ESTABLISHMENT OF CORRELATION BETWEEN DESTRUCTIVE STRENGTH OF CONCRETE AND ULTRASONIC PULSE VELOCITY VALUES BY USING REGRESSION ANALYSIS

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***Abstract*:** There are many test methods to assess concrete in situ, such as Non-destructive Testing methods (Ultrasonic Pulse Velocity), and this method consider indirect and predicted tests to determine concrete strength in situ, whereas this test affected by many parameters depend on the nature of materials used in production concrete. So, there is a difficulty in determine strength of hardened concrete in situ precisely by this methods. This research aim to find unified relationship connect the results of this test and correlate them with the results of compressive strength of cubes by using Regression analysis .In this process laboratory tests carried on concrete cubes with different mixing ratios of various grades of concretes, and finding correlation curves to predict the strength of concrete much better.. An attempt was made to correlate the compressive strength of concrete with surface hardness obtained from pulse velocity (m/sec) in the current work. Fifteen concrete cubes of different grades namely M20, M_{25}, M_{30} and M_{35} were experimented using both non-destructive and destructive methods. It was found that, linear equation is best suited for obtain the compressive strength by using pulse velocity.

***IndexTerms* - MixDesign, Compressive Strength(N/mm^2),Ultrasonic pulse velocity(m/sec),Regression analysis.**

1 .INTRODUCTION

Concrete is a composite material produced from the combination of cement, fine aggregate, coarse aggregate and water in their relative proportion. It is a ubiquitous building material because its constituents are relatively cheap, and readily available. In addition to that, concrete in its fresh state has the ability to be moulded into any desired shape and size. Instead of the good care in the design and production of concrete mixture, many variations are happened in the conditions of mixing, degree of compaction or curing conditions which make many variations in the final production. Usually, this variation in the produced concrete have been assessed by standard tests to find the strength of the hardened concrete, and inspire of the type of these tests, considered a good one to determine the quality during the process of producing concrete but they have some considerable disadvantages, such as the test sample may be not present the concrete in the structure actually. So, as a results, many trials were carried out in the world to develop fast and cheap nondestructive methods to test concrete in the labs and structures and to observe the behavior of the concrete structure during a long period, such this test is Ultrasonic Pulse Velocity test.

The strength of concrete is its most important property (especially when needed for structural purposes) alongside its durability. Therefore, it is very important to ascertain the compressive strength of concrete before subjecting it to its anticipated loads. Compressive strength of the hardened concrete can be determined using the destructive and non-destructive testing (NDT) methods. The destructive testing (DT) method is carried out by crushing the cast specimen to failure while the non destructive is carried out without destroying the concrete specimen.

2.LITERATURE REVIEW

This chapter presents an overview of literature on the various experiments conducted by many authors on the destructive and non destructive testing of concrete. This literature reviews gives the idea about various topics likes ultrasonic pulse velocity and Regression analysis for finding relationship between them.

Lopez *et al*., (2016) experimentally studied about the concrete compressive strength estimation by NDT. The main aim was to produce a correlation between results of surface hardness, UPV and compressive strength of structural concrete in bleachers of soccer stadium in Parana, Brazil. Concrete structure used in the study was 26 years old and had some severe deformities i.e. segregation, corrosion and cracks. Mapping reinforcement was performed and UPV test was done. 26 specimens of concrete were collected from the bleachers and rebar mapping was done for the defect of corrosion in the pillars. Correlation curves between NDT results were plotted. The results showed that stronger the concrete, higher shall be its surface index as well as its wave propagation velocity. Results also showed a good correlation between both surface hardness test and UPV test.

