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STRUCTURAL STABILITY AND ASSESSMENT OF OLD RC STRUCTURES USING NON-DESTRUCTIVE TECHNIQUE

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Abstract-*Assessment of concrete structures is required every now & then. Applications of nondestructive testing techniques in Structures become more specific since these have to serve for longer time. Various Non-Destructive Testing techniques are available to accomplish the task. Being indirect in nature in depth study of these techniques is prerequisite for both qualitative and quantitative analysis. Visit to site at the time of Non Destructive Testing of Concrete Structures is vital for appropriate inferences.*

Keywords- *Non-destructive testing, Schmidt Rebound Hammer, TICO Ultra sonic Pulse Velocity, water logging*

I. INTRODUCTION

The issue of upgrading the existing engineering structures has been one of great importance for over a decade. Deterioration of beams and columns in buildings, parking structures and others may be attributed to ageing, environmentally induced degradation, poor initial design and/or construction, lack of maintenance, changes in codel provisions and to accidental events such as earthquakes. Lifetime prediction and damage assessment of engineering structure is a growing part of infrastructure planning. So, the field of condition assessment and Non-Destructive evaluation of engineering structure is an integral part of the Civil Engineering in future.

1.1 Problems in structures:

There could be a number of problems in concrete structures well known to an engineer some of them are: Related to Foundation, Poor design/ detailing, Construction techniques, inferior material, Deterioration due to various reasons, excessive loading, natural catastrophes etc. Distress in structures can be seen visually at a later stage resulting in physical / chemical changes. Problems may be limited to few structural elements or the structure as a whole.

Visual inspection is essentially required to plan NDT assessment of the concrete structure. Needless to mention that structure has to be checked and identified for good and bad quality of concrete, distressed locations in the structure, basic problems in the structure, nomenclature of structural elements. Structural health performance/ condition assessments can be made using NDT methods, such as

- Member dimensions
- Location of cracking, delamination and de-bonding
- Degree of consolidation, presence of voids and honey combing
- Steel reinforcement location and size
- Corrosion activity of reinforcement; and
- Extent of damage from freezing and thawing, fire or chemical exposure

1.2 User Requirement:

Agency approaching Non Destructive assessment will have certain queries namely- Quality of constructed structure, Problems in structures with their reasons, Residual strength/ life or the structure, Retrofitting/ remedial measures etc.

Before visiting the site some important data is required: Age of the structure, reasons for its assessment, Geo technical investigation report, Ambient Environment, Design and detailing of the structure, Use of the structure and its repair history etc. This provides certain status to consider appropriate NDT techniques for investigation.

1.3 Techniques for Assessment:

Non Destructive Testing techniques available are:

1. Visual observations to find common defects e.g. cracking, excessive deflection, corrosion/ deterioration of concrete, Dimensional changes, Construction defects, problems of natural or manmade disasters etc.
2. Hardness based technique: Schmidt Rebound hammer can be used to find hardness of the concrete structure surface.
3. Ultra sound wave transmission: Ultra sonic Pulse Velocity Equipment can be used to observe wave transmission through Concrete structure.

4. Impact Echo technique: This Technique is used for two types of equipment's namely Sonic Integrity Tester and Pile Integrity Tester. The technique is used to observe feature of a pile or structural element.

II. PROBLEM STATEMENT

In response to Clint's request above certain information was desired. Except two Planning drawing nothing could be provided by client for reference purposes. It was decided to inspect the site and carry out Non Destructive Testing with techniques deemed fit.

2.1 Work Strategy:

On the basis of preliminary site visit it was decided that NDT will be carried out using appropriate technologies available in the institution. Limitations of the study were also discussed. The existing building has office i.e. Manager's Room, Main and side Hall for office staff, Entry Lobby Duplex, Toilet block, Store room at the rear, and some space at the roof level. It is proposed to construct first floor on the existing building keeping ground floor for parking. Needless to say that addition / alterations are necessary for the same. There is land dispute reported with owner of the rear plot. The locality has recently faced water logging problem in nearby area e.g. Laxmi Nagar. The building was reported to be constructed in the year 1999. Since then no major repair is reported.
As agreed up on Techniques used are: Schmidt Rebound Hammer Digital model of Proceq (Swiss company), TICO Ultra sonic Pulse Velocity also of Proceq, Profometer, additionally some other instruments were used as deemed fit. The site was visited on 7th, 9th, 23rd and 27th Sep 2012. The building is abutting Main road leading to Mandore. The building as per drawing A-01 is single storey RCC frame structure with isolated footing foundation. Columns are numbered as 1 to 8 on line parallel to Main road alignment and A to D across it. Column A' and B' are marked for extra column away from the standard lines. With no A1 assigned to front left (road side) column & D8 to right back column.

