Development of Correlation between Destructive Strength and Rebound Value of Concrete by Using Regression Analysis

Dr. K. Chandrasekhar Reddy[1] and M.Murali[2]

[1]Professor & Principal, [2]PG student
Department of Civil Engineering
Siddharth Institute of Engineering & Technology, Puttur, Andhra Pradesh, India
kamasani.kcr@gmail.com, msmurali013@gmail.com

Abstract

The characteristic compressive strength of concrete before construction can be estimated with the established laboratory practices. However the compressive strength of the concrete when it is an integral part of the structure cannot be determined by destructive testing. Rebound hammer and ultrasound pulse velocity are the methods usually employed in field to assess the quality of hardened concrete as structural member. An attempt was made to correlate the compressive strength of concrete obtained by destructive test and surface hardness obtained by rebound hammer in the current work. Fifteen concrete cubes of different grades namely M 20, M 25, M 30 and M 35 were experimented using both non-destructive and destructive methods. Regression analysis is used to find relationship between destructive and non-destructive values. It was found that, linear regression equation is best suited for obtain the compressive strength by using rebound value.

Keywords: Mix Design, Compressive Strength, Rebound value, 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 mould into any desired shape and size. The strength of concrete is the 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 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.

NDT of concrete is of great scientific and practical importance especially the need for quality characterization of damaged constructions made of concrete. Its importance can also be seen in the desire for a proposed change of usage or extension of a structure, acceptability of a structure for purchase, assessment of the quality or integrity of the repairs, monitoring of strength development in relation to formwork stripping, curing, pre-stressing or load application. This research therefore seeks to compare the most common non-destructive techniques, the re-bound hammer and the ultrasonic pulse velocity methods so as to see which method has a superior capability in the sense that it is capable of providing more information on concrete properties.

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 rebound hammer, ultrasonic pulse velocity and Regression analysis for finding relationship between them.

Nilam Bhosale, P.A. Salunkhe Proposed that the Non destructive test methods are used to examine the properties and compressive strength of hardened concrete. In existing concrete structures there was no direct relation between the results of non destructive tests. This paper describes the correlation between Rebound hammer, Ultrasonic pulse velocity, core compressive strength and cylinder compressive strength of hardened concrete. It also describes the relation between bond strength and cube compressive strength and comparison of modulus of elasticity by different standards. An experimental program was carried out, involving both destructive and non destructive methods applied to different concrete mixtures, such as M 20, M 25 and M 30.

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.

Patil *et al*., (2015) experimentally investigated on the comparative study of effect of curing on strength of concrete using DT and NDT methods. 27 cubes of M25 grade were casted and allowed to be cured for 7, 14 and 28 days and rebound hammer test and compressive strength test was performed on 9 cubes of 7, 14 and 28 days respectively. The results showed that rebound number increased as the compressive strength increased and vice-versa. For 28 days of curing decrease in percentage strength was less as compared to 7 days percentage decrease in strength and average error in measuring compressive strength for 7, 14 and28 days by rebound hammer and CTM was found out to be 20.01%, 1.37% and 0.99% respectively. Results also showed that compressive strength or rebound number could be produced if only one of the values was known.

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 1.

Table .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 Le-Chatelier Expansion (mm) Autoclave Expansion (%)	 0.8 0.01
28 days Compressive strength (MPa)	57

3.1.2 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.

3.1.3 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.

3.1.4 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.

3.1.5 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 Test on Cubes

3.2.2 Rebound Hammer

The most satisfactory way of establishing a correlation between compressive strength of concrete and its rebound number is to measure both the properties simultaneously on concrete cubes. The concrete cube specimens are held in a compression testing machine under a fixed load, measurements of rebound number taken and then the compressive strength determined as per IS 516:1959. The fixed load required is of the order of 7 N/mm^2, when the impact energy of the hammer is about 2.2 Nm. The load should be increased for calibrating rebound hammers of greater impact energy and decreased for calibrating rebound hammers of lesser impact energy. At least nine readings should be taken on each of the two vertical faces accessible in the compression testing machine when using the rebound hammers. The points of impact on the specimen must not be nearer an edge than 20 mm and should be not less than 20 mm from each other. The same points must not be impacted more than once. Rebound hammer equipment and testing are shown in Fig.2.

