Correlation between Non-Destructive Testing (NDT) and Destructive Testing (DT) of Concrete for Linear, Quadratic and Cubic Relation

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Abstract— *This work present a correlation and comparison between Non- Destructive test (Rebound Hammer) & Destructive test of testing the compressive strength of concrete cubes for Linear, Quadratic & Cubic Relation. Concrete cubes of 150mm×150mm×150mm were cast of M-20, M-25, M-30 and M-35 grades and each grade cured for 7days, 14days and 28days. A total 120 cubes were cast. When analyses were carried out, there are a relation between the results of rebound number obtained from rebound hammer and compressive strength obtained from compression machine. These results i.e. rebound number and compressive strength value of cubes M-20, M-25, M-30 and M-35 grades were correlate and compared with Linear, Quadratic & Cubic Equation and checked from which equations among these three gives a more accurate results with compressive strength. After analyses it was found that among three of them predicted strength of cube only the linear and quadratic equation gave more accurate relationships with compressive strength of concrete. And at the end it also gave statistical analysis of the results which shows that there were a significant difference between the rebound number and compressive strength.*

Keywords— Concrete, Compressive Strength, Destructive Testing (DT), NON-Destructive Testing (NDT), Correlation.

I. INTRODUCTION

Concrete is a composite material which is produced from the combination of fine aggregates, coarse aggregates and water with proper proportion. The strength of concrete is most important along with its durability. Therefore it is important to check or find out the compressive strength of concrete before used in structural purpose. Therefore, it is very important to check the compressive strength of concrete before subjecting it to its anticipated loads. Compressive strength of a hardened concrete can be determine using destructive & non- destructive test (NDT) methods. The (DT) is carried out by crushing the cast specimen to failure while the NDT method is carried out without destroying the cast specimen. The Rebound Hammer (Schmitz) is one of the most popular NDT methods used to test the strength of concrete. The aim of this project is to compare the concrete compressive strengths measured using destructive method and those measured using the NDT for Linear, Quadratic & Cubic Relation and to check from which equations among these three gives a more accurate results with compressive strength.

II. MATERIALS & METHODS

Materials: Throughout the project work CCI brand of PPC is used. The coarse aggregates and fine aggregates used for experiments are taken from laboratory of college. Portable drinking water is used in concrete.

Methods: Concrete of grades M-20, M-25, M-30, M-35 was used for the study. The mix design was done in accordance with IS: 10262 (2009) specification. Mixing was done in concrete mixer. Concrete cube 150mm×150mm×150mm were cast. The specimen were demoulded after 24 hours and immersed into curing tank filled with water and cured for 7days, 14days & 28days.

NDT of concrete using Rebound Hammer: The NDT of compressive strength of concrete was carried out using rebound (Schmitz) hammer. The test was based on the principle that the rebound of an elastic mass depend on the hardness of the surface against which the mass impinges.

Destructive Testing (DT) using the Compression Machine: The compressive strength test was carried out using the compression machine. The test was carried out in accordance with IS: 516 (1959) specification. 30 concrete specimens for each concrete grade of M-20, M-25, M-35, and M-40 were tested after curing for 7, 14and 28 days.

III. RESULTS AND DISCUSSION

Materials Cement: Table 1 shows the test results of CCI brand of PPC. The cement test results obtained meets the standard values in IS: 1489 (Part 1):1991. Hence it is good for concrete works.

Coarse Aggregate: Table 1 shows the results of the test conducted on the coarse aggregate. The aggregate impact value (AIV) of the aggregate used was 19%. These values are less than the IS: 2386 (Part IV)-1963, and specific gravity 2.73, the coarse aggregate used was good for concrete works.

Fine Aggregate: Specific gravity of fine aggregates 2.67. This is good for concrete works.

TABLE 1
RESULTS OF PRELIMINARY TEST ON MATERIALS

TEST	RESULTS	STANDARD CODE	LIMIT IN CODE
Specific Gravity of Cement	3.15		3.15
Initial Setting Time of Cement(Min)	54	IS :1489 (Part 1) -1991	Greater than 30min
Final Setting Time of Cement(Min)	210	IS :1489 (Part 1) -1991	Less than 600min
Specific Gravity of Fine Aggregate	2.67	IS :2386 (Part III)-1963	2.5 to 3
Specific Gravity of Coarse Aggregate	2.73	IS :2386 (Part III)-1963	2.5 to 3
AIV	19%	IS:2386 (Part IV)-1963	Good aggregate (10% to 20%)

