STRENGTH ASSESSMENT OF REINFORCED CONCRETE STRUCTURE BY NON-DESTRUCTIVE TESTING

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Abstract - *Non-destructive testing of concrete is a method to obtain the compressive strength of concrete from the existing structures. This test provides immediate results and actual strength of concrete structure. Non-destructive testing causes minimal damage to the structure on which the test is being performed. The types of non destructive tests to be performed are Rebound hammer test, Ultra sonic pulse velocity test, Carbonation test. The area of building of which testing is to be done is 750 square feet. It was constructed in the year 1996 and the reinforcement of the building is exposed to the atmosphere due to spalling of concrete. The objective is to find out structural stability of the structure by non-destructive testing and give rehabilitation procedures if necessary.*

Key Words: **NON DESTRUCTIVE TEST(NDT),REBOUND HAMMER,ULTRASONIC PULSE VELOCITY,CARBONATION DEPTH)**

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 moulded into any desired shape and size. The strength of concrete is its most important property (especially when needed for structural purposes) alongside its durability. Deterioration or damage of reinforced concrete may be caused due to several reasons and is nowadays commonly observed because of improper construction techniques. Deterioration of concrete has significant effect on the performance and serviceability of structures. Many factors can contribute to the deterioration of concrete structures such as; poor construction, overloading, aging, corrosion of steel, chemical reactions, natural disasters, etc. Unfortunately, damage propagation is a time dependent process with serious effect on structural capacity and durability. Deterioration signs can be visible such as concrete cracking or excessive deflections which can be detected with visual inspection. In these cases, the concrete member has probably reached significant level of damage. Early detection of damage minimizes the repair costs and preserves the service-life of the structure.

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 or insurance, 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 is to assess the condition of existing reinforced concrete structure by non destructive testing and recommend rehabilitation procedures.

2. LITERATURE REVIEW

Pardeep K. Gupta, **Niharika Gupta** and **Amandeep Singh** conducted experimental study on parameters affecting the results to estimate its reliability, the original Schmidt curve provided by the producers along with the hammer and is used in Structural Engineering Applications. This paper discussed an extensive research, and application, of this technique to assess the compressive strength of a raft foundation of a government building, showing that several phenomena strongly affect the test: moisture content, maturity, stress state among the others. The present paper gives a combined test method for compressive strength assessment by a suitable correlation between the two tests-Rebound Hammer Test and the test by compressive testing machine. The results were verified using compression testing machine and these were reliable. It is found that the use of NDT techniques like Rebound Hammer Test is much reliable and can well be fit to assess the quality of concrete structures.

Naser Alenezi done study to evaluate the structural integrity of a villa located in Kuwait by rebound hammer, UPV tests. The building consists of two storey floors and basement floor. The building showed huge cracks in most of the concrete structural elements. The recent study of structural integrity and evaluation included, comparing the as built with the design drawings, detailed visual inspection, evaluating the quality of concrete by using field and laboratory tests and structure analysis to determine the safety factors. Problems encountered in reinforced concrete buildings are not limited to those where the concrete was not designed for durability. It includes also concrete which was not constructed for good performance and for durability

3. METHODOLOGY

3.1 REBOUND HAMMER:

The rebound hammer method could be used for:

i) Evaluation of expected compressive strength of concrete using appropriate correlation between restitution index and compressive strength ii) Evaluation of concrete homogeneity iii) Evaluation of concrete quality in relation to standard requirements and One concrete element related to the element.

Figure 3.1: Rebound Hammer

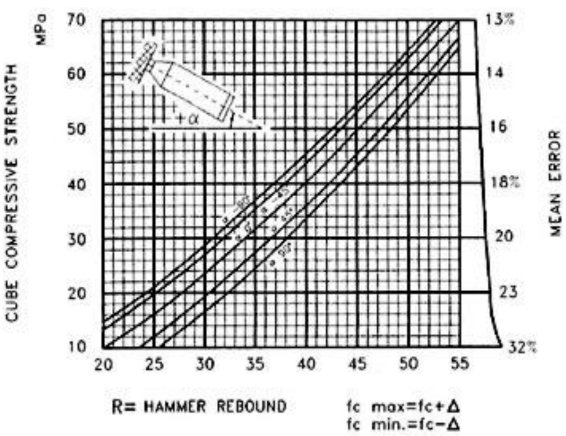


Figure 3.2: Graph on Rebound Hammer

3. 2 ULTRASONIC PULSE VELOCITY:

It can be determined using the ultrasonic pulse velocity method.

