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Assessment of deterioration in RCC building

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ABSTRACT

Concrete is considered as a durable material but it is still potentially vulnerable to deterioration, unless certain precautions are taken. The assessment of concrete structures consists of not only evaluation of the present condition but also prediction of the cause of deterioration and its residual life. Number of tests need to be carried out to assess the extent of distress and to estimate the quality of concrete, before taking up any repair measures. This paper discusses the assessment of RCC building by using Non Destructive Testing. The main aim of the paper is to highlight the importance and significance of different test methods employed to assess the present condition of RCC structure.

Keywords: *Cracks, Structural distress, Structural Audit, Non-Destructive Testing, Rehabilitation*

1. INTRODUCTION

The detailed inspection work began with the marking of Column and beam positions on the copy of drawing sheet. This was necessary to divide the structure into a grid and facilitate ease in working. Non-destructive test in the form of Rebound Hammer test, ultrasonic pulse velocity, carbonation test, corrosion tests, cover meter test were carried out on selected Reinforced Concrete members. The result of the above-mentioned tests along with visual observations forms the bulk of data in the report. The Photographs of major defective portions are taken.

Distressed RCC Findings.

Structural Cracks on the Staircase Passage.

Structural Cracks on the Dead wall.

RCC column failure.

Concrete chipping off from slab exposing reinforcement.

Exposed reinforcement.

2. INTERNAL OBSERVATIONS

GROUND FLOOR
Room no.-161 is recently painted. Hollow sound heard on tapping by ebonite hammer on various walls & columns at different rooms. Leakage at kitchen & bathroom area is observed. Dampness marks at bathroom slab are observed. Minor crack at column is observed in room no.-163. A peeling of paint is observed at few points in room no.-164. Minor crack at columns & beams are observed in room no.-164. Room no.-165 is in good condition, said by tenants. Room no.-166 was locked. Room no.-167 & 168 were locked.
FIRST FLOOR
A peeling of paint is observed in many rooms. Minor crack at columns& slab plaster are observed in room no.-169& 170.

Fallen cover concrete with exposed reinforcement at beams are observed in room no.-169& 170. Leakage at kitchen & bathroom area is observed. Dampness marks at bathroom slab are observed. Black molds at kitchen are observed in room no.-172. Spalled cover concrete with exposed reinforcement at few locations is observed in room no.-172& 173. Mostly exposed reinforcement at loft which is provided in kitchen is observed. Minor cracks at beam are observed in room no.-173. Distress slab at bathroom area is observed in room no.-174. Distress plaster at hall slab is observed in room no.-175. Room no.-176 was locked.
SECOND FLOOR
Leakage at kitchen & bathroom area is observed. A peeling of paint is observed in many rooms. Hollow sound heard on tapping by ebonite hammer on various walls & columns at different rooms. Minor crack at columns beams & slab plaster are observed in room no.-177 & 178. Spalled cover concrete with exposed reinforcement at kitchen slab & at column is observed in room no.-178. Bulged columns in room no.-183 are observed. Room no.-179 is recently painted. Room no.-180 was locked. Dampness marks at kitchen & bathroom area are observed in room no.-181. Minor cracks to beams in room no.-181 &182 are observed. Bulged column in room no.-183 is observed. Dampness marks at hall slab are observed in room no.-183. Minor crack at columns beams & slab plaster are observed in room no.-184.
THIRD FLOOR
Room no.-185 is recently painted. Leakage at kitchen & bathroom area is observed in many rooms. Room no.-186 was locked. Hollow sound heard on tapping by ebonite hammer on various walls & columns at room no.-187. Fallen cover concrete with exposed reinforcement at kitchen slab is observed in room no.-187. No response from room no.-188, 191 & 192 tenants. Wall tiles at kitchen in room no.-189 are observed in broken condition. Minor cracks at hall slab plaster in room no.-190 are observed.
FOURTH FLOOR
Room no. 193, 194 & 199 were recently painted. Minor cracks at slab & beams are observed in many rooms. Leakage at kitchen & bathroom area is observed in most rooms. Work in room no.-195 was going on. Since 14to15 years there was no tenant in room no.-196. Patch work at kitchen area is observed in room no.-197. Room no.-200 was locked.