Relationship between compressive strength and Rebound Number: The results of both DT and NDT are presented in Tables 2, Table 3 and Table 4 for concrete cubes of ages 7, 14 and 28 days respectively. The results show that a higher rebound number result gives high compressive strength value and vice versa. Table 5 and Table 6 and Table 7 shows the results of compressive strength and rebound number with predicted values of linear, quadratic and cubic relation of different mix M-20, M-25, M-35, and M-40 for 7, 14 and 28days respectively. So the results are shown given below:

TABLE 2
COMPRESSIVE STRENGTH AND REBOUND NUMBER FOR DIFFERENT CONCRETE CURED FOR 7DAYS

M-20		M-25		M-30		M-35	
C.S	R.No	C.S	R.No	C.S	R.No	C.S	R.No
11	12.5	16.52	18.01	16	17.45	20.5	22.12
10	11.5	15.3	17.01	13.5	14.7	18.6	19.65
10	11.5	14	15.26	14.5	16.23	20.5	22.53
11.5	13	16.42	17.92	17	17.97	19	21.51
12	13.54	17.25	18.95	15.5	16.92	17.5	18.54
13.5	14.28	15.24	17.21	16.5	17.94	16.5	18
12	13.25	15.98	17.45	14.1	16.12	17	18.05
11.7	13.11	16.47	18.02	16	17.081	18	19.88
11.6	12.7	17.48	18.23	14	15.98	18.5	20
12.5	13.4	16.24	18.82	14.5	16.31	19	21.21

TABLE 3
COMPRESSIVE STRENGTH AND REBOUND NUMBER FOR DIFFERENT CONCRETE CURED FOR 14 DAYS

M-20		M-25		M-30		M-35	
C.S	R.No	C.S	R.No	C.S	R.No	C.S	R.No
17	18.01	22.5	22.68	17.3	18.5	22	25.9
14.2	15.04	21.3	22.47	20.6	22.92	22.5	26.8
13.6	14.48	23.45	25.01	18.6	19.75	19.5	21.47
15	16.47	24.02	26.04	17.5	18.9	23	27.5
14.7	15.33	23.40	24.92	22.2	26.34	23.5	29.05
13.9	14.95	22.10	23.45	19	21	24	31
14.3	15.12	21.01	22.31	18.5	20.02	25.5	34.25
15.3	16.9	24.10	26.31	19	21.34	17.5	19.05
16	17.43	21.98	23.01	20.2	22.56	20	21.98
13.8	14.72	22.97	24.45	17	18.14	21	23.7

TABLE 4

COMPRESSIVE STRENGTH AND REBOUND NUMBER FOR DIFFERENT CONCRETE CURED FOR 28 DAYS

M-20		M-25		M-30		M-35	
C.S	R.No	C.S	R.No	C.S	R.No	C.S	R.No
23.5	27.2	28.2	34.50	33.3	44.23	38	51.9
20.5	22.8	30.1	37.00	34.	46.18	36.5	47
20	22.5	27	33.98	31.5	41.67	41	54.5
24	28.83	25.12	33.01	32	42.5	42.5	55.6
23.5	26.5	26.87	33.45	34	46.25	38.5	52.4
21.5	24.87	29.45	36.47	36.5	47.52	37.5	50
28.5	34.5	26.57	33.25	37.5	50.02	35.5	46.75
24.5	29.84	27.00	33.98	29.5	29.5	38.8	53
22	25.4	29.21	36.25	33.7	45.45	40	54.11
21	23.05	25.01	33.00	37	49	43.5	60.3

Data Analysis: *The above results are compared with Linear, Quadratic & Cubic Equations respectively.*

TABLE 5

CORRELATION BETWEEN COMPRESSIVE STRENGTH & REBOUND NUMBER WITH PREDICTED CONCRETE STRENGTH FOR 7 DAYS.

