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EVALUATION OF CONCRETE STRENGTH OF IN-SERVICE BUILDINGS BY NON-DESTRUCTIVE TESTING TECHNIQUES

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Abstract: *Non-Destructive techniques are the methods predominant these days. These methods in civil engineering are used to determine the strength of a structure. As the name suggest, in these techniques strength are determined without causing any harm to the structure. These techniques have their own advantages as well as limitations, when compared to conventional strength estimation and damage detection tests. Evaluation of In-service Buildings structural elements like beams, columns, roofs etc., is a difficult proposition to assess their strength parameter due to many factors like age, weathering action, distress, improper maintenance or any repairs required to assess its structural stability, after their construction and utility and also the possible means is by Non-Destructive Techniques namely. Rebound Hammer; Ultrasonic pulse velocity test; In this investigation it is proposed to carryout required test using rebound hammer and pulse velocity tests on existing buildings which are used for education and research in RGMCET campus. The collected data is grouped structural element wise by both the methods and analyzed scientifically to infer their validity and reliability by these two methods. Also a comparative analysis of the data by these two methods has been done to correlate and also to evaluate the studies carried out by this investigations. The compressive strength of concrete is affected with its age. In this project time series analysis can be done to estimate the compressive strength of various elements of buildings and different age of buildings in RGMCET campus and compare the strength parameter of the buildings. Structural analyses will throw light in developing futuristic models to establish this type of techniques are much relevant and reliable in replacing the conventional respective testing methods.*

Keywords: Rebound hammer test, Ultrasonic pulse velocity test, Age of building, Regression.

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INTRODUCTION

Non-Destructive Techniques

Non-destructive testing (NDT) as the name implies refers to a test that does not impair the intended performance of the element, member or structure under investigation. These techniques have been grown during recent years especially in the case of construction quality assessment. The main advantage of these tests is to avoid the concrete damage or the performance of building structural components. Additionally their usage is simple and quick. These techniques have their own advantages as well as limitations, when compared to conventional strength estimation and damage detection tests. By using these Non destructive tests has been performed to assess the compressive strength of concrete employed in the structures. In this project both rebound hammer method and ultrasonic pulse velocity method are used to determine the compressive strength of in-service buildings in RGMCET campus

Project Objective

In this study the experimental work is carried out by using Rebound Hammer and Ultrasonic pulse velocity equipments on the existing buildings (Civil block and UG block) in RGMCET Campus. The members tested in this study are Beams, Columns and Slabs. The collected data analyzed by using Regression, correlation and time series analysis. The relationships between compressive strength, Rebound number, and Pulse velocity can be developed. And by using Time Series analysis the strength is forecasting for future values and compares the compressive strength of beam, column, and slab members for both civil block and UG block.

METHODOLOGY AND TECHNIQUES APPLIED

The non- destructive tests used in this project are

1. Rebound Hammer
2. Ultrasonic pulse velocity test

In this investigation it is proposed to carryout required test using rebound hammer and pulse velocity tests on existing buildings which are used for education and research in RGMCET campus. The collected data is grouped structural element wise by both the methods and analysed scientifically to infer their validity and reliability by these two methods.The compressive strength obtained from rebound hammer and the velocity obtained from the ultrasonic pulse velocity equipment has been done to correlate and also to evaluate the studies carried out by this investigations. Rebound Hammer Test and Ultrasonic Pulse Velocity Test are use in this project work.

1 Rebound Hammer

The rebound hammer is a surface hardness tester for which an empirical correlation has been established between strength and rebound number. It consists of a spring-controlled hammer mass that slides on a plunger within a tubular housing. The hammer is forced against the surface of the concrete by the spring and the distance of rebound is measured on a scale. The test surface can be horizontal, vertical or at any angle but the instrument must be calibrated in this position.

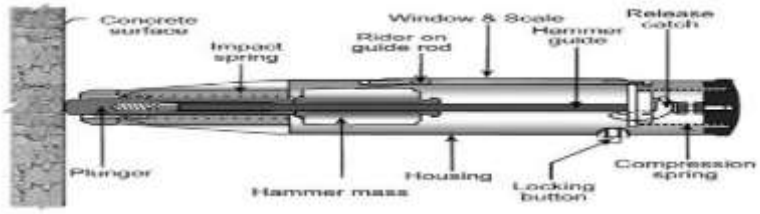

Fig 1 Rebound Hammer with Various Parts

Limitations and Advantages: The Schmidt hammer provides an inexpensive, simple and quick method of obtaining an indication of concrete strength, but accuracy of ±15 to ±20 per cent is possible only for specimens cast cured and tested under conditions for which calibration curves have been established. The results are affected by factors such as smoothness of surface, size and shape of specimen, moisture condition of the concrete, type of cement and coarse aggregate, and extent of carbonation of surface.

