MEASUREMENT OF ULTRASONIC PULSE VELOCITY IN CONCRETE FOR ASSESSING COMPRESSIVE STRENGTH

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ABSTRACT

Evaluating in- place compressive strength of concrete by employing non-destructive testing method is a cardinal approach to assess concrete strength in present condition. But strength cannot be measured because non-destructive tests are relative in nature. So indispensability arises for establishing experimental relation between the property being measured by a given test and the strength of the specimen. Concrete strength increases with time due to curing but when its use being started, environmental exposure may also deteriorate its strength. To assess the concrete strength in present condition of a structure ultrasonic pulse velocity method is used among all other non-destructive methods in order to find a correlation with concrete compressive strength. Therefore, to derive such correlation and evaluating its reliability using local material and local condition is important for judging the concrete. Finally, further observations are made on effect of concrete age and coarse aggregate which are known to be the most important parameters that affect the correlation.

Key Words: Ultrasonic pulse velocity, compressive strength, saturation condition.

1.0 INTRODUCTION

For inspection, operations and monitoring of concrete structures the UPV methods have been used. UPV test is also used for the measurement as well as to control a series of basic parameters in order to ensure the quality of concrete. The matters of concern are interpretation of these test results and for that proper knowledge about the influential factors are necessary [1]. As per IS number 13311 in part one in 1992 The underlying principle of the test is the method consists of measuring the time of travel of an ultrasonic pulse passing through the concrete being tested; comparatively higher velocity is obtained when concrete quality is good in terms of density, uniformity, homogeneity etc. Concrete technologist has been working for decades in order to determine the properties of concrete using nondestructive tests. Many test methods have been proposed for laboratory test specimens using vibrational methods beginning in the 1930s. Powers, Obert, Hornibrook, and Thomson were the first to conduct extensive research using vibrational techniques such as the resonant frequency method[2].World War 2 accelerated research regarding nondestructive testing using stress wave propagation methods. The development of the pulse velocity method began in Canada and England at about the same time. In Canada, Leslie and Cheesman development an instrument called the soniscope While in England, jones developed an instrument called the ultrasonic tester. In principle, both the soniscope and the ultrasonic tester were quite similar, with only minor differences in details. Since the 1960s, pulse velocity methods have been moved out of laboratories and to construction sites. Malhotra has compiled an extensive list of papers published on this subject. Many nations have adopted standardized procedures to measure pulse velocity in concrete. [2]

2.0 EXPERIMENTAL DETAILS

2.1 Materials

Cubes of different grades of concrete M15, M20 and M35 were casted out of the concrete matrix during construction. To improve workability of concrete, water reducing admixture was added into each grade of concrete to control the slump and to prevent the occurrences of bleeding and segregation. Materials Used for making specimen includes cement, fine aggregate, coarse aggregate and water reducing admixture. For each type of aggregate different strength combinations were used.

Tests were conducted on different specimens. The mixture contained cement and four types of coarse aggregates such as stone, brick, recycled brick, recycled stone. Specimens with different strength and mixing ratio were casted. The specimens were allowed to gain strength on 3, 7, 14, 28, 56, 90, 107, 114, 120 days in achieving the required strength of concrete, it is needed to specify a proper mix design with appropriate mix proportion of water, cement, fine aggregate and coarse aggregate for trial mix. Hence for the concrete in this context with strength several mix design need to be analyzed before coming up with a most suitable mix design. This is to configure the proportional content of concrete, which could also affect the ultrasonic pulse velocity.

2.2 Mix Design

Mix design was performed in accordance to BS 5328-1997 with the BRE (Building Research Establishment) concrete mix design-British method (1988) to determine the mix proportion of the materials used in casting of concrete.