C.S	R. NO.	PREDICTED CONCRETE STRENGTH		
		LINEAR EQUATION	QUADRATIC EQUATION	CUBIC EQUATION
11	12.5	11.21	11.12	11.13
10	11.5	10.26	10.09	10.16
10	11.5	10.26	10.09	10.16
11.5	13	11.68	11.64	11.62
12	13.54	12.20	12.18	12.15
13.5	14.28	12.90	12.93	12.88
12	13.25	11.92	11.89	11.86
11.7	13.11	11.79	11.75	11.73
11.6	12.7	11.40	11.33	11.32
12.5	13.4	12.07	12.04	12.01
14	15.26	13.83	13.89	13.85
16.42	17.92	16.36	16.43	16.44
17.25	18.95	17.34	17.38	17.41
15.24	17.21	15.69	15.77	15.76
15.98	17.45	15.92	15.99	15.99
16.47	18.02	16.46	16.52	16.54
17.48	18.23	16.66	16.72	16.74
16.24	17.82	16.27	16.34	16.35
16	17.45	15.92	15.99	15.99
13.5	14.7	13.30	13.34	13.30
14.5	16.23	14.76	14.83	14.81
17	17.97	16.41	16.48	16.49
15.5	16.92	15.41	15.49	15.48
16.5	17.94	16.38	16.45	16.46
14.1	16.12	14.65	14.73	14.70
16	17.81	16.26	16.33	16.34
14.5	16.31	14.83	14.91	14.89
20.5	22.12	20.35	20.17	20.13
18.6	19.65	18.01	18.01	18.04
19	21.51	19.77	19.64	19.64
17.5	18.54	16.95	17.00	17.03
16.5	18	16.44	16.50	16.52
17	18.05	16.49	16.55	16.57
18	19.88	18.23	18.21	18.25
18.5	20	18.34	18.32	18.35
19	21.21	19.49	19.39	19.39

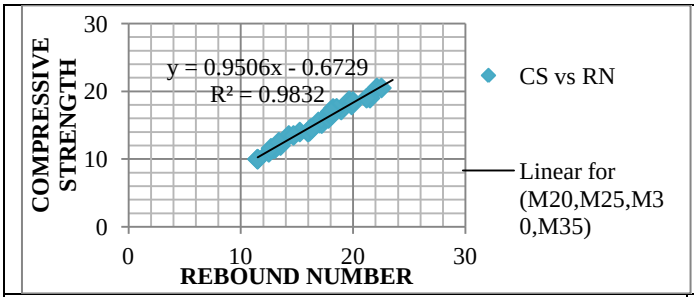

FIG 1. LINEAR RELATION BETWEEN COMPRESSIVE STRENGTH & REBOUND NUMBER

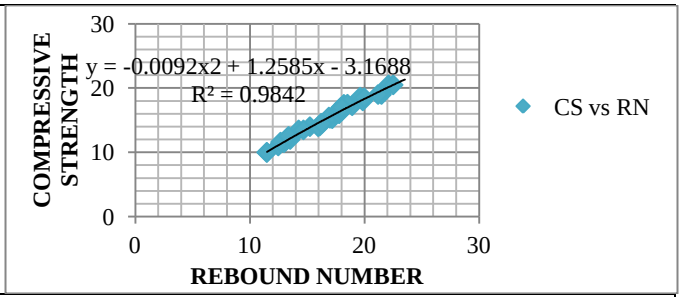

FIG 2. QUADRATIC RELATION BETWEEN COMPRESSIVE STRENGTH & REBOUND NUMBER

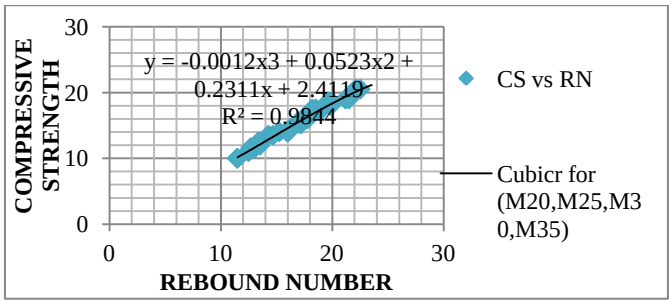

FIG 3. CUBIC RELATION BETWEEN COMPRESSIVE STRENGTH & REBOUND NUMBER

TABLE 6

CORRELATION BETWEEN COMPRESSIVE STRENGTH & REBOUND NUMBER WITH PREDICTED CONCRETE STRENGTH FOR 14 DAYS.