Kumavat*et al.*, (2017) carried out an experimental study on combined methods of NDT in concrete and evaluation of core specimen from existing buildings. Ultra-pulse velocity, rebound hammer and core tests were performed on the specimens according to IS standards and combining the two methods. Regression analysis was carried out and correlation coefficients were given. Charts were plotted between rebound numbers, UPV against compressive strength of the core specimen. The comparison showed that use of combined methods gives higher accuracy on estimation of concrete compressive strength. The results obtained gave correlation coefficient of 0.003 and 0.355 for rebound value and UPV value. A higher correlation coefficient of 0.441 was obtained when two methods were combined.

Shariati *et al.*, (2010) assessed the strength of RC structures through UPV and rebound hammer tests and a correlation between DT and NDT tests was established. Main members of an existing building including a column, beam and slab were tested by NDT. Regression analysis was done and calibration curves were drawn. Correlation between predicted and actual compressive strength of concrete was interpreted by plotting average rebound no/ultrasonic pulse velocity against compressive strength of each member. Results obtained from the experimental study showed that regression model achieved from the combination of two NDT methods was more precise as compared to the individual methods. Results also showed that rebound number method was more effective in forecasting the compressive strength of concrete than the UPV test method

3. EXPERIMENTAL PROGRAMME

3.1 Materials

Constituent materials used to make concrete can have a significant influence on the properties of the concrete. The following sections discuss constituent materials used for manufacturing of concrete.

3.1.1 Cement

Ordinary Portland Cement 53 grade was used corresponding to IS 12269 (1987). The physical properties of the cement as obtained by the manufacturer are presented in the Table 3.1.

Table 3.1 Physical Properties of Cement

Physical properties	Test result
Specific gravity	3.15
Fineness (m^2/Kg)	311.5
Normal consistency	30%
Initial setting time (min)	90
Final setting time (min)	220
Soundness Lechatelier Expansion (mm) Autoclave Expansion (%)	 0.8 0.01
Compressive strength (MPa) 28 days	57

3.1.3 Coarse aggregate

Crushed granite stones of size 20 mm used as coarse aggregate. The bulk specific gravity in oven dry condition and water absorption of the coarse aggregate 20 mm per IS 2386 (Part III, 1963) are 2.6 and 0.5% respectively.

3.1.4 Fine aggregate

Natural river sand is used as fine aggregate. The bulk specific gravity in oven dry condition and water absorption of the sand as per IS 2386 (Part III, 1963) are 2.7 and 1% respectively. Fineness modulus of sand is 2.26.

3.1.5 Water

Generally, water that is suitable for drinking is satisfactory for use in concrete. When it is suspected that water may contain sewage, mine water, or wastes from industrial plants or canneries, it should not be used in concrete unless tests indicate that it is satisfactory. Water from such sources should be avoided.

3.1.6 Super plasticizer

Sika is used as Super plasticizer in this research for making the M 35 grade of concrete. it is used 0.4% by the weight of cement. Sika "Viscocrete"-10 R is a third generation super plasticizers for concrete and mortar. It meets the requirements for Super plasticizers according to SIA162(1989) and prEN 934-2

3.2 Test Methods

This section describes the test methods that are used for testing the hardened properties of concrete.

3.2.1 Compressive strength test

Compressive strength test was conducted on the cubical specimens for all the mixes at different curing periods as per IS 516 (1991) shown in fig 3.1. Three cubical specimens of size 150 mm x 150 mm were cast and tested for each age and each mix.

The compressive strength (F_{ck}) of the specimen was calculated by dividing the maximum load applied to the specimen by the cross-sectional area of the specimen.

$$\text{Compressive strength (N/mm}^2\text{)} = \frac{\text{Ultimate compressive load } (N)}{\text{Area of cross section of specimen} (mm^2)}$$

Fig.1 compressive strength testing of cubes

3.2.2 Ultra sonic Pulse Velocity

The test involves determination of pulse velocity through concrete as per procedure give in ASTM C 597-02. Battery operated Portable Ultrasonic Non-destructive Digital Indicating Tester was used to measure the pulse velocity through concrete. Pulses of longitudinal stress waves are generated by an electro acoustical transducer held in contact with one face of concrete and are received by another transducer held in contact with other face of concrete specimen. The time (T) taken by pulse to pass through specimen of length (L) is known as transit time. The pulse velocity (V) is calculated by dividing the length of specimen (L) by transit time (T). Average value of three specimens was considered as the pulse velocity of concrete mix. The apparatus set for the test is shown in Fig 3.2 and values of pulse velocity for grading concrete as per BIS 13311-92 (Part-I) are given in Table 3.3.

