"STRUCTRAL AUDIT OF RESIDENTIAL BUILDING- SAINATH APARTMENT, VIRAR EAST"

[1]Vighnesh S. Berde, [2]Dr. Sachin B. Mulay,

[1]Pursuing M.Tech, [2]Ph.D (SVNIT)
[1]Department Structural Engineering & Sandip University, Nashik,
Mumbai, India

Abstract : This study is being under taken to check the structural stability and integrity of the residential structure so as to keep in check any defects found and to safeguard the structure and human life. Structural stability also known as structural audit consists of two major activities. The visual survey of the structure and the NDT testings. The visual survey of the entire premises was being carried out along with tapping of the structural components to identify any structural as well as material defects in the structure NDT play a vital role in determining the compressive strength and working stats of the concrete also the status of the steel reinforcements. Thus the NDT's being carried out are Rebound Hammer test, Carbonation test, Half-cell potential test, Ultrasonic pulse velocity test and Core test. Thus based on the Visual survey and NDT testings a Proforma-B was being established and final report was being compiled. Thus based on all of he collected data and the test results an appropriate category is identified for the structure and based on the category it is being decided whether the structure is suitable for human habitation.

***Index Terms* – Structural audit, Visual survey, NDT testings, Rebound Hammer test, Carbonation test, Half-cell potential test, Ultrasonic pulse velocity test and Core test.**

I. INTRODUCTION

In Mumbai there are more than over 14,000 structure having age of beyond 50 years which are on the verge of collapsing due to instability and improper maintenance. Also in India, there is a major loss of life and material due to the collapsing of structure caused because of improper maintenance and negligence towards the structural and material integrity of the structure. Thus the process of Structural audit became important so as to save the human life and loss of material. An incident which took place on 23rd July 2021, a G+2 stored building was found to be collapsed in the Govandi area of Mumbai which resulted in the death of three members of the society Thus to avoid such mishaps conducting regular audits of structures is of utmost importance.

Structural audit is generally conducted to identify any defects on the structural components such as defect caused due to strain in the R.C.C frame work, defects due to overloading on structure, material detoriation, etc also the non-structural defects in the form of scaling of plaster, peeling of paint, drainage related defects, etc. The earlier these defects are identified easier it is to solve the issues. Thus a structural auditor helps in highlighting these defects caused and helps in identifying appropriate repair techniques to repair and rehabilitate the structure and in some cases increase the life expectancy of the structure.

Generally structural audit is conducted during the monsoon period as the seepage of water from the major and minor cracks on the structure are clearly visible but as per the bye laws of the co-operative housing society's a society is liable to conduct structural audits after every 5 years for structure having age between 15-30 years while for a structure beyond 30 years structural audit is to be conducted every 3 years.

II. OBJECTIVES

1. To conduct visual survey of the entire periphery of the building. To identify the defects and highlight it in the Porforma-B.
2. To conduct NDT testings with proper surface preparations need and compile test results.
3. To identify any overloading on the structure due to construction/alternation in the structure.
4. To compile the data which will consist of Proforma-B, NDT testings, Observed defects and remedies.

III. REASERCH METHODOLOGY

In this chapter we will discuss the methodology which will be adopted for the research, the methodology is divided into three steps:

1. Visual Survey.
2. Compiling Proforma-B.
3. NDT testings.

1. Visual Survey:
   Visual survey along with taping of structural components with rubber hammer will be conducted for the entire internal as well as external portions of the buildings, which will help us to identify any defects in the structural members, the condition of external plaster and paint will be assessed which will help us to prepare the observational chart in the form of Proforma-B which is compulsory as per the BMC norms.

2. NDT testings:
   Non-destructive testings helps in understanding the actual working condition of the concrete as well the extent of corrosion in the steel reinforcements. The NDT's being conducted are Rebound Hammer test, Carbonation test, Half-cell potential test, Ultrasonic pulse velocity test, Core test and cement:Aggregate.

- Rebound Hammer test:
  As per IS 13311 part 2-1992 the Rebound hammer test also referred to as Schmidt hammer test helps to determine the surface hardness of the concrete, Uniformity and Quality of concrete.

- Carbonation test:
  Carbonation is a process by which carbon dioxide from the atmosphere when comes in contact with concrete results in conversion of calcium hydroxide to calcium carbonates. Phenolphthalein is used as an indicator in this test. Phenolphthalein when comes in contact with alkaline concrete changes its color to pink. Carbonation is directly proportional to the probability of corrosion in steel reinforcement.

