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Study of Concrete Quality Assessment of Structural Elements Using Rebound Hammer Test

Tarun Gehlot[1], Dr. S. S. Sankhla[2], Akash Gupta[3]
[1]*M.E. Scholar, M.B.M. Engineering College, J.N.V. University, Jodhpur, Rajasthan, India*
[2]*Assistant Professor, M.B.M. Engineering College, J.N.V. University, Jodhpur, Rajasthan, India*
[1]*M.E. Scholar, M.B.M. Engineering College, J.N.V. University, Jodhpur, Rajasthan, India*

ABSTRACT: *Structures are assemblies of load carrying members capable of safely transferring the superimposed loads to the foundations. Their main and most looked after property is the strength of the material that they are made of. Concrete, as we all know, is an integral material used for construction purposes. The concept of nondestructive testing (NDT) is to obtain material properties of in place specimens without the destruction of neither the specimen nor the structure from which it is taken. However, one problem that has been prevalent within the concrete industry for years is that the true properties of an in-place specimen have never been tested without leaving a certain degree of damage on the structure. . The investigation reported here is to present study of Calibration Graphs for Non Destructive Testing Equipment, the Rebound Hammer and to study the quality of the concrete in existing structures. These Rebound Hammer Test were then used to test the quality of the concrete of the various structural elements (columns & beams) of single storied newly under constructed building of TPO office of MBM Engineering College Jodhpur. The use of this method produces results that lie close to the true values when compared with other methods A correlation between rebound number and strength of concrete structure is established, which can be used as well for strength estimation of concrete structures. The method can be extended to test existing structures by taking direct measurements on concrete elements.*

Keywords : *Rebound number, Rebound hammer, calibration, impact energy, NDT, SD, IRLOAD,* f_{ck}

I. INTRODUCTION

To keep a high level of structural safety, durability and performance of the infrastructure in each country, an efficient system for early and regular structural assessment is urgently required. The quality assurance during and after the construction of new structures and after reconstruction processes and the characterization of material properties and damage as a function of time and environmental influences is more and more becoming a serious concern**.** In recent years, innovative NDT methods, which can be used for the assessment of existing structures, have become available for concrete structures, but are still not established for regular inspections Therefore, the objective of this investigation is to study the applicability, performance, availability, complexity and restrictions of NDT .The purpose of establishing standard procedures for non destructive testing (NDT) of concrete structures is to qualify and quantify the material properties of in-situ concrete without intrusively examining the material properties. There are many techniques that are currently being research for the NDT of materials today. This work focuses on the NDT methods relevant for the inspection and monitoring of concrete quality. The NDT being fast, easy to use at site and relatively less expensive can be used for testing any number of points and locations it can assess the structure for various distressed conditions like damage due to fire, chemical attack, impact age. It is also helpful in Detecting cracks, voids, fractures, honeycombs, weak location and actual condition of reinforcement.

II. TEST METHODLOGY

2.1 The Rebound hammer test

The Schmidt rebound hammer is basically a surface hardness test with little apparent theoretical relationship between the strength of concrete and the rebound number of the hammer. Rebound hammers test the surface hardness of concrete, which cannot be converted directly to compressive strength. The method basically measures the modulus of elasticity of the near surface concrete.. The distance travelled by the mass, expressed as a percentage of the initial extension of the spring, is called the *Rebound number*. This is a simple, handy tool, which can be used to provide a convenient and rapid indication of the compressive strength of concrete. It consists of a spring controlled mass that slides on a plunger within a tubular housing.