Table 1 Concrete quality grading as per BIS 13311-92 (Part-I)

Pulse velocity (m/s)	**Concrete quality grading**
Above 4500	Excellent
3500 – 4500	Good
3000 - 3500	Medium
Less than 3000	Doubtful

Fig.2 Ultrasonic Pulse Velocity test of cubes

3.3 Mix Design

The concrete mix is designed as per The Indian Standard (IS: 10262-1982) method. The following mix proportions are adopted for various grades of Concrete.

Table 2: Mix Proportions of various grades of concrete

S.No.	Grade of concrete	Mix Proportions
1	M 20	1: 2.10: 3.16
2	M 25	1: 1.83: 2.9
3	M 30	1: 1.57: 2.6
4	M 35	1: 1.89: 3.20

4. EXPERIMENTAL INVESTIGATIONS

Test cubes are made based on the mix proportions as done above. There are 15 cubes of size 15x15x15 cm are prepared. Fresh Concrete are placed on moulds and they are compressed by means of vibrators by placing 3 layers. Moulded Cubes are allowed for Casting up to 24 hours, After casting of cubes moulds should be removed and then cubes are allowed to curing up to 28 days. The following observations should be taken after 28 days of curing with the apparatus of Ultrasonic pulse velocity tester and Compressive testing machine.

4.1. 28 days test results of M 20 grade of Concrete:

Table 3: 28 days test results of M 20 grade of Concrete

S.NO	Ultra sonic Pulse velocity(m/s)	Compressive Strength (N/mm^2)
1	3004	25.8
2	3195	28.3
3	3189	27.2
4	3289	28.1
5	3405	29.8
6	3346	28.7
7	3108	26.9
8	3358	28.8
9	3297	28.2
10	3086	26.4
11	3338	28.5
12	3389	29.6
13	3372	28.9

14	3097	26.8
15	3150	27.1

4.2. 28 days test results of M 25 grade of Concrete:

Table 4: 28 days test results of M 25 grade of Concrete

S.NO	Ultra sonic Pulse velocity(m/s)	Compressive Strength (N/mm^2)
1	3478	31.8
2	3579	32.4
3	3626	33.65
4	3587	32.6
5	3684	34.1
6	3536	32.5
7	3643	33.85
8	3715	34.63
9	3595	32.75
10	3652	33.85
11	3524	32.3
12	3615	32.89
13	3678	33.9
14	3693	34.5
15	3508	32.09

4.3 28 days test results of M 30 grade of Concrete:

Table 5: 28 days test results of M 30 grade of Concrete

S.NO	Ultra sonic Pulse velocity(m/s)	Compressive Strength (N/mm^2)
1	4060	39.69
2	4156	40.9
3	3915	38.3
4	4002	39.43
5	4018	39.58
6	4123	41.72
7	4198	41.79
8	4139	40.86
9	4206	41.83
10	4039	39.6
11	4105	40.68
12	3982	39.39
13	4080	40.39

14	3942	38.43
15	4180	41.6

4.4 28 days test results of M 35 grade of Concrete

Table 6: 28 days test results of M 35 grade of Concrete

S.NO	Ultra sonic Pulse velocity(m/s)	Compressive Strength (N/mm^2)
1	4462	45.8
2	4309	43.79
3	4250	43.2
4	4350	44.43
5	4396	44.68
6	4318	43.86
7	4400	44.75
8	4326	44.28
9	4284	43.7
10	4262	43.31
11	4436	45.02
12	4375	44.63
13	4298	43.72
14	4496	46.1
15	4412	45.90

5. RESULTS AND DISCUSSIONS

5.1 Introduction

In this Chapter, the test results are presented and discussed. Linear regression analysis were conducted to study the correlation between ultrasonic pulse velocity and compressive strength of standard concrete cubes. Graphical representations are shown for various grades of concrete along linear variations for various parameters. The Linear equation and correlation coefficient value (R^2) are shown on graph. The various types of Linear equations for various grades of concrete is denoted below.