2 Ultrasonic Pulse Velocity Test

At present the ultrasonic pulse velocity method is the only one of this type that shows potential for testing concrete strength in situ. It measures the time of travel of an ultrasonic pulse passing through the concrete. The fundamental design features of all commercially available units are very similar, consisting of a pulse generator and a pulse receiver. Pulses are generated by shock-exciting piezo-electric crystals, with similar crystals used in the receiver. The time taken for the pulse to pass through the concrete is measured by electronic measuring circuits. The quality of concrete in structures in terms of ultrasonic pulse velocity.

Fig 2 Ultrasonic Pulse Velocity Equipment

In-Service Buildings use for testing in our campus is

1. Civil Engineering Block
2. UG Block

Experimental Work

- The members testing in Buildings are Beams, Columns and Slabs.
- Here the slab is divided as small panels (small parts) for testing with RH and UPV
- In civil Block total Beams =181
  Columns=187
  Slabs =74
- In UG Block total Beams =172
  Columns =245
  Slabs =62 are tested
- In Rebound Hammer Test compressive strength is directly obtained from the graph which depends on rebound number.
- The Compressive strength is calculated by pulse velocity using formula from IS 13311(part1):1992, clause 7.4

$$E=\frac{\rho(1+\mu)(1-2\mu)}{1-\mu}V^2$$

Where E = dynamic young's modulus of concrete

V = pulse velocity in m/sec.

ρ = Density of concrete is 2400kg/m^3

μ = Poisson's ratio taken as 0.24 (from clause 7.4)

- From dynamic young's modulus we can find static young's modulus of concrete by using formula (IS 456-2000; clause 6.2.5)

$$E_{ce}=\frac{E_c}{1+\theta}$$

Where E_C = Static young's modulus of concrete

E_{ce} = Dynamic young's modulus of concrete

θ = creep coefficient and its average value is 0.5 (from IS 456-2000; clause 6.2.5.1)

- From IS 456-2000

  Static modulus of concrete is

  $E_c=5000\sqrt{f_{ck}}$ Where f_{ck} = Characteristic compressive strength of concrete

From above we can calculate compressive strength of concrete using pulse velocity. From the experimental data the compressive strength is calculated from both Rebound Hammer test and Ultrasonic Pulse Velocity test methods. The age of the building is also consider to analyses

- From the available data

Age of Civil Engineering block is taken as 7 years

Age of UG block is taken as 19 years

Data Analysis

The analysis used in this project is

1. Regression analysis
2. Correlation analysis
3. Time series analysis

The analysis done by using MINITAB.

- Regression analysis is gives the equation indicates relationship between two or more variables.
- Correlation is a measure of association between the two variables.
- Time series forecasting is the use of a model to predict future values based on the previously observed values.

In this analysis regression equation gives relationship between the compressive strength of concrete, rebound number and age of building. The compressive strength obtained from both methods are correlated. Here the predictors are taken as rebound number, age of building, pulse velocity.

Table 1 Analysis of Civil block using Rebound hammer and Ultrasonic pulse velocity

S. No	Element	No.of Elements	Avg.RN	Compressive strength (N/mm^2) by RH	Avg.age (months)	Avg.UPV (m/sec)	Compressive strength (N/mm^2) by UPV
1	Beams	181	36.93	33.9	63	3407.73	35.28
2	Columns	187	34.61	31.05	62	3337.96	32.52
3	Slabs	74	35.78	26.22	61	3234.85	28.03

Table 2 Analysis of UG block using Rebound hammer and Ultrasonic pulse velocity

S.No	Element	No.of elements	Avg.RN	Compressive strength (N/mm^2) by RH	Avg age(months)	R^2 value (%)	Compressive strength (N/mm^2) by UPV
1	Beams	172	35.40	32.17	217	92.27	33.50
2	Columns	245	34.17	34.88	222	63.67	36.68

3	Slabs	62	32.70	22.03	216	81.71	24.39

Table 3 Comparison of compressive strength of Civil Block using RH and UPV method