Type of concrete	free water content (kg)	cement content (kg)	Total Aggregate Content (kg)	Fine Aggregate Content (kg)	Coarse Aggregate content (kg)
S10	14.41	17.84	127.67	51.06	76.60
S20	14.41	22.65	123.55	49.42	74.13
S35	15.44	30.28	114.89	42.50	72.38
B10	14.41	17.84	127.67	51.06	76.60
B20	14.41	22.65	123.55	49.42	74.13
B35	15.44	30.28	103.22	38.19	65.03
RS10	14.41	17.84	127.67	51.06	76.60
RS20	14.41	22.65	123.55	49.42	74.13
RS35	15.44	30.28	110.42	40.85	69.57
RB10	14.41	17.84	127.67	51.06	76.60
RB20	14.41	22.65	123.55	49.42	74.13
RB35	15.44	30.28	105.96	39.20	66.75

3.0 EXPERIMENTAL RESULTS AND DISCUSSION

Type of concrete	free water content (kg)	cement content (kg)	Total Aggregate Content (kg)	Fine Aggregate Content (kg)	Coarse Aggregate content (kg)
S10	14.41	17.84	127.67	51.06	76.60
S20	14.41	22.65	123.55	49.42	74.13
S35	15.44	30.28	114.89	42.50	72.38
B10	14.41	17.84	127.67	51.06	76.60
B20	14.41	22.65	123.55	49.42	74.13
B35	15.44	30.28	103.22	38.19	65.03
RS10	14.41	17.84	127.67	51.06	76.60
RS20	14.41	22.65	123.55	49.42	74.13
RS35	15.44	30.28	110.42	40.85	69.57
RB10	14.41	17.84	127.67	51.06	76.60
RB20	14.41	22.65	123.55	49.42	74.13
RB35	15.44	30.28	105.96	39.20	66.75

3.1 Effect of Course Aggregate

Among different influential factors the effect coarse aggregate is most important in terms of correlation between the ultrasonic pulse velocity and concrete compressive strength. For analyzing coarse aggregate effect brick, recycled brick, stone, and recycled sstone aggregate are chosen. Data are taken up to 28 days.The coarse aggregate effect is shown in figure 1.

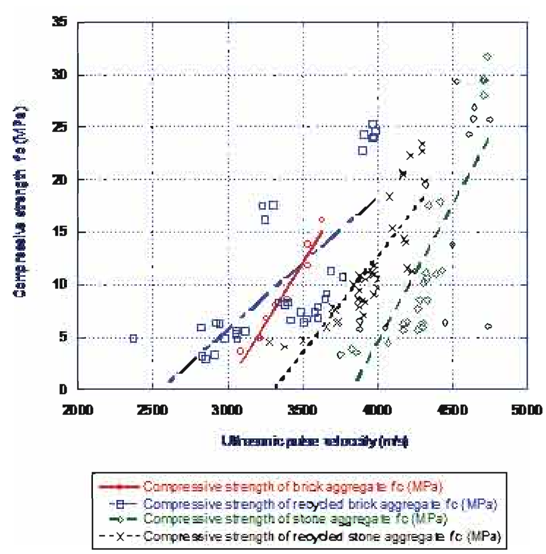

Fig 1: Compressive strength vs. ultrasonic pulse velocity (Coarse aggregate effect)

From the figure 1 it can be observed that the ultrasonic pulse velocity of recycled brick is lower than the brick. This is because the difference in density between two aggregate. Recycled brick has low density than the brick aggregate due to pores in recycled aggregate. That's why the UPV is higher in brick aggregate. Due to the similar reason the UPV in stone is higher than the UPV in recycled stone.

Table 01: Equation and co-efficient of determination for different coarse aggregate

Type of aggregate	Equations	Co-efficient of determination
Brick	y = -69.395 + 0.023268x	R = 0.9552
Recycled brick	y = -32.315 + 0.012857x	R = 0.616
Stone	y = -100.08 +0.026248x	R = 0.615
Recycled stone	y = -60.699 + 0.016328x	R = 0.697

3.2 Effect of Concrete Age

3.2.1 Correlation Between Compressive Strength And Upv for Saturated Condition

Correlations between compressive strength and ultrasonic pulse for brick, recycled brick, stone and recycled stone are find out using the data up to 28 days.