Table 7: Linear equations for various grades of Concrete

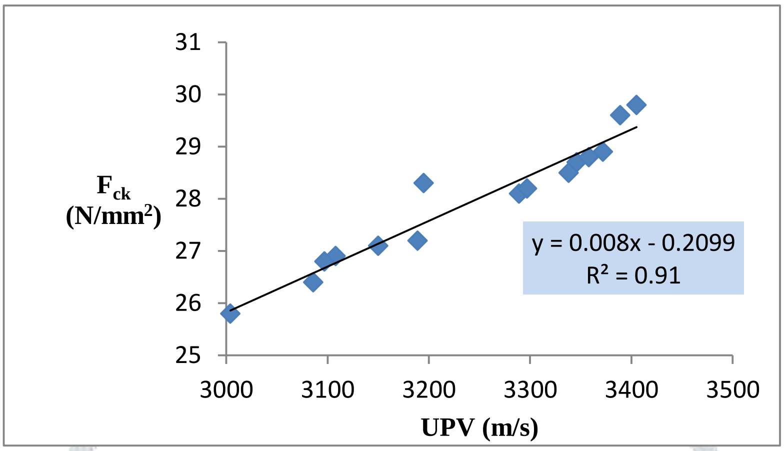
S.NO	Grade Of Concrete	Ultrasonic pulse velocity vs compressive strength
1	M 20	$y = 0.0086x - 0.2099$ $R^2 = 0.909$
2	M 25	$y = 0.0122x – 10.94$ $R^2 = 0.92$
3	M 30	$y = 0.0123x – 9.976$ $R^2 = 0.943$
4	M 35	$y = 0.0118x - 7.3491$ $R^2 = 0.910$

Note: Where x stands for UPV (m/s) and y stands for Compressive Strengths in N/mm^2.

5.2 Graphical Representations

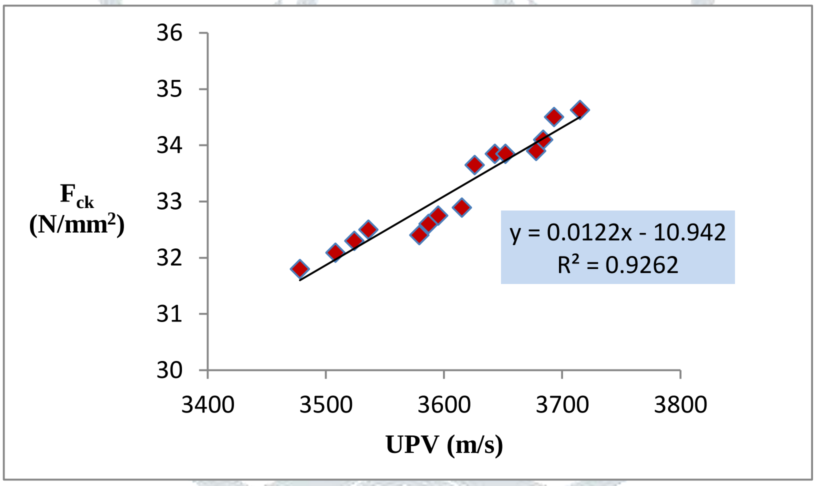
Graphs are drawn in this chapter between Ultrasonic Pulse Velocity (m/s) and Compressive Strength (N/mm^2) of Concrete.