- Half-cell potential test:
  As per ASTM C876-15 the test is a corrosion assessment test. The basic principle of the test is the assessment of the potential of the steel reinforcement to the reference of the half-cell placed on the concrete. The apparatus consist of a dielectric halfcell consisting of material in-reactive with copper or copper sulphate with a copper rod and a wooden plug and a voltmeter. The copper rod is placed directly on the steel reinforcement by drilling holes and a the half-cell is placed on the concrete surface by creating a capillary action by spraying of water. The reading in the voltmeter help us to identify the probability of corrosion.

- Ultrasonic pulse velocity test:
  As per IS 516 (Part 5/Sec1: 2018) Ultrasonic pulse velocity test is used to determine the homogeneity of concrete. Two probes are used in the apparatus a transmitter and a receiver with an electronic unit to catch the pulse and show its time msec. More the time required to travel the desired path more is the homogeneity of concrete.

- Core test:
  Core samples are taken out from the RCC components with the help of diamond drills then placed under compression testing machine and the compressive strength is measured of the core sample.

IV. RESULTS AND DISCUSSIONS

1. Visual Survey:
   The visual survey along with tapping exercise was carried out on the 11th July 2021 by Vighnesh S. Berde. Following are the observations made:

External Area.

- R.C.C columns were beams are found to be damaged in certain portions.
- R.C.C chajjas were found to be damaged in certain portions.
- Plaster over certain areas is found to be damaged due to material detoriation and due to the lack of any protective coating.
- Separation cracks were visible in between the column, beams and masonry walls.
- Dense regions of hairline cracks were visible around the entire periphery of the building.
- Vegetation and fungal growth was found around the external plaster.
- Plumbing joints were found to be leaking around certain joints.

Staircase Area.

- Staircase R.C.C components were found to be damaged around certain areas.
- Certain R.C.C pardis were found to be damaged and incompletely constructed.
- Plaster around certain portions in the staircase area was found to be damaged and incompletely plastered.
- Balcony M.S railing is fixed by constructing masonry wall in the balcony area, the wall needs plastering and M.S railing was found to be corroded.

Internal Flats.

- Due to the damaged external plaster and incomplete plastering work major seepage of water was observed into the internal walls, thus causing damage to the internal plaster.
- Major and minor cracks were visible along the R.C.C components.

Terrace and O.H tank.

- Due to the absence of terrace waterproofing layers in the form of IPS or china chips laded waterproofing, seepage of water from the terrace slab into the structure was observed.
- Vegetation and fungal growth was found around the parapet walls.
- Vegetation growth was found along the O.H tank and masonry walls are incompletely constructed.
- Exposed steel reinforcements of the bottom slab of O.H tank were visible.

Fig.4.1 Exposed steel reinforcement in flat no.003.

Fig.4.2 Seepage of water into the internal walls of flat no.007.

Fig.4.3 Seepage of water into the internal walls of flat no.007.

Fig.4.4 Damaged R.C.C column of flat no.201.

Fig 4.5 External east side wall.

Fig.4.6 External East side wall.

Fig.4.7 External North side wall.

Fig4.8 Terrace area.

Fig.4.9 O.H tank bottom slab steel reinforcements found to be exposed.

2. **Proforma-B.**

After thorough visual survey of individual flats and the external portion of the building **SAINATH APARTMENT**, the following findings are observed:

Table 4.1 Proforma-B.

Sr.No	Particulars	Observations
1.	Residential	Yes
	Life of the structure	11 years
	No. of storey's	G+4 (4TH FLOOR UNDER-CONSTRUCTION)
	Commercial	-
	Industrial	-
	Educational	-
	Assembly	-
2.	Types of structure	R.C.C
3.	Particulars of building premises	
	Basements	-
	Number of entrance/ Exits/Lifts	1 entrance
	Details of ceiling/column/beams/flooring/balconies	
	Drainage pipe condition	Joints found to be leaking.
	Parking	-
4	Location of building/premises	SAINATH APT, PHOOLPADA RD,VIRAR EAST.
	Any history of repairs? If done in which year?	NO
	Was there terrace waterproofing done?	NO
	Was external painting work done?	NO
	Whether any plumbing work was done?	NO
6.	Machine Testing:	
	Rebound hammer	Mentioned in results.
	Ultra Sonic pulse Velocity	
	Half Cell potential	
	Carbonation	
7.	Based on the visual survey following observations were made:	
	7A. Building External Components.	
	➢ R.C.C column	Minor repair needed.
	➢ R.C.C beams	Minor repair needed.
	➢ R.C.C chajjas	Minor repair needed.
	➢ R.C.C balconies	Minor repair needed.
	➢ Balcony pardies	Minor repair needed.
	➢ External plaster	Found to be seriously damaged, re-plastering is needed.
	➢ External paint	-
	➢ Chambers	Satisfactory.
	➢ Flooring Paving	-
	➢ Watchman Cabin	-
	➢ Compound wall	-
	7B. Building Internal Components	
	➢ Member Flats	Chart sheets attached separately
	➢ Entrance Canopy	-