(i) Concrete Homogeneity

(ii) Presence of cracks, voids and other imperfections, changes in concrete structure that may occur over time

(iii) Concrete Quality Standard Requirements,

(iv) Quality of one concrete element relative to another.

Fig 3.3: Ultrasonic Pulse Velocity Testing Machine

Pulse velocity (m/s)	Concrete quality grading
Above 4500	Excellent
3500 – 4500	Good
3000 – 3500	Medium
Less than 3000	Doubtful

Table 3.1: Velocity Criterion for Concrete Quality Grading

3.3 CARBONATION TEST:

OBJECT:

The carbonation test could be used for:

(i)To find if carbonation has occurred.

(ii)To know approximate pH value.

PRINCIPLE:

Carbonation of concrete occurs when the carbon dioxide, in the atmosphere in the presence of moisture, reacts with hydrated cement minerals to produce carbonates, e.g. calcium carbonate. The carbonation process is also called depassivation. Carbonation penetrates below the exposed surface of concrete extremely slowly

A 1% phenoptalein solution is prepared by dissolving 1 g of phenoptalein in 90 ml of ethanol. Distilled water is then added to bring the solution to 100 cc. The phenolphthalein solution is sprayed on the core just taken out, and the depth of the uncoloured layer (carbonized layer) from the outer surface is measured in millimetres at or 8 points, and the average is taken. If the test is performed in a borehole, first airbrush the hole to remove dust, then again measure the depth of the clean layer at or 8 locations and average. If the concrete still retains its alkalinity, the colour of the concrete will turn purple. When carbonation occurs, the pH changes to 7 (ie neutral state) and no colour change occurs.

4. BUILDING DETAILS AND CONDITION ASSESSMENT

BUILDING DETAILS :

- AREA = 750 sqft
- Constructed in the year 1996
- Thickness of slab 120 cm

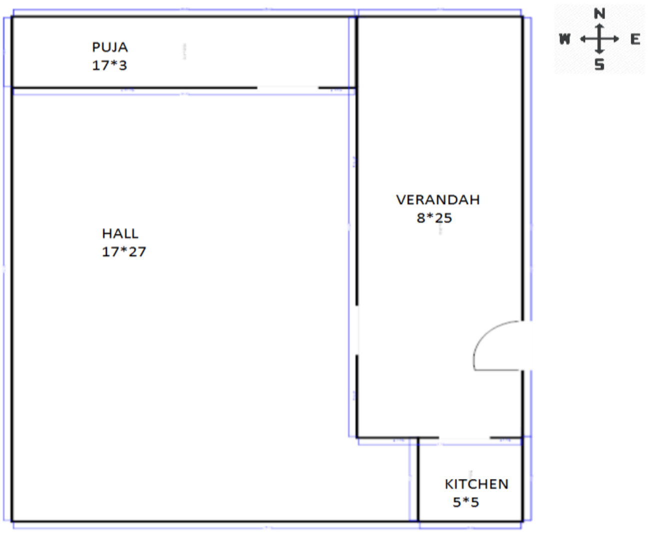


Figure 4.1:Plan of The Building

4.1 CONDITION ASSESSMENT:

- On visual inspection it is seen that spalling has occurred in many parts of slab.
- Cover till the reininforcement is removed in many areas.
- Reinforcement is exposed to atmosphere in portions of slab ,10-20% reinforcement is visible
- Full extent of carbonation is observed by the full discolored portion of the concrete, which indicates severe carbonation took place in the structure concrete consequently the reinforcement embedded in it .
- Minimum grade of concrete for Reinforced Cement Concrete structure is M15

