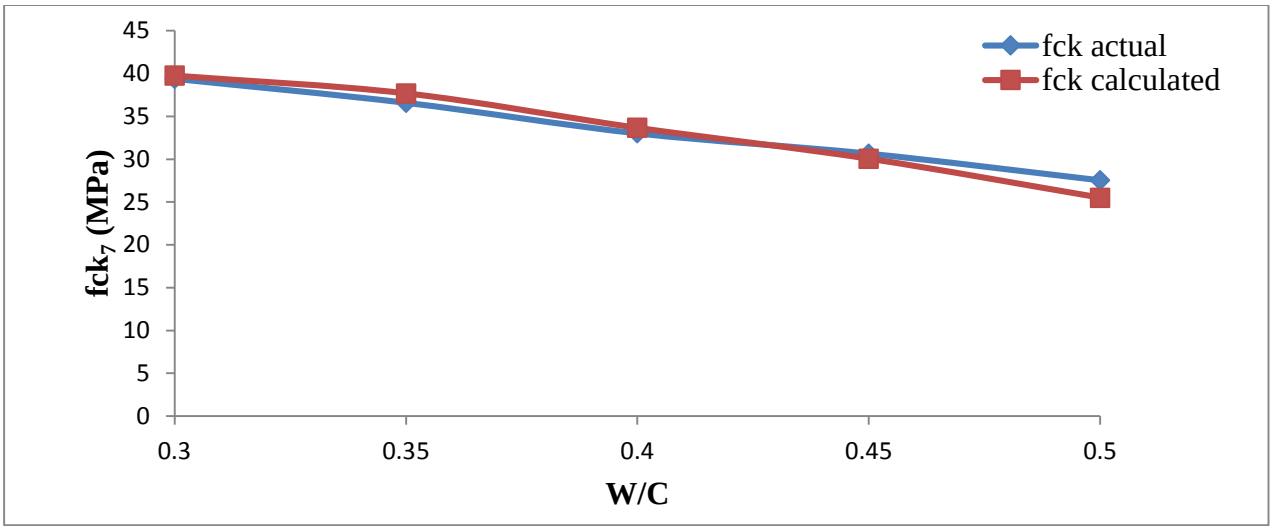
Sr. No.	Two opposite Faces	UPV (m/s)		
		Sample 1	Sample 2	Sample 3
1	2	3	4	5
1	1-4	4580	4960	4170
2	2-5	4680	4730	4090
3	3-6	4630	4890	4140
	Average	4630	4860	4130



Graph:UPV with respect to w/c ratio

Table: Comparison of actual and calculated compressive strength

Sr. No	W/C	fck_{actual} (MPa)	$fck_{calculated}$ (MPa)
1	**2**	**3**	**4**
2	0.30	39.40	39.77
3	0.35	36.60	37.70
4	0.40	33.03	33.67
5	0.45	30.66	30.06
6	0.50	27.55	25.51
	Avg	**33.45**	**33.34**



Graph: Comparison of actual and calculated compressive strength

CONCLUSIONS

- The UPV method is an ideal tool for establishing whether concrete is uniform or non uniform.
- UPV method shows the inner characteristic of concrete whether it is good quality or poor quality and homogeneity of concrete.
- UPV gives the quality of concrete to be predicted and then compared, it gives ±20 percent test results, provided the type of aggregate and mix proportion.
- The UPV method seems to me more efficient in predicting the strength of concrete under the laboratory conditions. However the use of such method alone would not give good reliable prediction of the strength of concrete.

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