2.2 Principle of Rebound hammer test

The method is based on the principle that the rebound of an elastic mass depends on the hardness of the surface against which mass strikes. When the plunger of rebound hammer is pressed against the surface of the concrete, the spring controlled mass rebounds and the extent of such rebound depends upon the surface hardness of concrete. The surface hardness and therefore the rebound is taken to be related to the compressive strength of the concrete. The rebound value is read off along a graduated scale and is designated as the rebound number or rebound index. The compressive strength can be read directly from the graph provided on the body of the hammer.
The impact energy required for rebound hammer for different applications is given below –

Table 1 : Impact Energy of Rebound Hammers (As per IS 13311 Part 2)

S. No.	Applications	Approximate impact energy required for rebound hammers (N-m)
1.	For testing normal weight concrete	2.25
2.	For light weight concrete or small and impact sensitive part of concrete	0.75
3.	For testing mass concrete i.e. in roads ,airfield pavements and hydraulic structures	30.00

Table 2 : Rebound Hammer types, impact energy and grade of concrete

Hammers type	Grade /type of concrete	Impact energy (N-m)
N	M-15 to M-45	2.2
L	Light weight concrete	0.75
M	Mass concrete	30
P	Below M-15	<2.2

2.3 Procedure for obtaining correlation between Compressive Strength of Concrete and Rebound Number:

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 cubes 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 N-m. The load should be increased for calibrating rebound hammers of greater impact energy and decreased for calibrating rebound hammers of lesser impact energy. The test specimens should be as large a mass as possible in order to minimize the size effect on the test result of a full scale structure. 150 mm cube specimens are preferred for calibrating rebound hammers of lower impact energy (2.2 N-m), whereas for rebound hammers of higher impact energy, for example 30 N-m, the test cubes should not be smaller than 300 mm. If the specimens are wet cured, they should be removed from wet storage and kept in the laboratory atmosphere for about 24 hours before testing. To obtain a correlation between rebound numbers and strength of wet cured and wet tested cubes, it is necessary to establish a correlation between the strength of wet tested cubes and the strength of dry tested cubes on which rebound readings are taken. A direct correlation between rebound numbers on wet cubes and the strength of wet cubes is not recommended. Only the vertical faces of the cubes as cast should be tested. 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 20mm and should be not less than 20 mm from each other. The same points must not be impacted more than once.

III. EXPERIMENTAL PROGRAM

To study the concrete quality assessment of the structural elements using non destructive testing methods, a detailed experimental study has been carried out. The aim of this investigation is to obtain the Calibration Graphs for Rebound Hammer and then used to test structural elements like (columns & beams) of single storied newly under constructed building of TPO office of MBM Engineering College Jodhpur. To achieve the above said objective, the detail step wise detailed experimental program has been carried out for evaluation of quality of concrete of different structural elements in the following phases:

1. Casting of the cubes for desired strength concrete
2. Rebound hammer test has been done on the cubes
3. Then the cubes were tested for the compressive strength

4. The Calibration a curve has been plotted for rebound hammer test
5. The results obtained from rebound hammer test and actual Compressive strength was correlated for different strength and a calibration curve has plotted on the basis of results found.
6. The detailed Rebound hammer test was done for the newly under construction TPO Cell building.
7. On the basis of the calibration curves and the actual NDT results, the assessment was made for the quality of the concrete of the various structural elements.
8. Also establish the interference for the location of readings of Rebound hammer

3.1 Results and Interpretations

3.1.1 Calibration Tests

The procedure that was followed during experiments consisted of the following steps-

1. Various concrete mixes were used to prepare standard cubes of 150×150×150 mm.
2. Concrete cubes of unknown history made under site conditions were also brought testing.
3. All cubes were immersed under water for a minimum period of 24 h before testing.
4. Just before testing, the cubes were rubbed with a clean dry cloth in order to obtain a saturated surface dry sample.
5. Once drying was complete, each of the two opposite faces of the cube were prepared for the rebound hammer test as described in the specifications.
6. The cubes were positioned in the testing machine and a slight load was applied. The rebound number was obtained by taking ten measurements on the four faces of the cube. The rebound hammer was horizontal in all measurements.
7. Once non-destructive testing on each cube was completed, the cube was loaded to failure and the maximum load was recorded.
8. Results were plotted as shown in respective figure.

3.1.2 Preparation of Specimen

6 cubes samples were cast, targeting at different mean strengths. Further, the cubes were cured for different number of days to ensure availability of a wide range of compressive strength attained by these cubes. Size of each cube was 150×150×150 mm.