Figure 4.2 :Damaged Slab

5. TESTS PROCEDURE AND VALUES

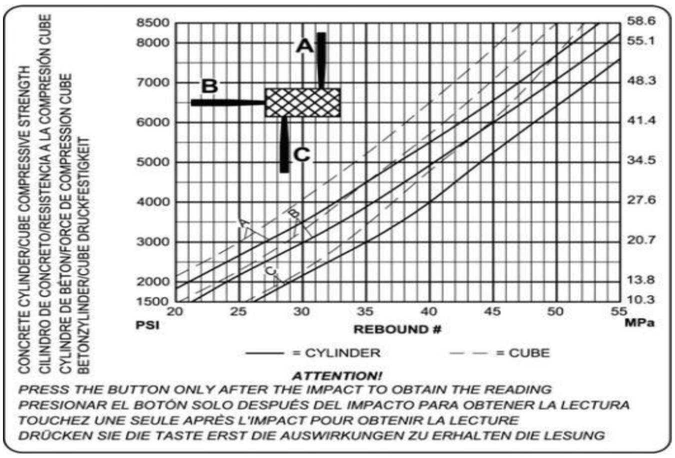
5.1 PAINTING OF GRID ON THE CEILING

A grid shaped pattern is drawn on the ceiling .The grid is drawn for marking nodes on the ceiling .Polyesterene thread is dipped in paint and paced at intervals of 1 feet in both x and y directions .The point of intersection in grid is taken as node and each square formed is known as element .

Figure 5.1: Grid pattern on the ceiling

5.2 REBOUND HAMMER TEST VALUES

The values at are noted and then converted into their respective cube compressive strength by using the graphs given on the rebound hammer.



Graph 5.2: Rebound number Vs Compressive strength

Figure 5.3: Rebound Hammer Test

Table 5.1: Rebound hammer test values

Nodes	Rebound Number	Compresssive Strength (N/mm²)
1	41	29.33
2	38	24.84
3	32	17.25
4	34	19.55
5	38	24.84
6	37	23.46
7	34	19.55
8	37	23.46
9	34	19.55
10	37	23.46
11	38	24.84
12	35	20.70
13	37	23.46
14	37	23.46
15	36	22.08
16	42	31.05
17	39	26.22
18	33	18.40
19	28	12.63
20	38	24.84
21	44	34.50
22	40	27.60
23	30	14.95
24	38	24.84
25	32	17.25
26	32	17.25
27	34	19.55
28	36	22.08
29	44	34.50
30	46	37.95
31	31	16.10
32	30	14.95
33	31	16.10
34	27	11.46
35	35	20.70
36	31	16.10
37	38	24.84
38	26	10.30
39	28	12.63
40	31	16.10
41	26	10.30
42	33	18.40
43	38	24.84
44	34	19.55
45	38	24.84
46	30	14.95
47	28	12.63
48	26	10.30
49	27	11.46
50	30	14.95
51	40	27.60
52	36	22.08
53	32	17.25
54	35	20.70
55	28	12.63
56	29	13.80
57	30	14.95
58	26	10.30
59	28	12.63
60	38	24.84
61	38	24.84
62	30	14.95

63	34	19.55
64	32	17.25
65	34	19.55
66	34	19.55
67	32	17.25
68	32	17.25
69	28	12.63
70	26	10.30
71	32	17.25
72	30	14.95
73	42	31.05
74	26	10.30
75	31	16.10
76	35	20.70
77	33	18.40
78	37	23.46
79	31	16.10
80	27	11.46
81	36	22.08
82	28	12.63
83	26	10.30
84	32	17.25
85	30	14.95
86	30	14.95
87	32	17.25
88	28	12.63
89	34	19.55
90	30	14.95
91	36	22.08
92	36	22.08
93	30	14.95
94	30	14.95
95	30	14.95
96	36	22.08
97	33	18.40
98	28	12.63
99	32	17.25
100	37	23.46
101	29	13.80
102	28	12.63
103	36	22.08
104	32	17.25
105	32	17.25
106	40	27.60
107	28	12.63
108	38	24.84
109	38	24.84
110	38	24.84