Linear relation between compressive strength and ultrasonic pulse velocity for brick aggregate are shown below where continuous lines represent the linear relation between compressive strength and ultrasonic pulse velocity.

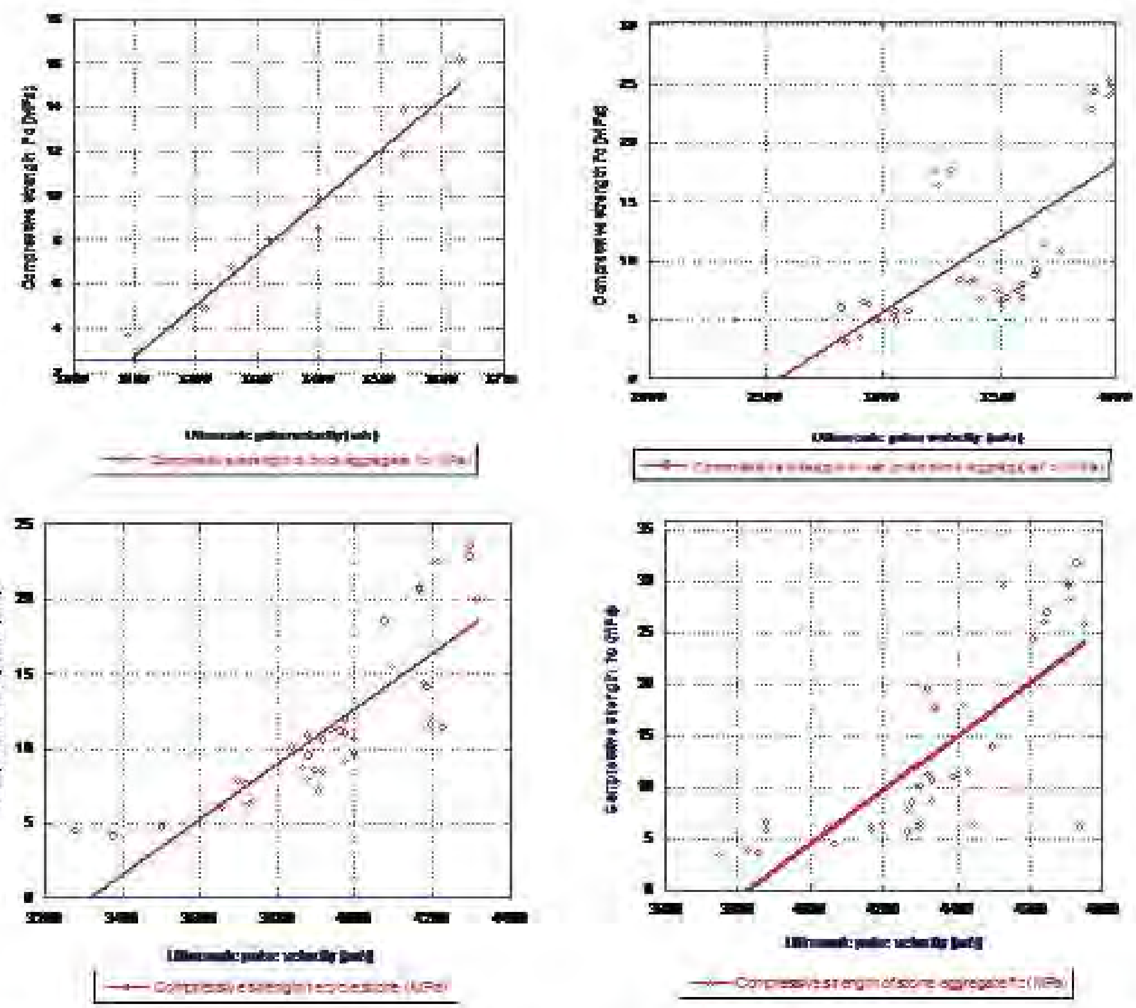

Fig 2: Correlation between compressive strength and ultrasonic pulse velocity for brick, recycled brick recycled stone, stone aggregate.

