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STRUCTURAL HEALTH MONITORING & AUDITING OF RCC BUILDING

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ABSTRACT: Structural audit is a health check-up of whole building. Structural auditing gives an idea about current condition of building and necessary measures taken so that the life of building can be increased. It also suggests some repair & retrofitting techniques required to increase the serviceability & overall health of old building. This paper deals with a case study of structural auditing of RCC building by visual inspection & NDT tests. From visual inspection, HRI is found out. Recently various methods and techniques are used for structural health monitoring called as NDE (Non Destructive Evaluation) techniques.

KEYWORDS*:* Structural auditing, SHM, NDT tests, HRI, Carbonation test, Core extraction test.

1. INTRODUCTION

In India RCC has been used extensively since last 50-60 years. After the independence a rapid development in multi-storied infrastructure is seen. Also after the independence, the construction activity in India has been increasing geometrically. Structural audit was first introduced by Indian society of structural engineers from 1975.

Due to increase in population, people migrating from village to cities therefore the population in cities increasing & number of people living in building are more than the actual design consideration. In India there are many old buildings which have reduced strength due to low quality material, improper techniques used in construction, the chances of failure of building are increased. The first step in repairing process of building is structural audit. Structural auditing is the process in which health of building is checked.

Structural audit also highlights and investigate risk areas, critical areas of building & also suggests if any urgent attention is required or not. Every structure has its own service life. Due to maintenance of the structure health of the building increases.

The building constructed usually reduces its strength when the building becomes older. Therefore it is compulsory for all building to carry out structural auditing once in 5 years whose age is 15 to 30 years & also for 3 years for building older than 30 years. If the structural condition gets bad, we can go earlier for structural auditing. The need of audit is to save life and building.

The major issues that occurs in structural audit is that the people are not aware about the structural audit & its importance.

2. LITERATURE SURVEY

2.1 "Structural Audit For An Educational Building", Abhinav Kale, Mahesh Gond, Pallavi Kharat

In this paper, authors were carried out the structural auditing of Sant. Tukaram Maharaj Vidyalaya which is located at Lohgaon, Pune. The shape of building is L-shaped, which RCC framed structure with two storied.The internal and external walls are made up of bricks. The authors were inspected external building faces, staircase, lobby, passage, rooms etc. From visual inspection and Rebound Hammer Test, they concluded that the building will require major repairs and the remaining members of the building need major up-gradation.

2.2 "Structural Audit of RCC Building", Sanket Sanjay Suryawanshi, Vaibhav Vishnu Vishe, Deepak Premchand Sah, Reetika Sharan

In this paper, authors were tried to find out the faulty mechanism in structure to prevent the failure of structure. The authors carried out the structural auditing of RCC building i.e. Vidhata apartment of G+4 floors which is located at Thane. The age of building was 28 years and also the weather effect is present. They performed Rebound Hammer Test, Ultrasonic Pulse Velocity Test & carbonation test to check the performance of the structural components like beams, slabs, columns, internal & external walls. They concluded that principle repairs are required at various levels, all the vegetation should be removed, minor cracks should be repaired by injection of Epoxy or by using grouting method, deteriorated plaster surface must be removed & plastering should be done with mortar proportions 1:3, corroded steel must be replaced wherever necessary.

2.3 "Structural Auditing With a Case Study", J.M. Sadamate, Dr. G.A. Hinge

This paper deals with a case study of RCC building i.e. Renuka Residency with G+8 floors which is located at Katraj. From visual inspection, they said that there is no serious problem in settlement of components, corrosion of steel and deflection of components. Also

the serious part observed is leakage problems, dampness & even cracks. They conducted Rebound Hammer test, core cutting test, carbonation test. From carbonation test, they concluded that there will be chances of corrosion in near future. Also they suggested some repairs in masonary work, waterproofing & tiling floorings. From visual inspection and NDT tests, it is cleared that repairs are required the buildings. At the time of performing NDT tests, it was observed that various columns and beams whose quality and strength is doubtful, jacketing should be done. From core tests, for first level slab, concrete should be classified as of M25 grade and M30 grade for first second level slab.

2.4 "Structural Audit: A Case Study of Nashik Residential Building, Maharashtra, India", K.R. Sonawane, Dr. A.W. Dhawale

The authors carried out the structural auditing of Malti-Vinayak building which is residential building & located at Lokmanyanagar, Gangapur Road, Nashik. They carried out visual inspection using scale, tape etc. They inspected external building faces, terrace etc. They carried out Rebound Hammer test & from that they concluded that the compressive strength of column (C2, C3, C4, C8, C10) and beam (B2, B3, B5, B7, B10, B11) is poor. Due to environment effect, spalling of concrete has occurred. Also there is corrosion of reinforcement in chajja & column (C6). From overall inspection, the authors suggested that the building should be repaired.