STAIRCASE
Peelings of paints observed at staircase area. Black molds are observed at some points. Structural cracks at staircase columns& beams are observed.

WATER TANK
Dampness marks observed at water tank wall. Black mold observed at water tank wall. Vegetation growth below water tank is observed. Minor cracks are observed at column which is supported to water tank.

TERRACE
IPS water proofing is observed at terrace. Minor cracks observed at terrace. Vegetation growth is observed at some locations.

PASSAGE AREA
Tilted balcony towards outside is observed at second& third floor. Structural cracks at staircase columns& beams are observed.

Distressed slab at few locations is observed. Major cracks at slab plaster & beams are observed. Sloped pardi is in damaged condition.

3. REBOUND HAMMER TEST RESULTS

HAMMER TEST READINGS										
Sr. No.	R.C.C. MEMBER	R1	R2	R3	R4	R5	AVERAGE REBOND No.	COMP. STRENGTH (MPa)	DIRECTION OF TEST	REMARKS
GROUND FLOOR										
1	C5	10	11	10	12	13	11	10.0	Horizontal	Hollow
2	C6	13	21	18	19	23	19	10.0	Horizontal	
3	C10	10	12	15	16	10	13	10.0	Horizontal	
4	C38	18	22	20	17	21	20	10.0	Horizontal	Hollow
5	C1	20	18	23	22	16	20	10.0	Horizontal	
6	C29	18	22	15	17	20	18	10.0	Horizontal	
7	C39	12	13	16	18	18	15	10.0	Horizontal	
THIRD FLOOR										
8	C-39	13	15	18	21	22	18	10.0	Horizontal	
FOURTH FLOOR										
9	C-40	15	20	21	23	24	21	11.5	Horizontal	
							Average=	10.2		
HAMMER TEST READINGS										
Sr. No.	R.C.C. MEMBER	R1	R2	R3	R4	R5	AVERAGE REBOND No.	COMP. STRENGTH (MPa)	DIRECTION OF TEST	REMARKS
FIRST FLOOR										
1	B-67	22	18	20	21	23	21	10.0	Horizontal	
SECOND FLOOR										
2	B-28A	20	13	15	18	19	17	10.0	Horizontal	
3	B-68	13	12	11	10	15	12	10.0	Horizontal	
THIRD FLOOR										
4	B-28A	20	18	21	18	22	20	10.0	Vertical Up	
5	B-68	22	18	15	14	13	16	10.0	Horizontal	
							Average=	10.0		
HAMMER TEST READINGS (SLAB)										
Sr. No.	R.C.C. MEMBER	R1	R2	R3	R4	R5	AVERAGE REBOND No.	COMP. STRENGTH (MPa)	DIRECTION OF TEST	REMARKS
FIRST FLOOR										
1	S-29	18	23	22	19	21	21	10.0	Vertical Up	
THIRD FLOOR										
2	S-30	20	21	19	18	23	20	10.0	Vertical Up	
FOURTH FLOOR										
3	S-27	18	20	22	21	20	20	10.0	Vertical Up	
							Average=	10.0		

4. ULTRASONIC PULSE VELOCITY TEST RESULTS

UPV TEST READINGS						
Sr. No.	R.C.C. MEMBERS	VELOCITY (km/Sec.) Set 1	VELOCITY (km/Sec.) Set 1	AVERAGE VELOCITY (km/Sec.)	METHOD OF TESTING	REMARKS
GROUND FLOOR						
1	C5	0.79	0.81	0.80	SD	Hollow
2	C6	0.85	0.87	0.86	SD	
3	C10	0.53	0.52	0.52	ID	
4	C38	0.42	0.41	0.42	ID	Hollow
5	C1	0.27	0.31	0.29	ID	
6	C29	0.22	0.25	0.23	SD	
7	C39	0.72	0.71	0.71	SD	
THIRD FLOOR						
8	C-39	1.00	0.99	1.00	ID	
FOURTH FLOOR						
9	C-40	0.63	0.63	0.63	ID	
Average integrity & deficiency				0.61		
Average quality of columns				DOUBTFUL		