3.1.3 Testing Of Specimen

1. 10 readings (rebound numbers) were obtained for each cube sample , at different locations on the surface of the specimen.
2. The cube samples was divided into grid blocks of equal spacing and 10 points were marked at equal intervals for taking the Rebound Hammer test
3. The cubes samples were then given a load of 7 N/mm^2 (as specified by the IS CODE 13311) in the Compression Testing Machine and the Rebound Values were obtained.
4. The cubes were then loaded up to their ultimate stress and the Breaking Load was obtained.

The following tables lists the Rebound numbers (rebound index), Mean Rebound Value, Standard Deviation, the Dead Load on the specimen at the time of testing, the Breaking Load, the Predicted Compressive Strength as predicted by the Rebound Hammer and the actual Compressive Strength as obtained by the Compression Testing Machine

Table 3 : Rebound number of various samples

Sample No. 1		Sample No. 2		Sample No. 3		Sample No. 4		Sample No. 5		Sample No.6	
S. No.	R .No.	S. No.	R. No.	S. No.	R. No.	S. No.	R. No.	S. No.	R. No.	S. No.	R. No.
1.	20	1.	20	1.	25	1.	41	1.	35	1.	39
2.	26	2.	21	2.	26	2.	41	2.	36	2.	39
3.	24	3.	20	3.	27	3.	40	3.	36	3.	38
4.	23	4.	21	4.	27	4.	41	4.	38	4.	38
5.	24	5.	20	5.	27	5.	41	5.	39	5.	39
6.	21	6.	19	6.	26	6.	41	6.	39	6.	39
7.	21	7.	18	7.	24	7.	44	7.	42	7.	38
8.	21	8.	19	8.	23	8.	44	8.	41	8.	38
9.	22	9.	18	9.	24	9.	44	9.	41	9.	39
10.	21	10.	21	10.	24	10.	43	10.	42	10.	39
Mean	22.3	Mean	19.7	Mean	25.3	Mean	42.0	Mean	38.9	Mean	38.6
S.D	1.88	S.D	1.16	S.D	1.49	S.D	1.56	S.D	2.60	S.D	0.52

Table 4 : Dead load , Breaking load & f_{ck} (Actual & Predicted) of Various Samples

Sample No.	Dead Load	Breaking Load	f_{ck} N/mm^2 (Predicted)	f_{ck} N/mm^2 (Actual)
1	150	300	15	13
2	150	350	14	16
3	150	300	18	13
4	150	850	43	38
5	150	700	36	31
6	150	800	40	36

The following graph is obtained between the Predicted Compressive Strength by the Rebound Hammer and the Actual Compressive Strength:

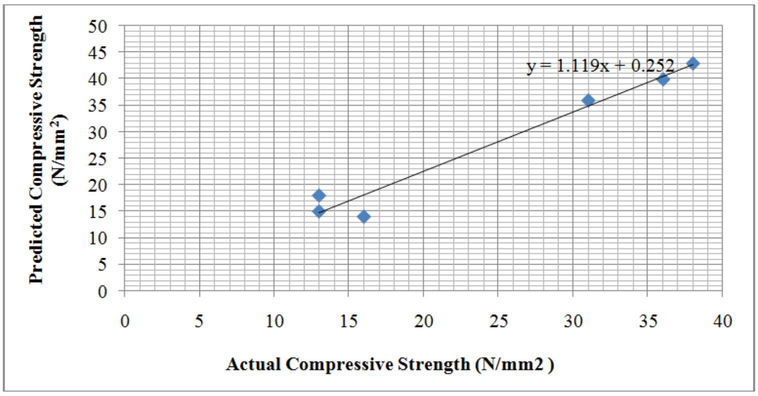

Figure 1 : Calibration Graph for Rebound Hammer

IV. COMPARATIVE STUDY

To Study the effect of reinforcement on the Rebound Values I have referred the work done by the previous researchers in Structural engineering the department JNV University Jodhpur ,INDIA . Those who have establish the correlation between the rebound hammer results with reference to the variation of the reinforcement present in the structural elements. The results were used for assessing the quality of the concrete of the newly under constructed building of TPO office of MBM Engineering College Jodhpur (INDIA)

