Comparison of Compressive Strength of Hardened Concrete Using Schmidt Rebound Hammer and Conventional Testing Method

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1 Introduction

It would be difficult for us to imagine ourselves without concrete. Concrete is a visco-elastic moldable liquid consisting cement, sand, coarse aggregate, water with admixtures. It is fundamental building component for present day society. Each significant development venture utilizes concrete in some frame. Its wide use is governed due to its strength, durability, rigidity, low maintenance, resistance against water and fire, workability, economy, etc. With the use of concrete in infrastructural activities comes the parameter of safety that must be kept in mind and hence determining compressive strength is paramount which is done in order to judge concrete quality. Often, structures of concrete should be checked for its strength once the concrete has hardened for determining if the structure is serviceable. Various DT and NDT methods for determining strength of concrete have been suggested. The analysis of the concrete strength in existing structures by destructive method is costly, troublesome in some case and might not be possible in some cases. Hence, it is not always appropriate since they affect the physical characteristics of concrete whereas Non- destructive tests are reliable and time saving without undergoing any damage to the structure. The two tests that have been performed during the following work are compression test by compression testing machine and Schmidt rebound hammer test. DT investigates the mechanism of failure of material to determine its mechanical properties viz. yield and compressive strength. Non-Destructive techniques investigate properties without getting into the core of structure. The principle involved for Rebound Hammer Test is: The elastic rebound depends on surface hardness on which it strikes. When the

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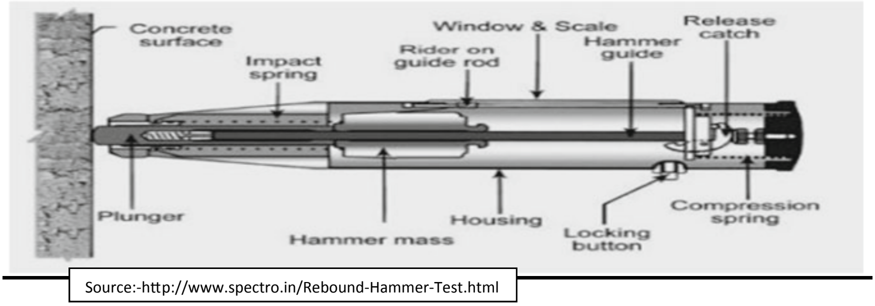

Fig. 1 Schmidt rebound hammer. *Source* https://1.bp.blogspot.com/-6wa2pOhP47o/Xpx0Tc_LtUI/AAAAAAAAAXo/NAY8qT6hepQvN0V_vMraQdbZLxQwKBe5ACLcBGAsYHQ/s1600/rebound%2Bhammer.jpg

plunger of Rebound Hammer is punched against the surface of hardened concrete, spring controlled mass rebounds and degree of such rebound depends upon hardness of the surface, thus rebound is related to the concrete's strength. Value of rebound is obtained from the graduated scale and is assigned as rebound number or index. The strength of the concrete can then be read straight from graph that is present on the hammer body (Fig. 1).

2 Literature Review

A series of connected works of national and global journals have been contemplated. Out of these, portions of the significant works are mentioned below:

1. R. Balamuralikrishnan (2017) have attempted to show that the percentage variation in the average compressive strength from NDT 25–32 N/mm^2 having w/c ratio ranging from 0.35 to 0.50 and destructive testing 30–36.24 N/mm^2 of same water-cement ratio varies from 11.50 to 16.70% with respect to destructive testing. The variation of the values of not more than 16.5% is the evidence that NDT by rebound hammer shows reliability in monitoring the health of structural elements. The study also suggested that the increasing rebound number represents the higher compressive strength and the results are affected by factors such as smoothness of surface, moisture condition of the concrete and the type of cement used.
2. Malek and Kaouther (2014) presented the calculations of compressive strength and modulus of elasticity determined from nondestructive and destructive tests. The investigation supported the use of NDT due to its ease of operation and economic advantages. The different results of the testing were conducted using compression testing machine and rebound hammer test. The compressive strength determined by destructive test (compression test) and Non-destructive

test (rebound hammer test) at different ages of the concrete (7 and 14 days) showed that the resistances obtained by the compression test were higher than those obtained by the rebound hammer test and decreases considerably at the age of 28 days. The authors suggested that the rebound hammer test can be used to evaluate the compressive strength of old concrete and not young concrete.