III. NDT TEST RESULTS

3.1 Schmidt Rebound Hammer Test Results:

Member No.	*Average Rebound no (6 readings)*	*Maximum Reading*	*Minimum Reading*	*Standard Deviation*	*Related Compressive Strength N /sq mm*	*Remarks*
COLUMNS Date 09/09/12 Direction of Hammer Horizontal & Plastered unless specified						
B-2	30.5	32	26	2.3	25.9	
B-2	31.5	34	30	2.0	27.5	
C-2	29.3	32	27	1.7	24.8	
C-2	30.2	33	28	2.0	25.3	
B-3	32.3	39	25	5.2	28.9	
B-3	32.5	37	30	2.5	29.2	
C-3	38.3	40	37	1.2	39.4	
C-3	28.3	42	21	7.1	22.4	
C-3	27.2	31	25	2.3	20.6	
C-4	31.3	34	29	1.9	27.3	
C-4	33.8	36	32	1.7	31.5	
B-4	30.3	33	27	2.2	25.6	
B-4	33.2	36	32	1.5	30.3	
B-5	31.8	34	30	1.5	28.1	
B-5	26.8	29	22	2.5	20.0	
C-5	30.5	33	28	1.9	25.9	
C-5	33.3	37	29	3.1	30.6	
A-1	33.5	36	31	2.1	30.9	Outside Bldg
A'	32.8	38	30	2.9	29.8	Outside Bldg
A-3	38.8	44	35	3.5	40.3	Outside Bldg
B'	36.8	39	32	2.6	36.7	Outside Bldg
C-1	23.8	38	11	1.2	15.5	Outside Bldg
D-7	31.0	34	29	1.8	26.7	Outside Bldg
D-3	32.7	35	31	1.4	29.5	Outside Bldg
D-1	29.0	35	22	4.2	23.5	Outside Bldg
BEAMS Date 09/09/12 Direction of Hammer Horizontal & Plastered unless specified						
B-C-2	31.8	37	26	3.9	28.1	
B-C-3	27.7	30	23	2.7	20.8	
B-C-3	27.8	29	25	1.6	21.6	
B-C-4	25.3	28	23	1.8	17.7	
B-C-4	25.5	27	24	1.0	18.0	

B-C-5	26.2	28	25	1.2	19.0	
B-C-5	26.8	32	21	3.7	20.0	
A-B-2	30	33	26	2.4	25.1	
A-B-2	28.2	31	23	2.8	22.1	
A-B-3	27.7	38	12	10.2	21.3 ↑	Vertical Up##
A-B-3	27.7	32	25	2.5	21.3	
A-B-4	23.0	26	18	2.8	14.2	
A-B-4	26.8	33	22	3.7	20.0 ↑	Vertical Up##
A-B-5	29.8	39	19	2.1	24.8	
A-B-5	18.1	38	11	10.1	----	No f_{ck} Value
C-D-2	25.0	28	19	3.3	17.2	
C-D-2	27.7	29	27	1.0	21.3	
C-D-3	17.0	23	11	4.8	-----	No f_{ck} Value
C-D-3	22.8	24	22	1.0	14.0	
C-D-3	20.3	24	10	5.4	10.4	
C-D-4	19.8	25	12	5.3	--------	No f_{ck} Value
C-D-4	23.3	27	16	4.6	14.7	
C-D-5	30.2	34	25	3.2	25.3	
C-4-5	25.5	27	24	1.0	18.0	
C-4-5	27.2	29	25	1.5	20.6 ↑	Vertical Up##
C-4-5	19.0	26	10	6.3	-------	No f_{ck} Value
C-3-4	26.0	31	14	6.0	18.8	
C-3-4	22.0	30	13	7.0	12.8	
C-2-3	28.0	29	27	0.9	21.9	
C-1-2	22.7	31	12	7.2	13.8	
C-1-2	27.2	32	18	4.3	20.6	
B-2-3	25.3	31	10	7.9	17.7	
B-3-4	25.0	34	12	8.3	17.2	
B-4-5	29.7	30	29	0.5	24.5	
BEAMS Date 23/9/12 Direction of Hammer Horizontal & Plastered unless specified						
B-C-4	25.8	29	24	1.9	18.5	Side face
B-C-4	21.7	24	15	3.3	12.3 ↑	Vertical Up##
B-3-4	31.0	40	27	5.3	26.7	Side face
B-3-4	24.8	28	13	5.9	17.0 ↑	Vertical Up##
B-C-2	34.0	39	29	3.6	31.8	Side face
B-C-2	31.0	33	29	1.8	26.7 ↑	Vertical Up##
##- From Bottom, Other-Horizontal						
Date	FOUNDATION (RIGHT SIDE REAR CORNER, Beam Top 1.25m from Plinth Band Bottom & 0.73m					
Left Side	30	37	27	4.5	26.2	
O. Rear	34.8	42	24	6.1	33.2	O.-Opposite
O. Rear	29.2	37	21	6.1	23.7	O.-Opposite
O. Rear	31.5	42	24	7.1	27.5	O.-Opposite