Two Beams were cast of the following dimensions:

Length = 60 cm, Breadth =60 cm, & Depth = 15 cm

Grade of Concrete Used: M20 and M25

The points where the reinforcements existed were known so the testing was done in two stages:

1. By avoiding the impact of reinforcements or by trying to minimize its impact.
2. By undertaking the effect of reinforcements or by maximizing its impact.

Table 5 : Rebound number of M20 and M25 Concrete Grade

Location's	Rebound Number			
	Concrete Grade M20		Concrete Grade M25	
	Without Reinforcement	With Reinforcement	Without Reinforcement	With Reinforcement
I	30	31	37	37
II	27	28	37	38
III	29	30	34	36
IV	29	30	38	40
V	30	30	40	40

Result of above table: The maximum variation obtained for Rebound Value is **3.6%**

V. REBOUND HAMMER TEST ON STRCUTURAL ELEMNTS (COLUMNS AND BEAMS)

Rebound hammer Tests were conducted on some of the Columns and Beams of newly under construction TPO CELL building for the assessment of their quality. The observations, results and discussions have been tabulated below:

Table 6 : Rebound number of various Column with Quality f_{ck} & Remarks

Column Name	Location	Rebound Value	Mean	Quality f_{ck} N/mm^2	Remarks
A1	Bottom	27, 28, 28, 26, 25, 25	26.50	23	Medium Quality Concrete

	Middle	14, 15, 15, 14, 16, 13	14.50	13	Poor Quality Concrete
	Top	14, 15, 14, 13, 16, 17	14.80	14	Poor Quality Concrete
A6	Bottom	31, 30, 33, 32, 30, 31	31.16	31	Good Quality Concrete
	Middle	31, 33, 31, 30, 31, 32	31.33	30	Good Quality Concrete
	Top	30, 30, 29, 31, 28, 32	30.00	30	Medium Quality Concrete
B3	Bottom	37, 37, 37, 36, 38, 36	36.83	34	Good Quality Concrete
	Middle	33, 34, 34, 33, 35, 32	33.50	33	Good Quality Concrete
	Top	34, 35, 36, 33, 35, 36	34.83	33	Good Quality Concrete
B5	Bottom	32, 33, 33, 32, 30, 30	31.66	32	Good Quality Concrete
	Middle	33, 33, 34, 35, 35, 34	34.00	34	Good Quality Concrete
	Top	32, 33, 29, 29, 28, 32	30.50	30	Medium Quality Concrete
B8	Bottom	35, 36, 37, 37, 36, 38	36.50	34	Good Quality Concrete
	Middle	29, 29, 28, 30, 28, 30	29.00	30	Good Quality Concrete
	Top	30, 30, 31, 31, 29, 30	30.16	30	Medium Quality Concrete
C2	Bottom	39, 36, 39, 37, 37, 38	37.67	36	Good Quality Concrete
	Middle	31, 29, 29, 30, 28, 30	29.59	30	Good Quality Concrete
	Top	31, 30, 32, 31, 29, 29	30.33	30	Medium Quality Concrete
D4	Bottom	40, 40, 39, 38, 37, 38	38.67	37	Good Quality Concrete
	Middle	32, 31, 30, 30, 28, 28	29.83	30	Good Quality Concrete
	Top	31, 31, 32, 32, 30, 30	31.00	30	Medium Quality Concrete
D7	Bottom	42, 41, 40, 39, 39, 40	40.16	38	Good Quality Concrete
	Middle	33, 32, 31, 31, 32, 33	32.00	31	Good Quality Concrete
	Top	32, 35, 34, 33, 32, 32	33.00	32	Medium Quality Concrete