M 20 Grade of Concrete:



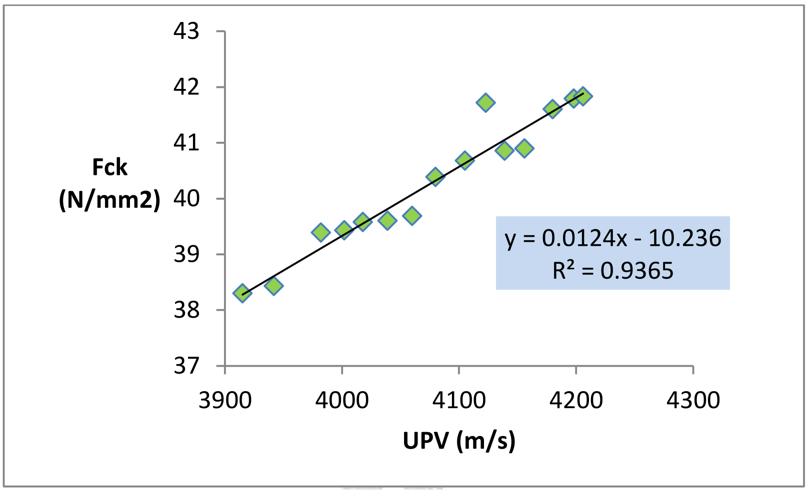
Graph 1: UPV vs Compressive Strength

M 25 Grade Of Concrete:



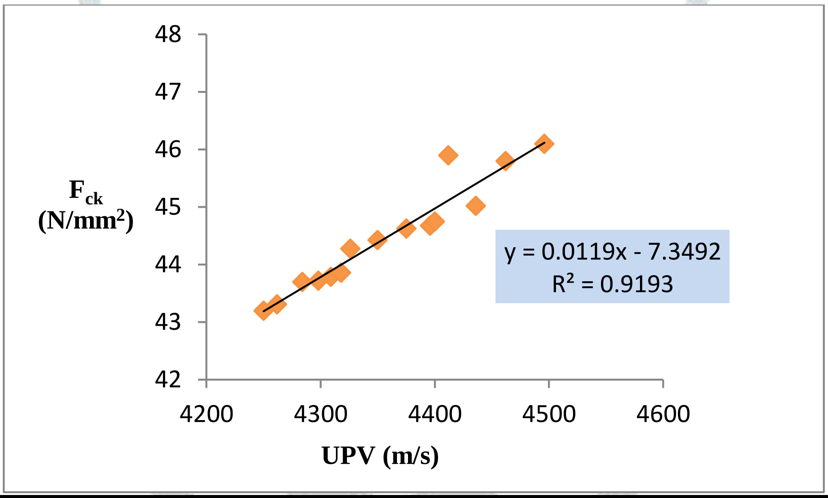
Graph 2: UPV vs Compressive Strength

M 30 Grade Of Concrete:



Graph 3: UPV vs Compressive Strength

M 35 Grade Of Concrete:



Graph 4: UPV vs Compressive Strength

Note: Where F_{ck} represents the 28 days of compressive strengths.

6. CONCLUSION

This chapter summarizes the overall conclusions drawn from the investigation of correlation between destructive and non destructive testing of concrete. The following conclusions have been drawn from the present investigation.

1. UPV is simple method for obtaining the compressive strength of concrete specimens.
2. An Linear relationship between UPV and compressive strength for the different concrete mix has provided an adequate approximation for comparing them with R^2 values in the range of 90 - 94%.
3. The present study puts forward a useful mathematical linear relationship that enables the engineer to predict confidently the crushing strength of standard concrete cubes at the age of 28 days, upon measuring the Pulse velocity.
4. The use of more than one non-destructive method would provide a better correlation, leading to predictable means of evaluation of strength in concrete.
5 Compressive strength or ultrasonic pulse velocity could be produced if only one of the values was known to us.

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