Fig.2 Rebound Hammer test

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 are publicized in table 2.

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: 2.90
3	M 30	1: 1.57: 2.60
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 is 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 found after 28 days of curing with the apparatus of Rebound Hammer and Compressive testing machine for M 20, M 25, M 30 and M 35 are give in Table 3 to Table 6.

Table 3 Test results of M 20 grade of Concrete after 28 days curing

S.NO	Rebound Value	Rebound strength (N/mm^2)	Compressive Strength (N/mm^2)
1	20	14	25.8
2	22	18	28.3
3	21	16	27.2
4	22	18	28.1
5	24	20	29.8
6	23	19	28.7
7	21	16	26.9
8	23	19	28.8
9	22	18	28.2
10	21	16	26.4
11	23	19	28.5
12	24	20	29.6
13	23	19	28.9
14	21	16	26.8
15	21	16	27.1

Table 4 Test results of M 25 grade of Concrete after 28 days curing

S.NO	Rebound Value	Rebound strength (N/mm^2)	Compressive Strength (N/mm^2)
1	23	19	31.80
2	25	22	32.40
3	26	24	33.65
4	25	22	32.60
5	26	24	34.10
6	24	20	32.50
7	26	24	33.85
8	27	25	34.63
9	25	22	32.75
10	26	24	33.85
11	24	20	32.30
12	25	22	32.89
13	26	24	33.90
14	27	25	34.50
15	23	19	32.09

Table 5 Test results of M 30 grade of Concrete after 28 days curing

S.NO	Rebound Value	Rebound strength (N/mm^2)	Compressive Strength (N/mm^2)
1	27	25	39.69
2	28	28	40.90
3	26	24	38.30
4	27	25	39.43
5	27	25	39.58
6	28	28	41.72
7	29	28	41.79
8	28	28	40.86
9	29	28	41.83
10	27	25	39.60
11	28	28	40.68
12	27	25	39.39
13	28	28	40.39
14	26	24	38.43
15	28	28	41.60

Table 6 Test results of M 35 grade of Concrete after 28 days curing

S.No.	Rebound Value	Rebound strength (N/mm^2)	Compressive Strength (N/mm^2)
1	33	35	45.80
2	30	30	43.79
3	29	29	43.20
4	31	32	44.43
5	32	33	44.68
6	30	30	43.86
7	32	33	44.75
8	31	32	44.28
9	30	30	43.70
10	29	29	43.31
11	32	33	45.02
12	31	32	44.63
13	30	30	43.72
14	33	35	46.10

15	29	29	43.64

5. Results and Discussions

The test results are presented and discussed. Linear regression analysis was conducted to study the correlation between compressive strength and rebound value of standard concrete cubes. The Linear equations and correlation coefficient (R^2) values are presented in Table 7. Graphical representations are shown for various grades of concrete along linear variations are shown in Fig.3 to Fig.6.

Table 7 Linear Equations for Various Grades of Concrete

S.No.	Grade of Concrete	Rebound Value Vs Compressive Strength	Correlation coefficient (R^2)
1	M 20	y = 0.943x + 7.110	0.9528
2	M 25	y = 0.690x + 15.78	0.90
3	M 30	y = 1.229x + 6.429	0.9072
4	M 35	y = 0.600x + 25.82	0.9302