2.5 "Structural Audit, Repair and Rehabilitation of Building", Rohit Newale, Yogesh Sartape, Ashish Remane, Shreya Telrandhe, Sachin Vairal, Prof. Girish Joshi

This paper studied the present state of structure and major areas where improvement is needed during its service life stage for sustainable development and also the method of carrying out repair, rehabilitation and retrofitting. They carried out the structural auditing of RCC building of G+4 floors which is located at Pune. The age of building was 27 years & there is effect of mansoon on building. The building was visually inspected flat by flat.
They carried out cover meter test, half cell potential test, ultrasonic pulse velocity test, petrography test, core test, water permeability test, chloride sulphate test & porosity test. The condition of the building appeared to be quite bad.

2.6 "Structural Health Monitoring, Audit and Rehabilitation of Building in Construction Building", Sachin Rambhau Shelke, Prof. Darshana Ainchwar

This paper deals with a structural auditing & health monitoring of RCC building of G+22 floors which is located at Mumbai. The age of building was 18 years. The building was observed flat by flat. They observed defects like cracks, spells, crazing. Seepage, corrosion etc. They conducted ultrasonic pulse velocity test. For structural health monitoring applications, they used capacitance based sensor to detect micro cracks. Overall study showed defects are due to combined effects of carbonation, corrosion and effect of continuous drying & wetting.

2.7 "Structural Audit ", B. H Chafeakr, O. S Kadam, K. B Kale, S. R Mohite, P. A Shinde, V. P Koyle

This paper deals with a structural auditing of G+4 structure. The age of building was 23 years. In this paper structural auditing is done on the basis of visual inspection. They found health rating index and said that the condition of building is a fair.

3. METHODOLOGY

3.1 Literature survey for selection of topic
For final selection of topic thorough literature survey was done on the initial topics decided, and the already existing research work done on these topics were studied.

3.2 Problem statement
Determining the main problem and deciding the method to deal with it.

3.3 Selection of topic for the Project
Final discussion on the topics was done and what new can be done was discussed and the final topic was decided.

3.4 Literature survey supporting topic of project
Thorough literature survey supporting the topic of project was done which made it very clear about the topic and what we should do.

3.5 Study of plan of building
After deciding the topic study structural plan of the building. If the structural plan is not available, the same can be prepared by any Engineer.

3.6 Visual inspection
The visual inspection of a structure is the most effective qualitative method of evaluation of structural soundness & identifying the typical distress symptoms together with associated problems. The various points should be checked on inspection like settlement in the foundation, detect dampness in wall, cracks in column, beams, slab & walls, any sign of material deterioration, the various addition & alternation made, status of balconies- sagging, deflection, cracks, electrical wiring from main connection to all rooms, leakages from terrace & toilet block etc.

Fig. 1 - Spalling of paint

Fig. 2 - Seepage through walls

Fig. 3 - Horizontal cracks on beam

Fig. 4 - cracks on walls

Fig. 5 - Diagonal cracks

Fig. 6 - Hairline cracks

3.7 Identification of critical areas

Based on visual inspection the report should conclude the critical areas that need immediate repairs and retrofitting.

3.8 NDT tests

To perform NDT tests depending upon defects in structure.

3.9 Results

After performing NDT tests obtain the results.

3.10 Discussions & conclusion & preparation of project report

After obtaining the results, we will analyze and final report of the project work will be prepared.

4. EXPERIMENTAL RESULTS & DISCUSSION

4.1 General Information of Building

Table 1 - General Information of Building

Basic Information	
Name of building	Saraswati Complex
Address	Hadapsar, 411028
Building Survey	
Name	Saraswati Complex
Mode of use	Residential

Type of structure	RCC frame structure
No. of stories	4
No. of lifts	1
Previous structural audit	This is first structural audit
Description of building	
Floor height	3 m
External walls	Brick
Internal walls	Brick
Survey	
Mode of survey	Visual inspection using scale & tape
Area Inspected	External building faces, terrace etc.

4.2 Structural Plan

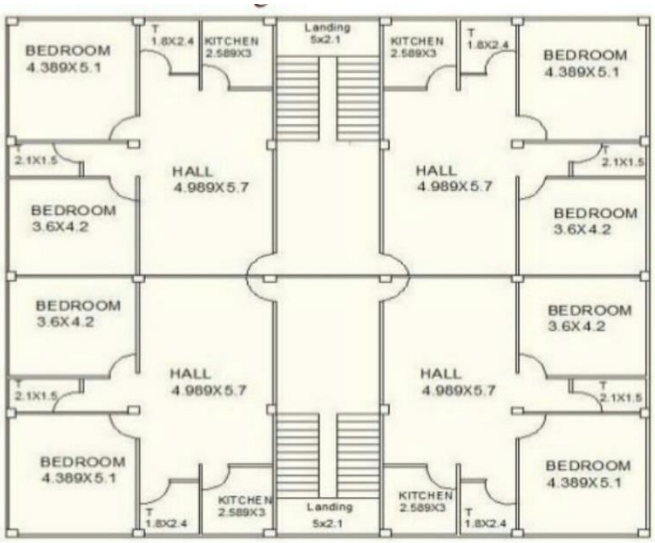

Fig. 7 – Structural plan of building

4.3 Health Rating Index from Visual Inspection

Table 2 - HRI from Visual Inspection

Sr. No.	Description	VB	B	F	G	VG
A	**External Building Faces**					
1	Columns & beams Cracks,bulging,corrosion		4			
2	Drainage & rainwater pipes Leaking, broken				8	
3	Water supply pipes				8	
4	Paint Weathering, fading			6		
B	**Staircase, Lobby & Passage**					
5	Columns, beams, slabs, parapets Cracks, dampness, vegetation				8	
6	Paint Weathering, fading				8	
C	**Terrace**					
7	Terrace slab Seepage into flats below			6		
8	Loading Overloading				8	

Where,

VB: Very Bad - 2

B: Bad - 4

F: Fair - 6

G: Good - 8

VG: Very Good - 10

From visual inspection, the ratings are given as 2, 4, 6, 8 & 10.