C.S	R. NO.	PREDICTED CONCRETE STRENGTH		
		LINEAR EQUATION	QUADRATIC EQUATION	CUBIC EQUATION
17	18.01	16.94	17.00	16.69
14.2	15.048	14.11	13.91	13.87
13.6	14.48	13.64	13.26	13.31
15	16.47	15.30	15.45	15.26
14.7	15.33	14.35	14.22	14.15
14.3	15.12	14.17	13.99	13.95
15.3	16.9	15.66	15.90	15.66
16	17.43	16.11	16.43	16.16
13.8	14.72	13.84	13.53	13.55
22.5	23.68	22.31	21.53	21.07
21.3	22.47	21.39	20.72	20.27
23.45	25.01	23.32	22.34	21.84
24.02	26.04	24.11	22.89	22.36
23.40	24.92	23.26	22.28	21.79
22.10	23.45	22.14	21.38	20.93
24.10	26.31	24.31	23.02	22.49
17.3	18.5	17.41	17.46	17.12
20.6	22.92	20.26	21.03	20.58
18.6	19.75	18.22	18.58	18.19
17.5	18.9	17.67	17.83	17.47
22.2	26.34	22.46	23.04	22.50
19	21	19.02	19.61	19.19
18.5	20.02	18.39	18.81	18.42
19	21.34	19.24	19.88	19.45
20.2	22.56	20.03	20.78	20.33
17	18.14	17.18	17.12	16.80
22	25.9	21.76	22.82	22.30
22.5	26.8	22.22	23.26	22.70
23	27.5	22.57	23.57	22.97
23.5	29.05	23.35	24.16	23.43
24	31	24.33	24.72	23.73
25.5	34.25	25.97	25.17	23.43
17.5	19.05	18.32	17.96	17.60
20	21.98	19.79	20.36	19.93

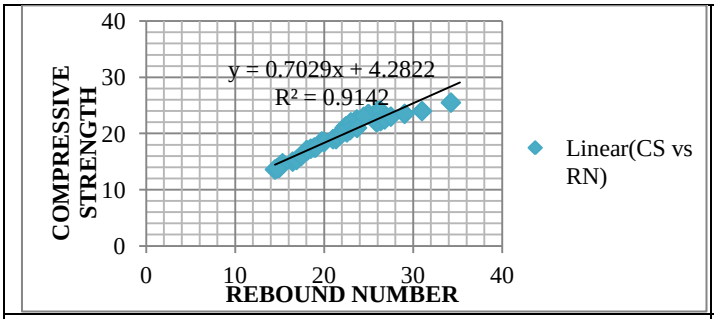

FIG 4. LINEAR RELATION BETWEEN COMPRESSIVE STRENGTH & REBOUND NUMBER

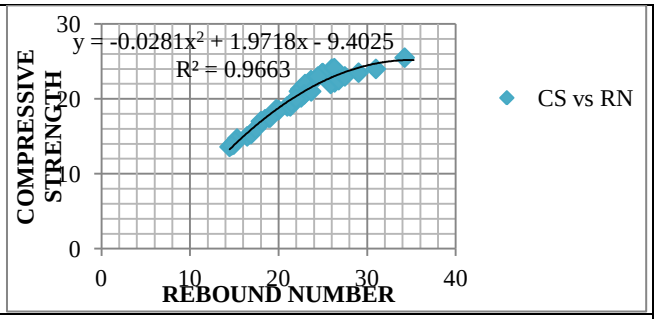

FIG 5. QUADRATIC RELATION BETWEEN COMPRESSIVE STRENGTH & REBOUND NUMBER

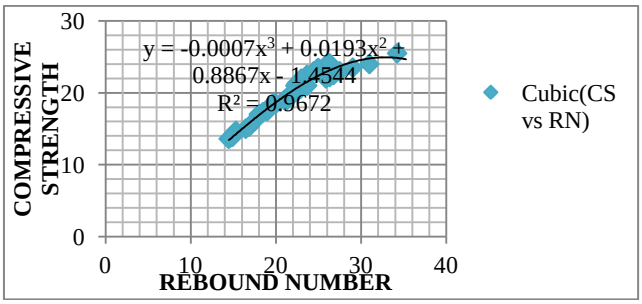

FIG 6. CUBIC RELATION BETWEEN COMPRESSIVE STRENGTH & REBOUND NUMBER

TABLE 7

CORRELATION BETWEEN COMPRESSIVE STRENGTH & REBOUND NUMBER WITH PREDICTED CONCRETE STRENGTH FOR 28 DAYS.