UPV TEST READINGS						
Sr. No.	R.C.C. MEMBERS	VELOCITY (km/Sec.) Set 1	VELOCITY (km/Sec.) Set 1	AVERAGE VELOCITY (Km/Sec.)	METHOD OF TESTING	REMARKS
FIRST FLOOR						
1	B-67	0.48	0.43	0.46	ID	
SECOND FLOOR						
2	B-28A	0.71	0.53	0.62	ID	
3	B-68	0.75	0.78	0.76	ID	
THIRD FLOOR						
4	B-28A	0.55	0.51	0.53	SD	
5	B-68	0.67	0.70	0.68	ID	
Average integrity & deficiency				0.61		
Average quality of beams				DOUBTFUL		

UPV TEST READINGS						
Sr. No.	R.C.C. MEMBERS	VELOCITY (km/Sec.) Set 1	VELOCITY (km/Sec.) Set 1	AVERAGE VELOCITY (Km/Sec.)	METHOD OF TESTING	REMARKS
FIRST FLOOR						
1	S-29	1.00	0.81	0.90	ID	
THIRD FLOOR						
2	S-30	0.96	0.95	0.95	ID	
FOURTH FLOOR						
3	S-27	1.10	0.95	1.02	ID	

Average integrity & deficiency	0.96		
Average quality of slabs	DOUBTFUL		

Pulse Velocity by cross probing (km/sec)	Concrete quality Grading
Above 4.5	Excellent
3.5-4.5 km/s	Good
3.0-3.5 km/s	Medium
Below 3.0 km/s	Doubtful

5. CARBONATION TEST RESULTS

CARBONATION TEST RESULTS					
SR.NO	R.C.C MEMBER COLUMN, BEAM & SLAB	Drill Depth (mm)	COLOUR INDICATION	DEPTH OF (mm) CARBONATION	Remark
GROUND FLOOR					
1	C-39		NCC		Exposed
2	C-33	40	NCC	40	
3	S-29		NCC		Exposed
4	B-67		NCC		Exposed
Average depth of carbonation for all members (mm) =				40.00	
Notations: CC - Colour Change, NCC - No Colour Change, LCC - Lightly Colour Change					

6. CORROSION TEST RESULTS

HALF-CELL POTENSIOMETER (CORROSION) TEST									
Sr. No.	R.C.C. Member	Half-cell potential (-mV)						Average half cell potential (-mV)	Probability of corrosion
GROUND FLOOR									
1	C-39	280	287	295	336	258	267	287	50%
2	C-33	285	283	289	278	292	335	294	50%
3	S-29	262	295	336	356	256	280	297	50%
4	B-67	255	265	338	342	340	299	307	50%

Corrosion Risk	No of Members
>95%	0
50%	4
<5%	0

Corrosion Risk	Potential
>95%	More Negative than –350mV
50%	-200 to –350mV
<5%	More positive than –200mV

7. PROFOMETER TEST RESULTS

PROFOMETER SCAN				
Sr. No.	R.C.C. Member	Diameter of Bar (mm)	Cover Concrete (mm)	Remark
GROUND FLOOR				
1	C-39			EXPOSED
2	C-33		65	
3	S-29			EXPOSED
4	B-67			EXPOSED

8. CHEMICAL TEST RESULTS

CHEMICAL TEST				
Sr. No.	SAMPLE ID	pH value	Chloride as Cl, (mg/l)	Sulphates as SO3, (mg/l)
Permissible Limit as per IS 456 (2000)		Not Less Than 8	For PCC 3000 mg/l & for RCC 600 mg/l	Max.400
1	S-29	9	40	60