5.3 Ultrasonic pulse velocity test

Distance is measured between elements (ie 1 feet) and velocity is calculated by using the relation given as follows

$$V = \frac{d}{t}$$

Here V= ultrasonic pulse velocity

d=distance between two elements

t= time taken for pulse to travel

Figure 5.4:Ultrasonic pulse velocity test

Table 5.2: Ultrasonic pulse velocity values

Nodes	Time (micro sec)	Distance (m)	Ultra Sonic Pulse Velocity (Km/S)
1	72.56	0.3048	4.2
2			
3	81.44	0.3048	3.74
4			
5	98.00	0.3048	3.11
6			
7	104.55	0.3048	2.91
8			
9	56.23	0.3048	5.42

10			
11 12	79.44	0.3048	3.83
13 14	73.44	0.3048	4.15
15 16	120.33	0.3048	2.53
17 18	81.74	0.3048	3.72
19 20	86.89	0.3048	3.5
21 22	84.66	0.3048	3.6
23 24	67.55	0.3048	4.51
25 26	54.96	0.3048	5.54
27 28	84.55	0.3048	3.6
29 30	67.24	0.3048	4.53
31 32	42.56	0.3048	7.16
33 34	100.00	0.3048	3.04
35 36	87.47	0.3048	3.48
37 38	55.79	0.3048	5.46
39 40	68.54	0.3048	4.44
41 42	94.66	0.3048	3.21
43 44	55.70	0.3048	5.47
45 46	66.10	0.3048	4.61
47 48	58.56	0.3048	5.2
49 50	114.86	0.3048	2.65
51 52	47.98	0.3048	6.35
53 54	68.54	0.3048	4.44
55 56	41.73	0.3048	7.3

57 58	87.45	0.3048	3.48
59 60	49.77	0.3048	6.12
61 62	73.66	0.3048	4.13
63 64	97.66	0.3048	3.12
65 66	64.77	0.3048	4.7
67 68	44.56	0.3048	6.84
69 70	58.77	0.3048	5.18
71 72	58.21	0.3048	5.23
73 74	62.31	0.3048	4.89
75 76	92.11	0.3048	3.3
77 78	113.10	0.3048	2.69
79 80	73.22	0.3048	4.16
81 82	96.22	0.3048	3.16
83 84	78.55	0.3048	3.88
85 86	64.77	0.3048	4.7
87 88	58.88	0.3048	5.17
89 90	72.66	0.3048	4.19
91 92	61.55	0.3048	4.95
93 94	71.55	0.3048	4.25
95 96	55.22	0.3048	5.51
97 98	63.42	0.3048	4.8
99 100	97.55	0.3048	3.12
101 102	77.44	0.3048	3.93
103	55.33	0.3048	5.5

104			
105	71.22	0.3048	4.27
106			
107	78.44	0.3048	3.88
108			
109	94.22	0.3048	3.23
110			