3. Ali-Benyahia et al. (2017) have attempted to optimize the methodology of the calibration of NDT model on site. Combination of NDT techniques has been promoted in many studies but its efficiency remains controversial. The conclusions were centered around the enhancement of the significance and the viability of the NDT techniques in such operational circumstances.
4. Kumavat et al. (2014) performed a case study on condition assessment of concrete with NDT. A reduction of 5% in the minimum average compressive strength was found. It was presumed that the present strategies for ultrasonic testing of concrete require direct contact between the surface of concrete and the transducers. Since the contact is not always perfect, the air trapped in between may cause variable errors in the measurements.
5. Saleem et al. (2012) focused on non-destructive evaluation of a five-storied concrete frame structure to assess the existing condition. For this purpose, load tests and core tests were performed on four floors from basement to first floor. Test results showed that the structure has adequate strength for future use although it was unprotected against severe environmental conditions for several years. Study further confirms that a combination of tests, instead of performing just one type of test, provides more suitable results to confidently accept or reject the structure as a whole or its component for future use.
6. Shankar and Joshi (2014) compared the actual strength of a concrete by destructive test (DT) method and that by NDT method using Schmidt Hammer (SH) (or rebound hammer) and ultrasonic pulse velocity (UPV) as NDTs and test by compression testing machine (CTM) as DT. In this study, separate comparisons have been done for two NDTs and a procedure to follow while estimating strength of concrete by NDT has been recommended.

3 Methodology

66 Samples (Fig. 2) of concrete cubes were casted with the mix design of M25 and M30. The experimental procedure included the following steps to study the variation of compressive strength by NDT and DT. These steps include:(As per IS 516: 1979)

- 66 Cubes have been casted.
- All the specimens were cured before testing.
- Nomenclature is done for each specimen using a unique number with 10 points marked on each cube to facilitate Rebound hammer test and make identical testing for all cubes (Fig. 3).
- Specimens were then put at the center of compression testing machine and loaded to about 25.0% of their ultimate compressive strength.

Fig. 2 66 cubes laid in order on ground

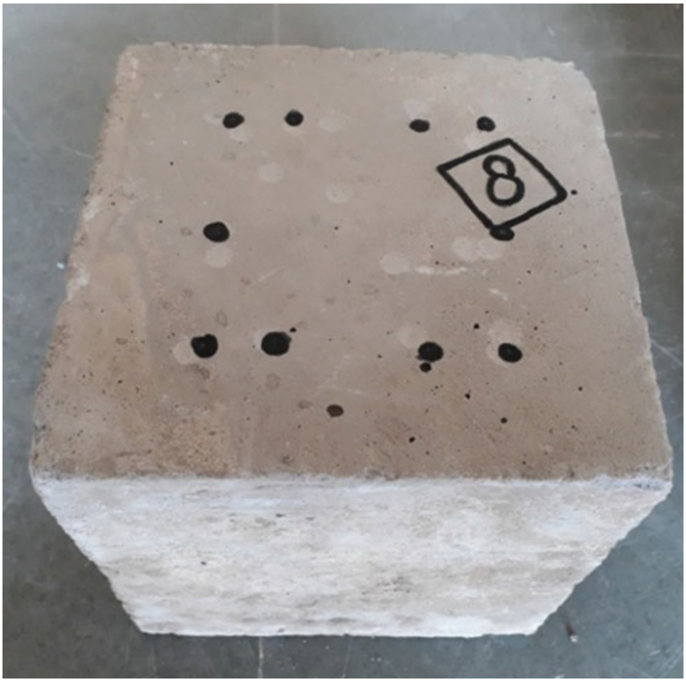

Fig. 3 Detailing of 10 points on each cube with a unique number

Fig. 4 The cube specimen placed in the testing machine

- Before commencing the rebound hammer test, the apparatus should be tested against the test anvil to get reliable results.
- Ten readings were then taken to estimate the average rebound number using ten points marked on each cube.
- After reading the rebound number, the applied load was increased at a rate of approximately 140 kg/sq cc/min until failure and then cube.
- The compressive strength of each specimen was calculated (Fig. 4).
- The values obtained from both the tests were compared and the variation is then obtained in the values of NDT with respect to DT values.

4 Result

66 cubes were experimented by Rebound Hammer and Compression Testing machine and the variation in compressive test results has been shown in Table 1 followed by graphical comparison (Fig. 5).

Table 1 Variation between NDT and DT test results

S No.	Grade	Rebound number	Strength by rebound hammer, N/mm^2	Avg. compressive strength, NDT, N/mm^2	DT compressive strength, N/mm^2	Avg. compressive strength, DT, N/mm^2	% Variation between NDT and DT
1	M30	51.7	25.5	25	27.26	28.43666667	12
2	M30	57.7	21.5		28.25		
3	M30	45.4	28		29.8		
4	M30	41.8	21	22	22.63	24.81333333	11
5	M30	57.7	25		28.25		
6	M30	52.9	20		23.56		
7	M30	47.3	27.5	25.33333333	30.93	29.74666667	15
8	M30	46.3	25.5		28.51		
9	M30	48.1	23		29.8		
10	M30	51.8	40	38	40.43	42.46666667	11
11	M30	51.4	38.5		44.93		
12	M30	48.3	35.5		42.04		
13	M30	44.8	35.5	38.5	42.86	42.04666667	8
14	M30	57.4	38		40.88		
15	M30	49.8	42		42.4		
16	M30	44.8	25	27.66666667	32.01	32.07333333	14
17	M30	52.1	30		31.48		
18	M30	42.7	28		32.73		
19	M30	48	32	32.16666667	34.14	36.35666667	12
20	M30	50.5	33.5		37.3		
21	M30	44.2	31		37.63		
22	M30	61.6	49	53.83333333	60.17	60.78	11
23	M30	50.5	56.5		63.42		
24	M30	54.8	56		58.75		
25	M30	59.8	45	42.66666667	50.35	48.71	12
26	M30	49.3	44		45.12		
27	M30	46.1	39		50.66		
28	M30	55.2	36	39	45.15	46.06333333	15
29	M30	53.9	42		49.42		
30	M30	46.2	39		43.62		
31	M30	60.8	62	61.66666667	66.8	69.27	11
32	M30	55.6	58		70.17		
33	M30	46	65		70.84		