	➢ R.C.C columns	Minor repair needed.
	➢ R.C.C beams	Minor repair needed.
	➢ Staircase R.C.C waist slab	Minor repair needed.
	➢ Staircase Risers and Landings	Satisfactory
	➢ Plaster work	Found to be seriously damaged, re-plastering is needed.
	➢ Internal Paint	-
	➢ Lift Duct	-
	➢ Lift cabin	-
	➢ Internal Meter Cabin	Satisfactory
	➢ Hanging and Damaged wires (if found)	None
	7C. Terrace Components	
	➢ Parapet walls	Fungal growth present.
	➢ Any repairs done	-
	➢ Leakage from terrace slab	YES
	➢ Rainwater lines	Satisfactory
	➢ Fire Fighting components	-
	➢ R.C.C Overhead Tank	Minor repairs needed
	➢ Bottom Ceiling of Overhead Tank	Major repairs needed
	➢ Leakage from Overhead Tank	-
	➢ Condition of plaster of Overhead Tank	-
	➢ Condition of Paint of Overhead Tank	-
8.	**Final conclusion**	C2-B category (No eviction and needs structural repairs.)

3. NDT testings:

NDT testings were conducted by M/S sttar Technologies on the 2th July 2021 by Mr. Kamlesh Prajapati.

Rebound hammer test:

As per IS 13311: Part 2 1992 the plaster over the R.C.C components was being chipped with the help of mechanical hammer, the method of surface probing being adopted was surface probing also all the necessary surface preparations were also being taken care of, the results of the test are as follows:

Table 4.2 Results for Rebound hammer test.

Sr.No	Member-ID	RCC Element	Avg. Rebound Index	Compressive strength (N/mm2)	Direction of Rebound
1.	C-1	Column	27	18	Horizontal
2.	C-2	Column	28	20	Horizontal
3.	C-3	Column	30	24	Horizontal
4.	S-1	Slab	32	20	Vertical up
5.	S-2	Slab	22	10	Vertical up
6.	S-3	Slab	24	11	Vertical up
7.	C-4	Column	26	18	Horizontal
8.	S-4	Slab	30	16	Horizontal
9.	B-1	Beam	28	20	Horizontal
10.	C-5	Column	32	26	Horizontal
11.	B-4	Beam	26	18	Horizontal
12.	C-10	Column	24	12	Horizontal

The test results conclude that the average compressive strength ranges from **15-20n/mm2**.

Ultrasonic pulse velocity test:

As per IS 516 (Part 5/Sec1: 2018) indirect surface probing method was being adopted and the readings were recorded following are the results of the test:

Table 4.3 Ultrasonic pulse velocity test.

Sr.no	Member ID	RCC Element	Distance (mm)	Time (Usec)	velocity (Km/Sec)	Method
1.	C-1	Column	400	140.3	2.85	Indirect
2.	C-2	Column	400	141.3	2.86	Indirect
3.	C-3	Column	400	148.9	2.69	Indirect
4.	S-1	Slab	400	160.5	2.49	Indirect
5.	S-2	Slab	400	162.3	2.46	Indirect
6.	S-3	Slab	400	145.1	2.76	Indirect
7.	C-4	Column	400	159.7	2.50	Indirect
8.	S-4	Slab	400	161.2	2.48	Indirect
9.	B-1	Beam	400	139.2	2.87	Indirect
10.	C-5	Column	400	147.1	2.72	Indirect
11.	B-4	Beam	400	150.5	2.66	Indirect
12.	C-10	Column	400	157.7	2.54	Indirect

From the results it is clear that the velocity of the pulse ranges from **2.2km/sec to 3.00 km/sec** which correlates to the conclusion that the quality of concrete is found to be in **doubtful condition**.