Schmidt Rebound hammer readings are related to surface hardness of the Concrete and its strength is related using inbuilt calibration curve in the instrument. The strength with rebound hammer number not necessarily be truly indicative of its compressive strength to the extent shown, these have to be corrected for different factors but it does give comparison of surface hardness for quality of concrete, Refer IS 13311 pt II.

3.2 Ultrasonic Pulse Velocity Test Results:

S N	***Column/Beam No.***	***Path length***	***Travel time μ sec***	***Velocity m/sec***	***Remarks/ Method***
COLUMN Date 09/09/12 Plastered unless specified					
1	B-2	350	11.9	3130 (D)	
2	B-2	350	143.3	2440 (ID)	
3	B-2	250	98.6	2540 (SD)	
4	C-2	350	109.7	3190 (D)	
5	B-3	350	109.7	3190 (D)	
6	C-3	350	106.8	3280 (D)	
7	C-4	350	101.9	3440 (D)	
8	B-4	350	121.7	2880 (D)	
9	B-5	350	113.7	3080 (D)	
10	C-5	350	113.3	2630 (ID)	
BEAM Date 09/09/12 Plastered unless specified					

11	B-C-2	350	120.7	3070 (D)	
12	B-C-3	350	116.2	3180 (D)	σ = 34 N/ sq mm
13	B-C-4	350	113.7	3250 (D)	σ = 35 N/ sq mm
14	B-C-5	350	586.0	630 (D)	Both sides Crack
15	A-B-2	350	131.7	2810 (D)	
16	A-B-3	350	130.8	2830 (D)	
17	A-B-4	350	156.0	2370 (ID)	
18	A-B-5	350	111.7	3310 (D)	
19	C-D-2	350	110.7	3340 (D)	
20	C-D-2	350	283.0	1310 (D)	Pipe hole near by
21	C-D-3	350	106.8	3460 (D)	
22	C-D-4	350	485.0	760 (ID)	
23	C-4-5	350	124.8	2970 (D)	
24	C-3-4	350	138.8	2670 (D)	
25	C-2-3	350	116.8	3170 (D)	
26	B-2-3	350	122.7	3020 (D)	
27	B-4-5	300	111.4	3320 (D)	
29 Date 23/09/12 Plastered unless specified					
30	B-C-4	200	110.7	1810 (ID)	
31	B-C-4	150	52.0	2890 (SD)	
32	B-C-4	350	112.8	3100 (D)	
33	B-C-4##	200	99.7	2010 (ID) ↑	Vertical Up
34	B-3-4	200	38.4	520 (ID)	
35	B-3-4	150	58.7	2560 (SD)	
36	B-3-4	350	127.9	2740 (D)	
37	B-3-4##	200	159.9	1250 (ID) ↑	Vertical Up
38	B-C-2	200	115.2	1740 (ID)	
39	B-C-2	150	51.7	2900 (SD)	
40	B-C-2	350	124.9	2800 (D)	
41	B-C-2	200	116.9	1710 (ID) ↑	Vertical Up
##- From Bottom, Other-Horizontal					
Crack Measurment Date 23/09/12 Plastered unless specified					
42	MEMBER	B (mm)	T1 (µS)	T2 (µS)	C (mm)
43	B-C-4 (BOTTOM)	100	472	524	345
44	B-C-4 (SIDE)	75	518	633	169
45	B-C-2 (BOTTOM)	75	192	263	117
46	B-C-2 (SIDE)	75	309	413	126
Date 09/09/12 Plastered unless specified					
47	B-C-2 (SIDE)	150	312	410	----
48	B-C-2 (SIDE)	150	433	802	73
49	B-C-2 (SIDE)	150	241	750	----
50	B-C-2 (SIDE)	150	587	878	179
51	B-C-4 (SIDE)	150	247	575	---
52	B-3-4 (SIDE)	150	268	537	----
53	B-C-3 (SIDE)	150	320	634	17
54	B-C-4 (SIDE)	150	282	552	10
55	B-C-5 (SIDE)	150	342	719	Both sides cracked
Date 27/09/12					
FOUNDATION (RIGHT SIDE REAR CORNER, Beam Top 1.25m from Plinth Band Bottom & 0.73m from Average					
56	Left Side	300	103.8	2890 (ID)	
57	O. Rear Side	300	140.6	2130 (ID)	O.-Opposite