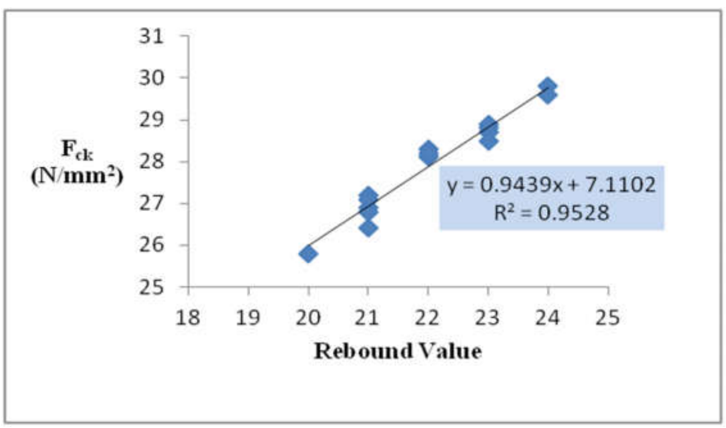

Fig.3 Compressive Strength (F_{ck}) vs Rebound value for M 20

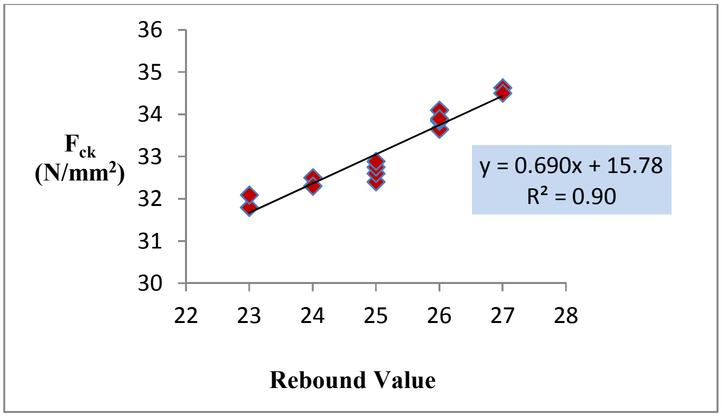

Fig.4 Compressive Strength (F_{ck}) vs Rebound value for M 25

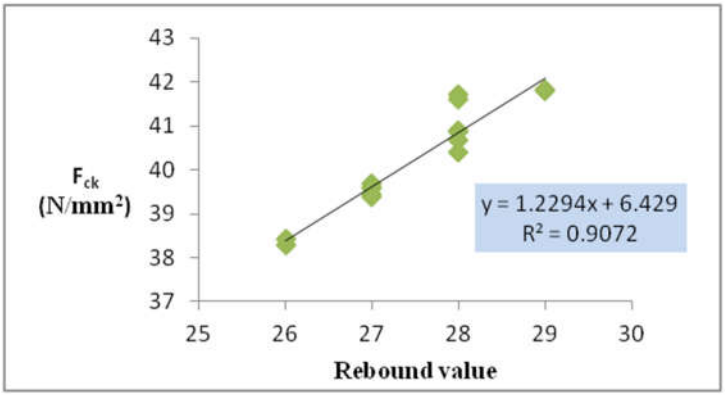

Fig.5 Compressive Strength (F_{ck}) vs Rebound value for M 30

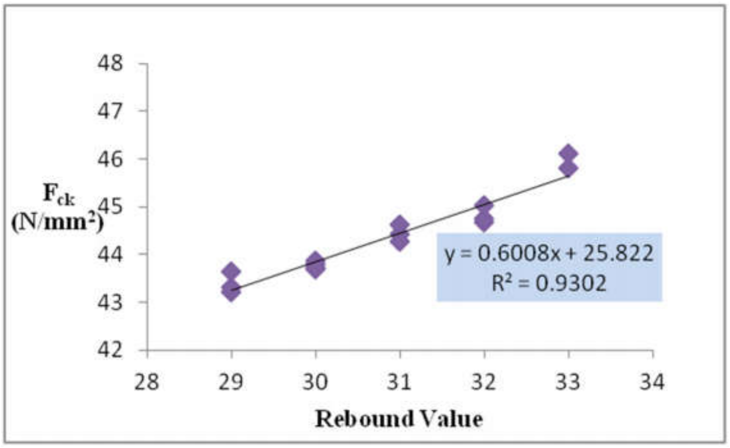

Fig.6 Compressive Strength (F_{ck}) vs Rebound value for M 35

6. Conclusion

This 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.

- Characteristic Compressive strength after 28 days curing was found by destructive test for M 20, M 25, M 30 and M 35 grades of concrete.
- Rebound values were found by Non-destructive test(Rebound hammer test) for corresponding M 20, M 25, M 30 and M 35 grades of concrete.
- For Each grade 15 samples were used for testing.
- Compressive strength vales are correlated with rebound hammer values using regression analysis.
- The developed regression equations were shown good correlation.
- The developed regression equations may be used for M 20, M 25, M 30 and M 35 grades of concrete to get the compressive strength using rebound values with reasonable degree of accuracy.

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