9. CORE TEST RESULTS

CORE TEST RESULTS	
Sr. No	1
Structure	Building no-5
Member ID	Core-4
Dia, D mm	68.88
Length, mm	129.02
h/d	1.87
Dry wt,kg	1.062
Wet wt,kg	1.078
Wet Density kg/m3	2.24
Water Absorption (%)	1.51
Failure Load kN	40
Core Strength,Mpa	10.74
Core Factor as per h/d ratio	0.98
Core Factor Eqv.150 mm Cube Strength	1.25
Final Eqv. 150 mm cube strength Mpa	13.19

10. ANALYSIS OF N.D.T. RESULTS:

Hammer readings for column indicate an average compressive strength of 10.20Mpa & average ultrasonic pulse velocity is 0.61km/sec.

Hammer readings for beam indicate an average compressive strength of 10.0Mpa & average ultrasonic pulse velocity is 0.61 km/sec.

Hammer readings for slab indicate an average compressive strength of 10.0Mpa & average ultrasonic pulse velocity is 0.96km/sec.

Carbonation has reached to an average depth of 40.0mm ranging from Half-cell potentiometer indicates the probability of corrosion is 50%.

The parameters that influence corrosion are pH value and chloride level. Chloride & Sulphate contents are in permissible limit so there is No. risk of corrosion & progressive loss of strength.
Core Test results shows an equivalent cube compressive strength of 13.19 MPa

The interpretation of the NDT results and the correlation of the results with the strength of the concrete are as per the extensive research carried out by us.

11. CONCLUSION

The building was constructed approximately 47 year back i.e. year 1969,hence to the best of our knowledge the design must have been based on the old code (IS 456, 1964) of practice. External faces show deterioration due to weathering. The detailed visual inspection has been performed to assess the condition of the building though to check the integrity & strength of members few NDT tests has been performed. The column, beams and slabs are deteriorated showing delamination of cover concrete and rusted reinforcement. No provision of column supports for front passage except at staircase. RCC elements of staircase/ mid- landing slab & porch area are in distress condition. Vegetation growth is observed at many locations. The slabs and sunken slabs show the patches of seepage at many locations. Bulging of cover concrete at some places, chajjas & balconies with fallen cover concrete are observed. The distresses observed in the RCC elements are primarily due to corrosion of reinforcing bars. Toilet block is severely deteriorated with leakages from slab and wall. In discussion with PWD engineers we recommend to remove chajjas from all windows and replace with FRP weathering sheets.

Passage area is in dilapidated condition, where carbonation of concrete has reached beyond steel reinforcement. Heavy corrosion of reinforcement has been noted with reduction in cross section. More over it is recommended to recast the entire passage area.

Results of the various NDT tests and the visual survey are combined to conclude the quality of the concrete. Rebound Hammer Test results indicate poor in-situ strength of concrete. Ultra sonic pulse velocity also shows doubtful in-situ quality of concrete. The carbonation has reached to the average depth of 40mm. Half cell potentiometer indicates the probability of corrosion to be 50%.

Primarily structure is capable to carry Dl + LL as it is in current condition. But major structural repairs should be carried out to avoid further deteriorations of RCC members. If adequate structural repair, strengthening & rehabilitation measure are undertaken as per BOQ enclosed herewith, the structure can be rehabilitated to required service level for gravity loads as per the provisions and requirements of I.S. codes at reasonable cost. However, we are in conclusion that the building is livable for any type of habitation (temporary or permanent). After repairs the expected life of structure is 12 to 15 years if periodically maintenance, minor repair and painting work has been done at regular interval.

The repair/rehabilitation shall be taken on prior basis as per the repair methodology and under the supervision of experienced repair/rehabilitation consultant.

Note:
After tabulating the analytical data of NDT Test, Visual Inspection & by virtue of our experience and expertise in the field of Retrofitting / Structural Repairs the quantity are calculated in Bill of quantity items. It may vary after actual Plaster / Concrete chipping.

Limitation: Foundation condition to be checked at the time of repair / retrofitting, if required strengthening measures should be carried out.

For Additional safety, remove the loose plaster & corroded steel sheets/angles to avoid accidents. Loose part of the structure cannot be left in their present condition.

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