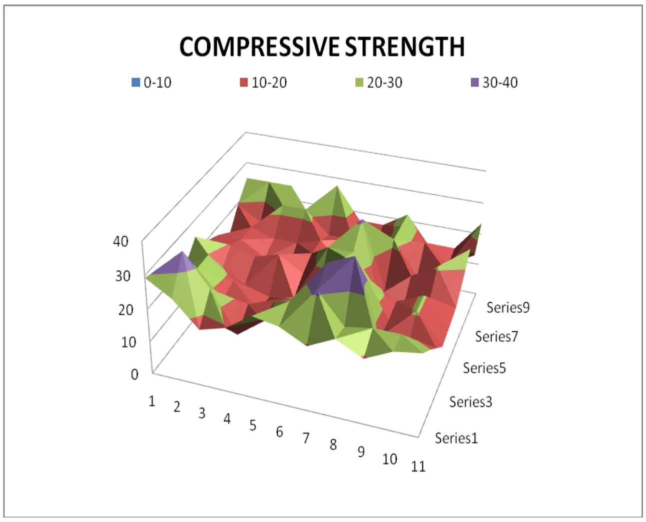
6. RESULTS AND DISCUSSIONS

6.1 COMPRESSIVE STRENGTH

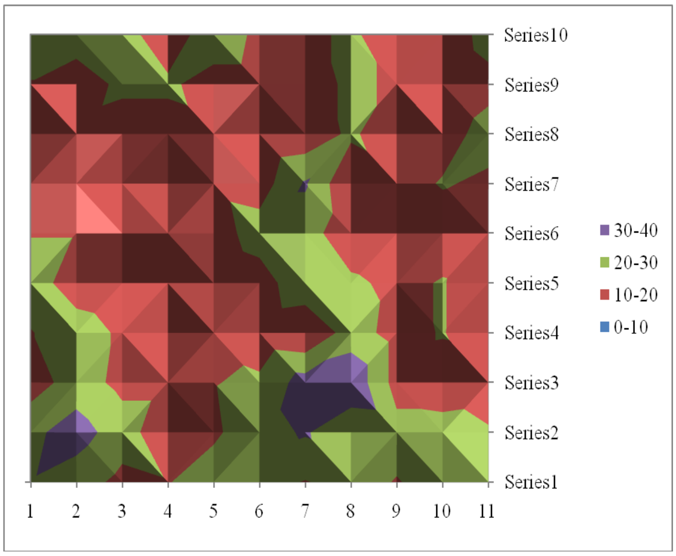
Table 6.1: Compressive strength values in nodal representation

N	1	2	3	4	5	6	7	8	9	10	11
1	29.33	24.84	17.25	19.55	24.84	23.46	19.55	23.46	19.55	23.46	24.84
2	27.6	34.5	24.84	12.63	18.4	26.22	31.05	22.08	23.46	23.46	20.7
3	14.95	24.84	17.25	17.25	19.55	22.08	34.5	37.95	16.1	14.95	16.1
4	19.55	24.84	18.4	10.3	16.1	12.63	10.3	24.84	16.1	20.7	11.46
5	24.84	14.95	12.63	10.3	11.46	14.95	27.6	22.08	17.25	20.7	12.63
6	19.55	19.55	17.25	19.55	14.95	24.84	24.84	12.63	10.3	14.95	13.8
7	17.25	17.25	12.63	10.3	17.25	14.95	31.05	10.3	16.1	20.7	18.4
8	12.63	17.25	14.95	14.95	17.25	10.3	12.63	22.08	11.46	16.1	23.46
9	19.55	14.95	22.08	22.08	14.95	14.95	14.95	22.08	18.4	12.63	17.25
10	24.84	24.84	24.84	12.63	27.6	17.25	17.25	22.08	12.63	13.8	23.46

Average compressive strength=19.02 N/mm2



Graph 6.1: 3D Surface graph of compressive strengths



Graph 6.2: Plane surface graph of compressive strength

6.2 CARBONATION TEST

Carbonation test is performed at the nodes where the compressive strength is low. As seen from the above graphs low compressive strength is observed at the nodes and it is shown as highlighted portion in the figures given below.

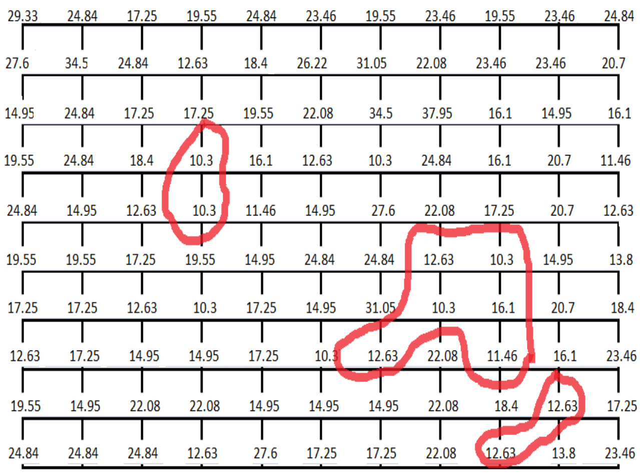


Figure 6.1: Weak Compressive strength zone

Figure 6.2: Weak Compressive strength zone

Carbonation test is performed at the nodes 41 ,48 ,78 ,63 ,83, 85, 84 ,90 ,103 by spraying 1% phenolphthalein solution.