S.No	Element	No.of Elements	Avg. Compressive strength (N/mm2)		Difference in compressive strength (N/mm2)
			Using RH	Using UPV	
1	Beams	181	33.9	35.28	1.38
2	Columns	187	31.05	32.52	1.47
3	Slabs	74	26.22	28.03	1.81

Table 4 Comparison of compressive strength of UG block Using RH and UPV method

S. No	Element	No. of Elements	Avg. Compressive strength (N/mm2)		Difference in compressive strength (N/mm2)
			Using RH	Using UPV	
1	Beams	172	32.17	33.50	1.33
2	Columns	245	34.88	36.68	1.80
3	Slabs	62	22.03	24.39	2.37

From code book IS 13311 (Part 1):1992

In UPV method the estimated compressive strength may vary from the actual strength by ±20% and also error due to improper used, instrumental error.

From code book IS 13311 (Part 2):1992

In rebound hammer method the estimated compressive strength may vary from the actual strength by ±25% and also error due to improper used, instrumental error.

Civil Block

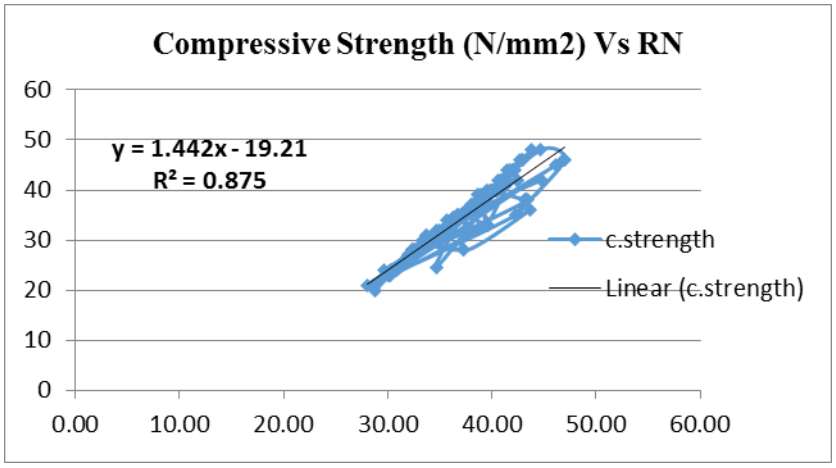

Fig 3 compressive strength Vs Rebound number

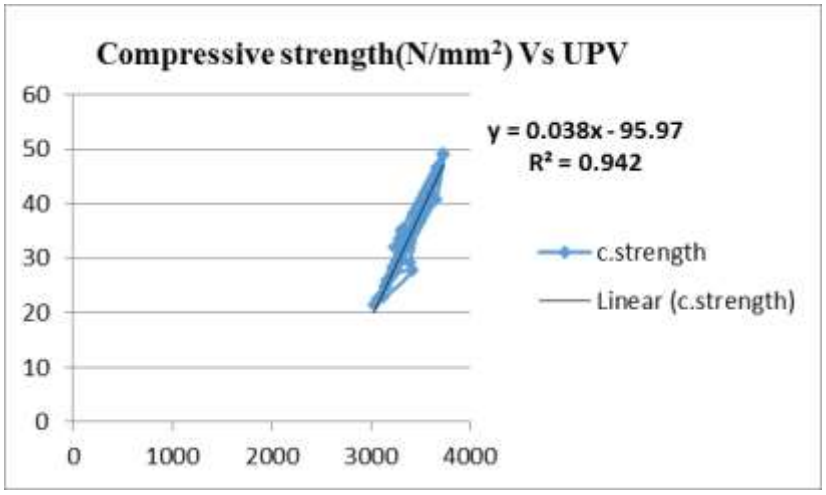

Fig 4 compressive strength Vs UPV

In Fig 4 the X-axis indicates Ultrasonic Pulse velocity

In Fig 3 the X-axis indicates Rebound number

In Fig 3 & Fig 4 Y-axis indicates Compressive strength

R^2 value indicates the amount of fit the data and equation indicates Regression equation. The line indicates the fitted line for the observed values.