It can be inferred from the graph that with increase in ultrasonic pulse velocity compressive strength also increases. For brick aggregate the linear equation is

y= -69.395+0.023268x..................................(1)

R= 0.97735, R2= 0.955

Where, y= Compressive strength, x= Ultrasonic pulse velocity and the value of coefficient of determination is R2. Similarly for recycled brick, stone and recycled stone aggregate.

Correlation between compressive strength and UPV are find out. For recycled brick, stone, recycled stone aggregate data are taken for 3, 7, 14, 28 days. Summary of results and correlation between concrete compressive strength and UPV are shown in table 2.

3.2.2 Correlation between Compressive Strength and UPV for Air Dry Condition

Correlations between compressive strength and ultrasonic pulse for brick recycled brick, stone and recycled stone are find out using the data after 28 days. For brick aggregate 35, 60 days data are taken. For recycled brick data of 90, 120, for stone 60, 90 and for recycled stone 90,107,120 days are taken. Summary of results and correlation between concrete compressive strength and UPV are shown in table 3

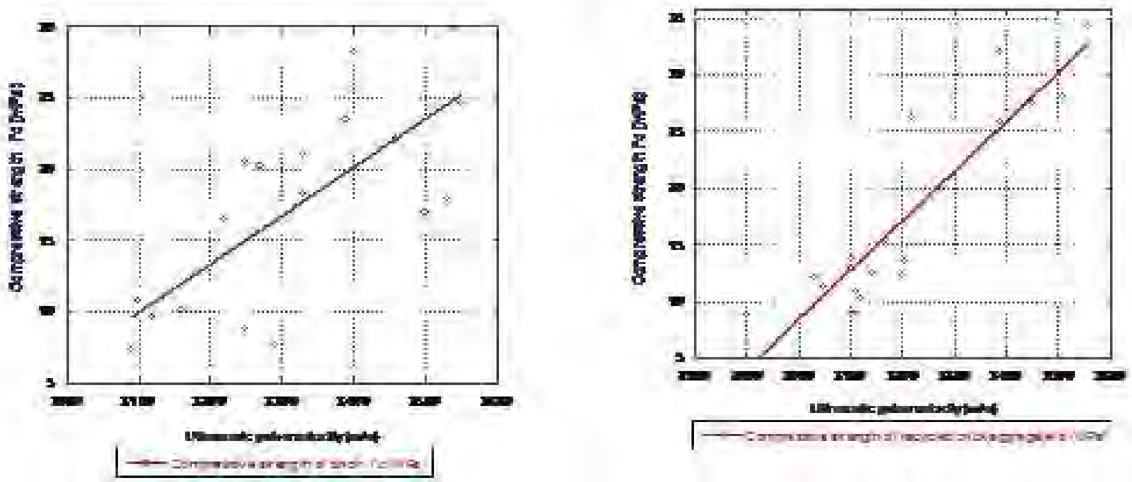

Fig 6: Correlation between compressive strength and ultrasonic pulse velocity for brick, recycle brick aggregate.