Figure 6.3: Carbonation test

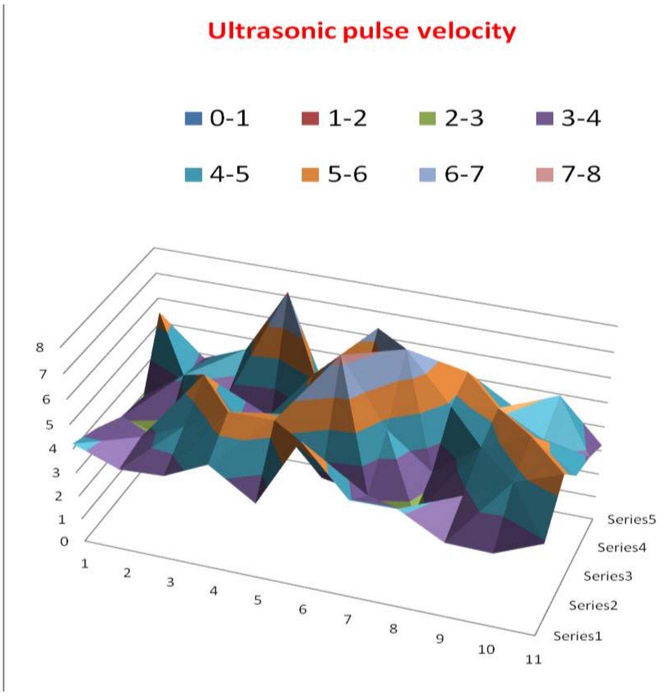
When performed corbonation test it is clearly seen that colour has not changed when phenolphthalein is sprayed at the nodes. Hence we can conclude that carbonation has occurred.

6.3 ULTRASONIC PULSE VELOCITY TEST

Table 6.2: Ultrasonic pulse velocity values in nodal representation

N	1	2	3	4	5	6	7	8	9	10	11
1	4.2	3.5	3.6	4.44	3.21	6.12	4.13	4.16	3.16	3.12	3.93
2	3.74	3.72	4.51	5.46	5.47	3.48	3.12	2.69	3.88	4.8	5.5
3	3.11	2.53	5.54	3.48	4.61	7.3	4.7	3.3	4.7	5.51	4.27
4	2.91	4.15	3.6	3.04	5.2	4.44	6.84	4.89	5.17	4.25	3.88
5	5.42	3.83	4.53	7.16	2.65	6.35	5.18	5.23	4.19	4.95	3.23

Average ultrasonic pulse velocity =4.3650 Km/sec



Graph 6.4: 3D Surface graph of ultrasonic pulse velocity

7. CONCLUSION AND RECOMMENDATIONS

CONCLUSION:

- Average compressive strength (19.02 N/mm^2) is above the allowable limit as per IS 456:2000 .
- Average ultrasonic pulse velocity value (4.3650 Km/s) is excellent as per IS 13311:1992 (part-2) .
- Carbonation has occurred at nodes 41 ,48 ,78 ,63 ,83, 85, 84 ,90 ,103.
- Highest compression strength values are seen at nodes 1, 13, 18, 29, 30, 73, 95.
- Lowest compressive strength values are seen at nodes 41 ,48 ,78 ,63 ,83, 85, 84, 90,103.
- Highest ultrasonic pulse velocity value is 7.3 Km/s between elements 55 and 56.
- Highest compressive strength is 37.95 N/mm2 at node 30.

RECOMMENDATIONS:

- If the cost of rehabilitation exceeds50% of recasting then rehabilitation is avoided as its life is maximum of 10 years .

- Rehabilitation Procedure for restoring damaged RCC slab by grouting systems including cracks , stitching with additional steel reinforcement.
    - Remove the plastering of cover concrete
    - Make grooves and zig zag lines to cracked lines
    - Drill holes for pressure grouting
    - Clean debris using air compressor
    - Fix the polymer coated steel rod over or in place of corroded rods
    - Fix plug materials in the drilled nozzle
    - Close the grooves and cracks by plastering with polymer modified mortar

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