UG Block

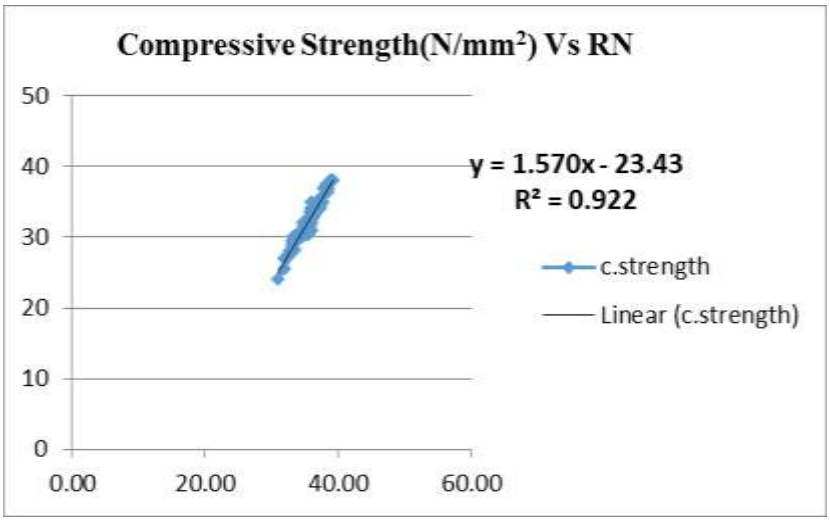

Fig 5 Compressive strength Vs Rebound number

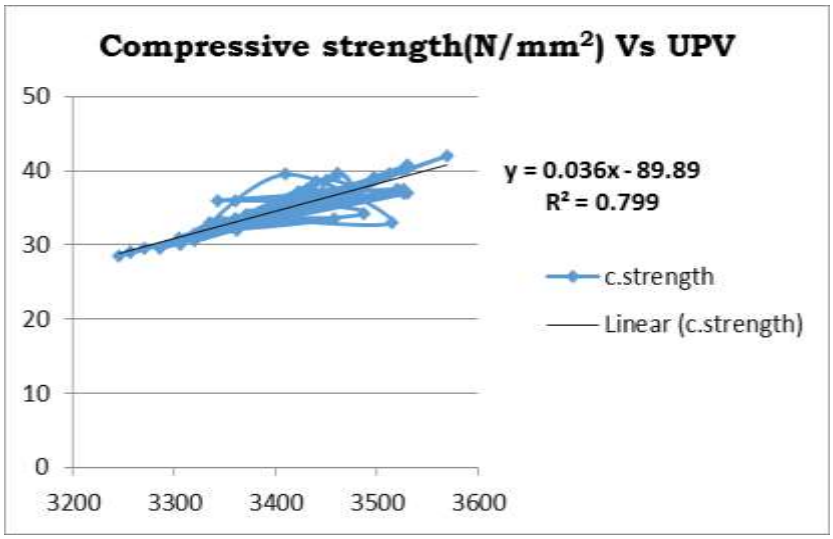

Fig 6 Compressive strength Vs UPV

In Fig 6 the X-axis indicates Ultrasonic Pulse velocity

In Fig 5 the X-axis indicates Rebound number

In Fig 5 & fig 6 Y-axis indicates Compressive strength

CONCLUSIONS

1. The NDT methods of RH and UPV are used to assess the compressive strength of concrete of in-service buildings(Civil Engineering block and UG block of RGMCET) in this investigation
2. It is observed from the analysis of compressive strength of concrete of CE block and UG block the values varies depending on the factors such as age of building that implies the

durability factor of the concrete. The relevant values are as indicated below as per the elements considered

S.No	Element	No.of tested elements In civil block	Civil block		No.of tested elements in UG block	UG block		Variance in compressive strength (N/mm^2)	
			RH	UPV		RH	UPV	RH	UPV
1	Columns	187	31	33	245	35	37	-4	-4
2	Beams	181	34	35	172	32	34	+2	+1
3	Slabs	74	26	28	62	22	24	+4	+4

3. There is no definite inference can be evolved by considering the age and durability factors of compressive strength of concrete used in CE block and UG block. This shows compressive strength of concrete obtained by RH and UPV methods differs by 20%. Hence a very intensive investigation may be essential to establish relationship between two methods.
4. The structural elements such as beams, columns, slabs are subjected various types loadings. For instance columns are subjected to axial loadings, where beams and slabs are serve due to bending. From the analysis it is found through for all the elements M_{20} grade concrete was used, the NDT results indicate a little variations in compressive strength of elements as shown in above given table.

The average compressive strength by RH & UPV	CE block (N/mm^2)	UG block (N/mm^2)
For columns	32	36
For beams	35	33
For slabs	27	23

5. The NDT methods are very useful in ascertaining the strength of concrete of in-service building to ensure its structural adequacy in terms of its obtain strength. Normally NDT methods yield higher compressive strength of concrete compared to the actual grade of concrete used in view of its age of the concrete.

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