Table 7 : Rebound number of various Beams with Quality f_{ck} & Remarks

Beam Name	Location	Rebound Value	Mean	Quality f_{ck} N/mm^2	Remarks
1	1st Support	39, 39, 36	38.00	40	Medium Quality Concrete
	Mid Span	33, 33, 35	33.67	30	Medium Quality Concrete
	2nd Support	33, 33, 34	33.33	31	Medium Quality Concrete
2	1st Support	32, 34, 31	32.33	31	Good Quality Concrete
	Mid Span	35, 36, 37	36.00	32	Good Quality Concrete
	2nd Support	33, 36, 33	34.00	32	Good Quality Concrete
3	1st Support	42, 38, 35	38.33	36	Good Quality Concrete
	Mid Span	37, 44, 36	39.00	36	Excellent Quality Concrete
	2nd Support	46, 50, 46	47.33	41	Excellent Quality Concrete
4	1st Support	25, 27, 26	26.00	20	Doubtful Quality Concrete
	Mid Span	26, 28, 28	27.33	20	Doubtful Quality Concrete
	2nd Support	30, 29, 25	28.00	20	Doubtful Quality Concrete
5	1st Support	30, 30, 33	31.00	30	Medium Quality Concrete
	Mid Span	34, 33, 33	33.33	30	Medium Quality Concrete
	2nd Support	34, 33, 36	34.33	31	Good Quality Concrete
6	1st Support	29, 29, 30	29.33	24	Doubtful Quality Concrete
	Mid Span	31, 33, 31	31.67	25	Medium Quality Concrete
	2nd Support	28, 32, 30	30.00	25	Medium Quality Concrete

5.1 Interpretation of Results

The results for the quality of concrete of the under construction TPO Cell building assessed with the help of Rebound hammer test correlated with the produced relation between the actual and predicted compressive strength of concrete. The interpretations on the basis of the experimental results are as below:

1. The increasing rebound number is representing the higher compressive strength.
2. The rebound number in between the 26 to 32 gives the compressive strength equal to the rebound number.
3. The rebound no increased in the nearby region of the reinforcement by around up to 10%.
4. The rebound no reduces with the height of the column. It is maximum in the bottom region and minimum in the top end region.
5. The reduction in the rebound number with the height of the column is ranging in between 8% to 14%.
6. The compressive strength obtained with the Rebound hammer is higher in the columns with respect to beams.
7. As such the estimation of strength of concrete by rebound hammer method cannot be held to be very accurate and probable accuracy of prediction of concrete strength in a structure is ± 15 percent.
8. If the relationship between rebound index and compressive strength can be found by tests on core samples obtained from the structure or standard specimens made with the same concrete materials and mix proportion, then the accuracy of results and confidence thereon gets greatly increased.
9. The rebound hammer showed erratic result when the compressive strength was below 15 N/mm^2. Above 15 N/mm^2 the predicted compressive strength varied almost linearly with the actual compressive strength.
10. A general trend was obtained in the columns. The trend was such that towards the base of the column the

tests always showed a higher quality of concrete i.e., higher compressive strength. The compressive strength went on decreasing as we go up towards the roof.

11. A graph has been plotted with increasing height against the predicted compressive strength obtained on the basis of the NDT evaluation with rebound hammer. It is evident from the graph that the compressive strength goes on decreasing with increase in height of column.
12. The reason for this variation is better compaction at the base. Since all the weight of the column acts at the base higher compaction is achieved and also better compaction facilities are available near the base and process compaction becomes difficult as we go up.
13. No such regular trend was observed for beams.