(continued)

Table 1 (continued)

S No.	Grade	Rebound number	Strength by rebound hammer, N/mm^2	Avg. compressive strength, NDT, N/mm^2	DT compressive strength, N/mm^2	Avg. compressive strength, DT, N/mm^2	% Variation between NDT and DT
34	M25	45	21.5	23.33333333	25.24	27.64333333	16
35	M25	49.6	25.5		29.73		
36	M25	45.3	23		27.96		
37	M25	48.2	20	20.5	22.72	23.94333333	14
38	M25	50.6	17.5		22.74		
39	M25	59.6	24		26.37		
40	M25	46.2	24.5	21.33333333	24.04	24.37	12
41	M25	43.1	20		23.29		
42	M25	36.1	19.5		25.78		
43	M25	43.1	30	30.5	37.62	35.56	14
44	M25	46.8	28.5		35.56		
45	M25	45.5	33		33.5		
46	M25	54.2	39.5	38.66666667	43.14	42.32	9
47	M25	52.7	41		44.29		
48	M25	46.8	35.5		39.53		
49	M25	44.3	30	32.16666667	37.15	36.05666667	11
50	M25	56.7	31.5		33.44		
51	M25	48.5	35		37.58		
52	M25	47.7	42.5	38.83333333	41.86	41.09333333	5
53	M25	43.9	39.5		39.38		
54	M25	53.3	34.5		42.04		
55	M25	45.6	28	31.83333333	38	38.53333333	17
56	M25	50.2	31.5		36.74		
57	M25	48.8	36		40.86		
58	M25	51.4	43	48.66666667	53.07	50.29333333	3
59	M25	51	48		48.17		
60	M25	53.5	55		49.64		
61	M25	50	47.5	49.33333333	65.33	59.47333333	17%
62	M25	54.1	55.5		56.29		
63	M25	59.4	45		56.8		
64	M25	52.8	56	48.33333333	53.06	51.55666667	6
65	M25	48.8	46		50.46		
66	M25	52.2	43		51.15		

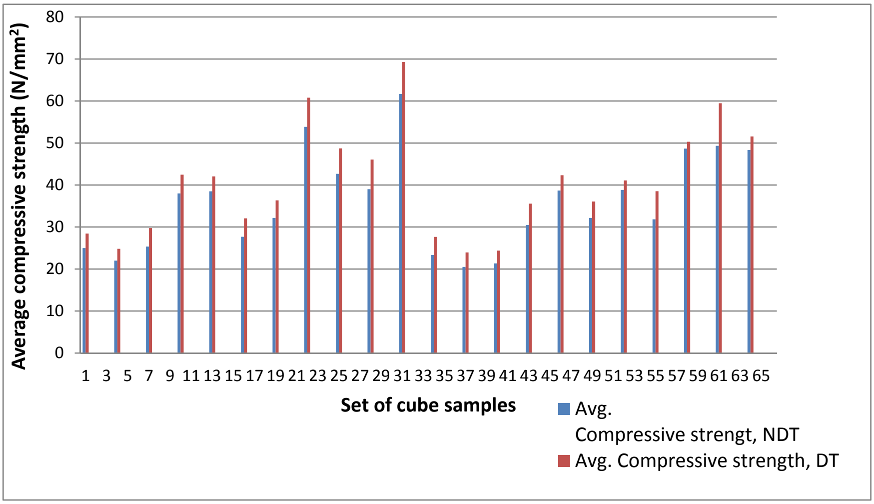

Fig. 5 Variation in compressive strength obtained from NDT and DT

5 Conclusion

This experimental study suggests that the variation in the compressive strength obtained by Non- destructive test with respect to the Destructive test vary with a value ranging from 0 to 15% for most of the cubes samples.

Destructive and Non-destructive tests were performed on 33 cube samples of M25 grade and the average variation in values of strength using NDT with respect to DT is observed as 11.09% whereas in case of M 30 grade concrete, the average variation for 33 cube samples is 11.90%.

The result obtained suggests that the use of Non- destructive methods is reliable and can be used to estimate the compressive strength of hardened concrete. It can therefore reduce the number of cores taken from the structures to estimate the strength.

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