Add the scores and divide it by 8 to get Health Rating Index (HRI).

$$HRI = (4+8+8+6+8+8+6+8)/8$$

$$= 56/8$$

$$HRI = 7.0$$

As per visual inspection HRI becomes 7.0 that means condition of building under visual inspection is good.

4.4 Ultrasonic Pulse Velocity Test

Table 3 - UPV Values

Sr. No.	Location			Velocity Km/sec	UPV Method	Quality of concrete
	Member	Location	Position			
1	Column	A10	Top	4.192	Semi-direct	Very Good
2	Column	A10	Bottom	4.151	Semi-direct	Very Good
3	Column	B3	Top	2.929	Direct	Doubtful
4	Column	B3	Bottom	1.807	Direct	Doubtful
5	Column	B7	Middle	2.366	Direct	Doubtful
6	Column	B9	Top	2.283	Direct	Doubtful
7	Column	B9	Bottom	2.327	Direct	Doubtful
	First Slab – Beams					
8	Beam	A3 - B3	North	2.104	Direct	Doubtful
9	Beam	A3 - B3	South	2.460	Direct	Doubtful
10	Beam	A9 - B9	North	2.663	Direct	Doubtful
	First Slabs					
11	Slab	A7, A8, B8	S1	2.752	Indirect	Doubtful
12	Slab	A6, A7, B6	S2	2.657	Indirect	Doubtful

4.5 Rebound Hammer Test

Table 4 - Rebound Hammer Values

Sr. No.	Location			Rebound Value	Quality of Concrete
	Member	Identification Mark	Position		
1	Column	A10	Top	38.00	Good
2	Column	A10	Bottom	33.00	Good
3	Column	B3	Top	25.00	Fair
4	Column	B3	Bottom	21.00	Fair
5	Column	B7	Middle	26.00	Fair
6	Column	B9	Top	29.00	Fair
7	Column	B9	Bottom	28.00	Fair
	First Slab – Beams				
8	Beam	A3 - B3	North	20.00	Fair
9	Beam	A3 - B3	South	25.00	Fair
10	Beam	A9 - B9	North	25.00	Fair
	First Slabs				
11	Slab	A7, A8, B8	S1	29.00	Fair
12	Slab	A6, A7, B6	S2	30.00	Fair

4.6 Core Extraction Test

Table 5 - Core Extraction Test

Sr. No.	Core Mark	Weight of core Kg	Dia of core mm	Ht of core mm	H/D ratio (n)	Correction Factor for dia Cd	Max. load KN	Compressive strength of core N/mm^2	Correction Factor F= 0.11n+0.78	Corrected Cube Strength
1	Column No. A1 Top	1.566	74.53	147.76	1.98	1.08	104.39	23.92	0.998	32.24
2	Column No. A10 Bottom	1.606	74.72	147.77	1.98	1.08	104.56	23.84	0.998	32.11
3	Column No. B3 Top	1.326	74.73	135.07	1.81	1.08	62.41	14.23	0.979	18.81
4	Beam A3B3 North	1.318	74.56	135.98	1.82	1.08	25.75	5.90	0.981	7.81
5	Beam A9B9 North	1.552	74.51	146.42	1.97	1.08	45.19	10.36	0.996	13.94

- As per Is 456 - 2000, average equivalent cube strength of the cores is equal to at least 85% of the cube strength of the grade of concrete specified for the current age and no individual core has a strength less than 75%.
- Conversion factor for cylindrical cube strength is equal to 1.25.

4.7 Carbonation Test

Table 6 - Carbonation Test

Sr. No	Member	Carbonation Present
1	Column No. A1 Top	No
2	Column No. A10 Bottom	No
3	Column No. B3 Top	No
4	Beam A3B3 North	No
5	Beam A9B9 North	No

5. CONCLUSION

According to visual inspection and NDT Tests it is concluded that repairs are required to the building.

- Minor cracks should be repaired by injection of epoxy or by using grouting method.
- Building is suffering from class 3 damage. (Class 3 damage stands for observation like structural cracks, seepage etc.)
- From Health Rating Index, the condition of building is good.
- At the time of performing NDT tests, it is observed that various columns, beams and slabs whose quality and strength is doubtful as shown in table 3 & 4 for such beams, columns and slabs jacketing should be done.
- From core extraction test, it is concluded that strength of concrete is in good condition.
- From carbonation test, it is concluded that building is not suffering from corrosion activity.
- As per specifications proper repairs and retrofitting should be done to maintain the condition of building healthy.

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