Carbonation Test:

As per BS 1881 Part 201: 1986 drills were being drilled into the concrete surface using 20mm drill bit, the indicator being used was Phenolphthalein being diluted with ethyl alcohol. The following are the test results:

Table 4.4- Results for Carbonation test.

Sr. No	Member-ID	RCC Element	Total Depth (mm)	Carbonation depth (mm)
1.	C-1	Column	70	40
2.	C-2	Column	60	35
3.	C-3	Column	60	35
4.	S-1	Slab	35	20
5.	S-2	Slab	35	20
6.	S-3	Slab	40	25
7.	C-4	Column	55	25
8.	B-4	Beam	35	20
9.	C-10	Column	35	20
10.	B-6	Beam	35	20

Each of the member tested resulted in showing colorless precipitation, none of them showed pink precipitation which concludes that the concrete in carbonated, thus increasing the risk of corrosion of steel reinforcements.

Half-cell potential test:

As per ASTM C-876-2015 the rebars were located with the rebar locator and holes were drilled to reach the steel reinforcements using 20mm drill bit. Following are the test results:

Table 4.5- Results for Half-cell potential test.

Sr.No	Member-ID	RCC Element	Halfcell potential (-mV)
1.	C-1	Column	305
2.	C-2	Column	325
3.	C-3	Column	320
4.	S-1	Slab	326
5.	S-2	Slab	300
6.	S-3	Slab	312
7.	C-4	Column	321
8.	B-4	Beam	309
9.	C-10	Column	320
10.	B-6	Beam	300

As per ASTM C-876-15 the readings in the voltmeter are ranging from -200 to -350 mv which indicate an increased probability of corrosion in steel reinforcements.

Core test:

As per IS 516-4: 2018 core samples were taken out with the of round knife cutting machine two samples were taken and sent to the lab, following are the test results:

Sr.no	Core height (mm)	Core dia (mm)	Core wt (kg)	Load (Kn)	Core comp. Strength (N/sq.mm)	Core comp strength after dia correction	h/d ratio	Correction factor for (h/h) ratio	Corrected comp strength (N/Sq.mm)	Equivalent cube comp. strength (N/sq.mm)	Equivalent cube comp. strength (Kg/sq.mm)
1.	135.00	68.01	1.500	36.0	9.91	10.51	1.99	0.998	10.49	13.12	133.70
2.	130.00	67.98	1.580	28.4	7.83	8.30	1.91	0.990	8.22	10.27	104.72

The average core compressive strength was found out to be 11069 N/sq.mm.

Cement Aggregate ratio:

The ratio of Cement: Aggregate was being found out in the lab from the core sample being extracted, following are results:

Sr.no	Test parameter	Test method used	Test result
1.	Cement : Aggregate	IS 1199:1959	1:3.21

As per IS 1199:1959 the results conclude that the grade of concrete being used is around **M20-M25 (N/mm2).**

V. CONCLUSIONS

1. The visual survey and tapping exercise was thoroughly executed and concluded to the fact that major of the non-structural damages were observed in the external as well as internal areas.
2. Due to the incomplete external plaster and absence of protective coating over the completed plaster in the form of Acrylic or Semi Acrylic paint major seepage of water was observed in the internal walls.
3. Also seepage of water from the terrace slab into the third and second floor slab was observed due to incomplete and faulty workmanship in execution of terrace waterproofing work. Entire fourth floor was incompletely constructed result in major structural damages due to incomplete and faulty workmanship.
4. The results of NDT testings concluded that due to dense region of cracks around the structural elements there was direct contact of moisture with the steel reinforcements resulting in corrosion of steel bars and carbonation of concrete.
5. The ultrasonic pulse velocity test concluded to the fact that the quality and homogeneity of concrete was found to be doubtful. Core test concluded that the average compressive strength of concrete came out to be 10.5 n/mm2 pointing towards the fact that the concrete mix used for concreting was not appropriate.
6. After collecting all of the data and conducting NDT testing we have a clear picture of the condition of the structure and the working status of concrete and steel and we categorize the structure to be in the C2-B zone which implies that no eviction and demolition is needed but major structural and non-structural repairing needs to be executed.
7. The scope of repairing should include structural repairing in the form of Micro-concreting the damaged concrete elements, Covering the masonry wall with a coating of plaster in two coats in the ratio 1:3 and 1:4 (Cement:sand). Completely painting the structure with acrylic paint.

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