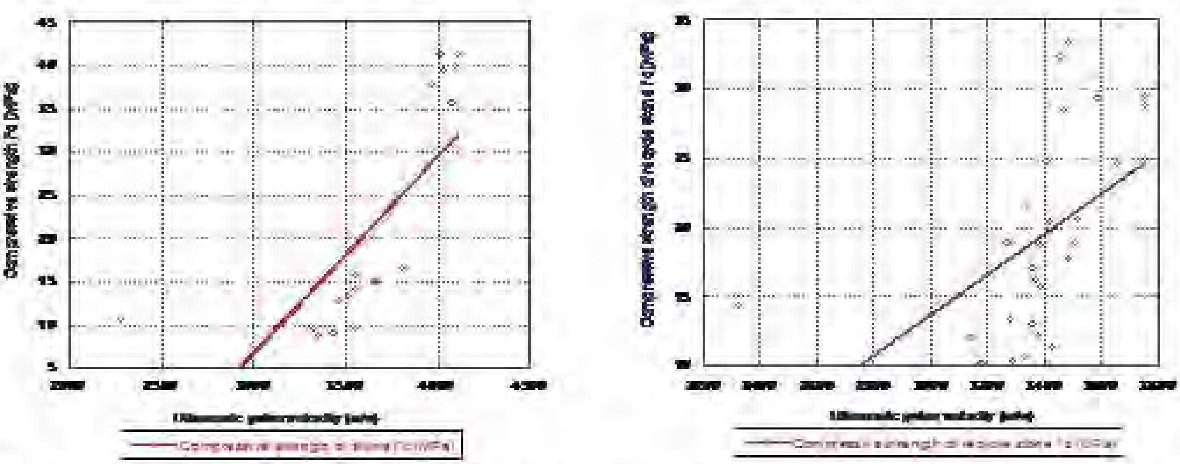

Fig 7: Correlation between compressive strength and ultrasonic pulse velocity forstone, recycle stone aggregate.

From the ACI committee report we know that at early maturities a given increase in compressive strength results in a relatively large increase in pulse velocity while at later maturity the velocity increment is smaller for the same strength increase. Analyzing the graphs and co-relations we found a concrete validity of that report.

Table 2: Summary of statistical analysis of ultrasonic pulse velocity for saturated condition

Aggregate type	Pearson coefficient (t)	Co-efficient of determination, R	Equation	Sig-F	Correlation
Brick	0.977	R = 0.955	y= -69.395 + 0.023268x	0.000	Strong
Recycled brick	0.718	R =0.515	y= -32.315 + 0.012657x	0.000	Strong
Stone	0.783	R = 0.613	y= -100.09 + 0.026148x	0.000	Strong
Recycled stone	0.835	R = 0.697	y= -60.689 + 0.018328x	0.000	Strong

Table 3: Summary of statistical analysis of ultrasonic pulse velocity for air dry condition

Aggregate type	Pearson coefficient (t)	Co-efficient of determination, R	Equation	Sig-F	Correlation
Brick	0.739	R = 0.544	y= -95.576 + 0.034022x	0.000	Moderate
Recycled brick	0.906	R =0.821	y= -121.87 + 0.043461x	0.000	Strong
Stone	0.739	R = 0.546	y= -61.19 + 0.022659x	0.000	Moderate
Recycled stone	0.518	R = 0.268	y= -29.775 + 0.014517x	0.006	Moderate

4.0 CONCLUSION

The concrete is a heterogeneous material and the interpretation of relation between compressive strength and ultrasonic pulse velocity is complex. The attempts are made for estimating the strength and other properties of concrete for getting more reliable and dependable information of the quality of concrete without crushing. The study may contribute towards the development of a guideline to determine compressive strength using ultrasonic pulse velocity. Based on the extensive experimental works and studies, the following conclusions are drawn:

The study indicates that the variation of the age and aggregate type can generate effects those are sensible in the UPV. With the increasing age, the velocity also increases . At early age the increasing rate is rapid. Among different types of aggregates used in the study, it has been seen that for a particular strength recycled stone aggregate gives lower UPV than stone aggregate concrete and similar case is happening to recycle brick and brick aggregate. So further research works can be done based on these aggregate properties by incorporating some other important parameters like porosity, moisture content etc

References

[1] D. Breysse, "Quality of NDT Measurements and Accuracy of Physical Properties," Concrete NDTCE'09, Nantes, 30 June-3 July, 2009.

[2] HANDBOOK ON NONDESTRUCTIVE TESTING OF CONCRETE, Chapter 8.The Ultrasonic Pulse Velocity Method