C.S	R. NO.	PREDICTED CONCRETE STRENGTH		
		LINEAR EQUATION	QUADRATIC	CUBIC EQUATION
23.5	27.2	23.01	23.08	23.12
20.5	22.8	20.24	20.54	20.63
20	22.5	20.06	20.37	20.47
24	28.83	24.03	24.03	24.07
23.5	26.5	22.57	22.67	22.71
28.5	34.5	27.59	27.42	27.50
24.5	29.84	24.66	24.63	24.66
22	25.4	21.88	22.03	22.08
21	23.05	20.40	20.69	20.77
28.2	34.50	27.59	27.42	27.50
30.1	37.00	29.16	28.95	29.06
27	33.98	27.26	27.10	27.17
25.12	33.01	26.65	26.52	26.58
26.87	33.45	26.93	26.78	26.85
29.45	36.47	28.83	28.62	28.73
26.57	33.25	26.80	26.66	26.73
29.21	36.25	28.69	28.49	28.59
25.01	33.00	26.65	26.51	26.57
33.3	44.23	33.70	33.49	33.74
34	46.18	34.92	34.75	35.03
31.5	41.67	32.09	31.86	32.06
32	42.5	32.61	32.39	32.60
34	46.25	34.97	34.79	35.08
37.5	50.02	37.33	37.26	37.61
29.5	39.5	30.73	30.50	30.66
33.7	45.45	34.46	34.28	34.55
37	49	36.69	36.59	36.92
36.5	47	35.44	35.28	35.58
41	54.5	40.14	40.25	40.65
38.5	52.4	38.83	38.84	39.22
37.5	50	37.32	37.25	37.59
35.5	46.75	35.28	35.12	35.41
40	54.11	39.90	39.99	40.39
43.5	60.3	43.79	44.23	44.64

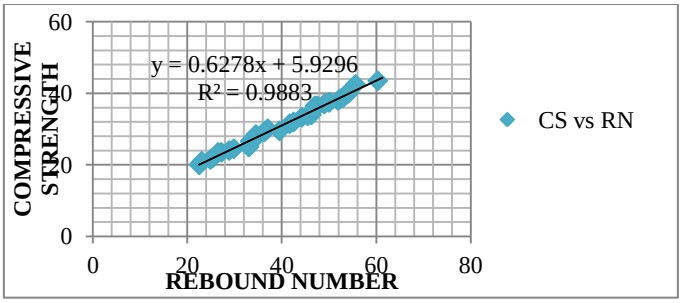

FIG 7. LINEAR RELATION BETWEEN COMPRESSIVE STRENGTH & REBOUND NUMBER

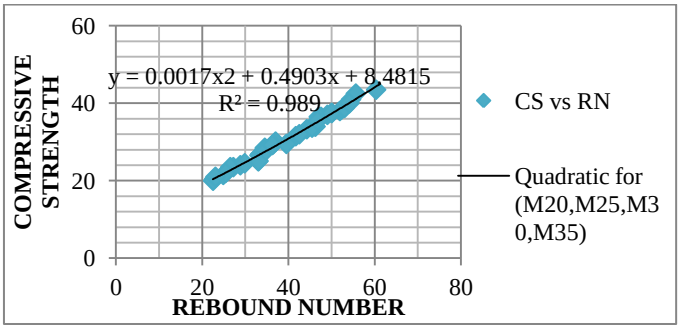

FIG 8. QUADRATIC RELATION BETWEEN COMPRESSIVE STRENGTH & REBOUND NUMBER

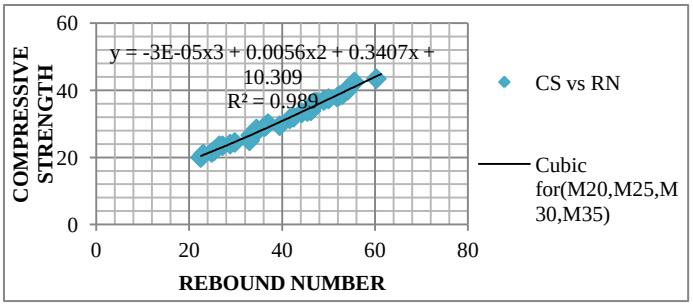

FIG 9. CUBIC RELATION BETWEEN COMPRESSIVE STRENGTH & REBOUND NUMBER

IV. CONCLUSION

The correlation among the strength values obtained by destructive and NDT test methods on

Concrete cubes have been established. Schmidt Hammer test method is used as a non-destructive test. The following principal conclusions have been drawn:-

- The use of rebound hammer test method on concrete cubes is not suitable to estimate its strength.
- Direct use of rebound hammer demonstrates high variations, which makes engineering judgment quite difficult.
- The Schmidt Hammer method could only be used as a reliable instrument to calculate the compressive strength.
- This project gives a useful mathematical linear and non-linear relationship that help the engineer to predict confidently the crushing strength of standard concrete cubes, by measuring the rebound index by means of Schmidt hammer.
- The linear and quadratic equations give perfect relationships with the compressive strength of concrete whereas there is a much difference in cubic equation results. It means only linear and quadratic mathematical expression is applicable for a wide range of concrete strengths.

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