D- Direct, SD-Semi Direct & ID- Indirect Transmission of Ultra Sonic Pulse Wave

Ultrasonic pulse velocity test indicate travel time through concrete continuous media. In Indirect method probes are kept on same side of the surface while in semi direct these are kept at right angles to each other. Higher pulse velocity indicates better quality of concrete. Difference in velocities obtained by different methods should be compared with corrections as given in IS 13311 pt I.

IV. OTHER OBSERVATIONS

Level Difference on beam (span 4.24m) BC2 was measured with water pipe tube holding it at the bottom face of the beam ends. No level difference was observed.

Rebars were traced using Profometer. On column B2, 4 bars of 20 mm dia and 4 bars of 25 mm dia as shown in the drawing could be confirmed. Ties of 8 mm dia @ 175 mm C/C were shown in the drawing which could be measured

with the instrument as 170 mm to 180 mm C/C. Similarly on Beam AB5 Shear stirrups were observed @ 150 mm C/C and on Beam B45 Main bars were observed @ 100 mm C/C. On beam 4BC heavy EMF did not allowed reliable readings.
A pit was excavated near rear corner of the building to visually inspect condition of the foundation. Certain Rebound hammer and UPV readings were observed.

V. SUMMARIZED OBSERVATIONS

The building was reported to be constructed in the year 1999. BIS code for RCC i.e. IS 456 was revised in the year 2000. Similarly IS 1893 was also revised in the year 2002. Provisions of these two codes made the building deficient necessitating its retrofitting. The Sun City Jodhpur faced acute Rising Ground water problem which aggravated since 2003 onwards & became worsen later. It is not a surprise that cracks in the building was observed in the 2006. Movement of ground water level also assumed to cause movement of the foundation strata. Being Isolated footing the movements cannot remain uniform at all footings; hence this can be attributed to be the cause of vertical cracks in beams at middle span. So far as quality of concrete is in concerned it appears to be satisfactory looking to the codal provisions. Cracks did appear due to certain other reasons which may not be structural for all the cases. State of the structure is shown in the photographs attached (on five pages thirty in numbers).
NDT test indicate in surface hardness. Ultrasonic pulse velocity test show quality in undisturbed part. Rebound readings with standard deviation more than 5.0 show wide range of data and quality as well. Quality of concrete with Compressive strength obtained with Rebound hammer test more than 20.0 N / sq mm can be considered meeting desired level. Point where this is not shown may be checked with other methods to confirm their quality. Ultrasonic Pulse Velocity obtained less than 2000 m/s shows doubtful quality of concrete. It can be considered well if the velocity obtained is more than 3000 m/s and excellent if it is more than 4000 m/s. At some point's compressive strength with combined Rebound and Ultra sonic Pulse Velocity are obtained showing more reliable results hence can be considered better. Observation with UPV for cracks, Level difference, Rebar tracing provided useful results.

VI. RECOMMENDATIONS/CONCLUSION

In view of the BIS code major relevant code revisions and state of cracks in the middle span beams it not advisable to continue with the proposed scheme. Rather it would be in the interest of the public at large and Staff in particular to Demolish RCC frame structure and go for Reconstruction. While planning for a new scheme due care for geotechnical investigation and foundation design must be taken. Current codal provisions must be implemented.

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