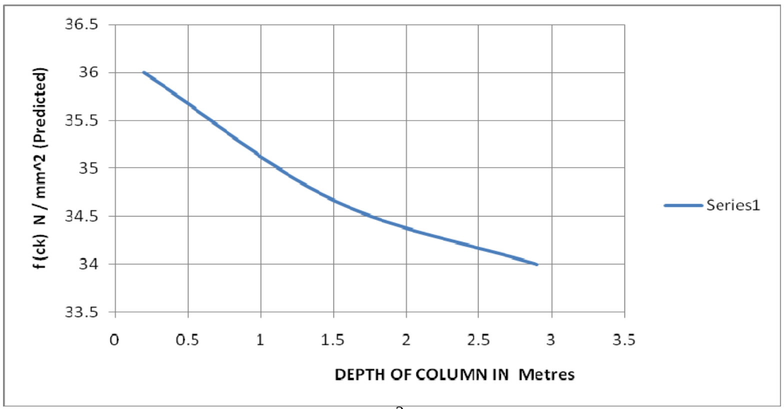

Figure 2: f_{ck} (N/mm^2) Predicted verse Depth of Column

VI. CONCLUSION

The main conclusions drawn from the investigation performed are:

1. Considerable engineering judgment is needed to properly evaluate a measurement. Misinterpretation is possible when poor contact is made. For example, in some cases it may not be possible to identify corroded reinforcing bar in poor quality concrete. However, it is possible to identify poor quality concrete which could be the cause of reinforcing bar problems. The poor quality concrete allows the ingress of moisture and oxygen to the reinforcing bars, and hence corrosion occurs.
2. Presently the system is limited to penetration depths of 1 ft. Research is ongoing to develop a system that can penetrate to a depth of 10 ft or more.
3. The Schmidt hammer provides an inexpensive, simple and quick method of obtaining an indication of concrete strength, but accuracy of around up to ±15 per cent is possible only for specimens cast cured and tested under conditions for which calibration curves have been established.
4. 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.
5. The deviation between actual results and predicted results may be attributed to the fact that a sample from existing structures was obtained by using various corrections introduced in the specifications
6. The method can be extended to test existing structures by taking direct measurements on concrete elements.
7. Unlike other work, the research ended with useful chart that require no previous knowledge of the constituents of the tested concrete.
8. The final results were compared with previous ones from literature and also with actual results obtained from samples collected from existing structures.
9. The correlation curves established in the study can be useful for the assessment of the quality of the concrete in an existing nearby structures made with the similar grade of the concrete and the similar sources of the materials.
10. The method presented is simple, quick, reliable, and covers wide ranges of concrete strengths. The method can be easily applied to concrete specimens as well as existing concrete structures.
11. The study can be done with the different types of the cements used for the concrete.
12. The study can be extended with the use of profometer to evaluate the effect of diameter of the bar.
13. This study can be done with the corrosion mapping in the old RCC elements and can evaluate the resistivity of concrete.
14. The study can be made with the RCC slab elements with conventional destructive testing methods.

REFERENCES

[1] ASTM C 805-85, Test for Rebound Number of Hardened Concrete, ASTM, USA (1993).

[2] BS 1881: Part 202, 1986: Recommendations for Surface Hardness Tests by the Rebound Hammer, BSI, UK (1986).IS 13311 (Part-2): 1992, Non-Destructive Testing of Concrete–methods of test, Part 2, Rebound hammer.
[3] G. Teodoru, The use of simultaneous nondestructive tests to predict the compressive strength of concrete. In: H.S. Lew, Editor, Nondestructive Testing vol. 1, ACI, Detroit (1988), pp. 137– 148 ACI SP-112.
[4] Handbook on Non destructive Testing of Concrete, Second Edition, Edited by V.M. Malhotra and N.J. Carino, ASTM & CRC Press, 2006.
[5] In Place Methods for Determination of Strength of Concrete; ACI Manual of Concrete Practice, Part 2: Construction Practices and Inspection Pavements, ACI 228.1R-989, Detroit, MI (1994)
[6] Kishore Kaushal, "Testing Hardened Concrete by Surface Hardness", I.C.I., Bulletin No. 20, Sept 1987, pp 17-20.
[7] S. Amasaki, Estimation of strength of concrete structures by the rebound hammer. CAJ Proc Cement Concrete 45 (1991), pp. 345–351.
[8] Testing Hardened Concrete: Non destructive Methods by V.M. Malhotra, Published Jointly by the IOWA State University Press & American Concrete Institute (ACI) 1976.