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Practical Implementation of Structural Health Monitoring of a Residential Building

Mr. Vikki Roy[1], Ms. Rutuja Mohature[2], Ms. Shubhangi Yawalkar[3], Mr. Rohit Hatwar[4], Prof. Nidhi Jejurikar[5]
[1, 2, 3, 4]UG Scholar,[5]Assistant Professor, Department of Civil Engineering , Wainganga College of Engineering & Management, Nagpur, Maharashtra, India.

Abstract: ***Residential buildings need structural health monitoring to remain healthy and durable. This study focuses on an alternative strategy for SHM relying only on visual inspection, material analysis, and freshly up-to-date constraints coming from aging, environment, and design constraints, without advanced sensor technology. Some of the major types are periodic clothing inspection, non-destructive testing (NDT), etc. The conclusion is that systematic SHM with accompanying manual inspection and computational tools to ensure structural integrity is needed. The approach is validated through case studies of residential buildings to demonstrate its applicability to resource-constrained settings. The results suggest that traditional approaches are not perfect for real-time monitoring but offer essential information on maintenance and mitigation over time. This paper attempts to argue for low-cost, non-sensor-based SHM methods emerge that offer a possible adjunct, long-term sustainable path toward iteratively preserving sufficient safety and resilience of the massive housing stock in the world at large, especially in settings where sophistication in technology is not affordable.***

Keywords: SHM, Residential Building, NDT, Visual Inspections, Structural damage detection, Repair

I. INTRODUCTION

SHM systems provide information about any significant change or damage occurring in a structure. The primary purpose of structural damage detection is to identify the reason, location, and type of damage so as to measure the damage severity and predict the structure's remaining service life. Structural deficiencies causing collapses may result from internal factors, such as corrosion, fatigue, and aging, and external factors, such as earthquakes, wind loads, and impact loads. The damage caused by the above factors may progress very slowly and become observable only when the structure's damage is considerable, and sometimes it is only repairable at a high cost. The detection of structural damage is essential in ensuring structural safety during a structure's lifetime.

The structural damage detection objective is to evaluate the computable and qualitative deterioration of the structural system in service or under a severe load. It is necessary to monitor the location, occurrence, and extent of deterioration from both safety and performance viewpoints. As witnessed by the worldwide development of smart structures and materials, recent advancements in materials and sensing technologies have provided powerful new tools for improving building systems. While many of the structures have existed for decades in their basic form, the intelligence added through the various damage detection methods addresses the practical problems that challenge the effective implementation of active damage control in building structures. SHM has become a primary option for evaluating the overall behavior, preferably from the manufacturing process to the end of its service life.

A. Advantages of SHM

1) Improved understanding of field structural behavior.
2) Detect damages at an early age of problem initiation.
3) Reduced inspection and repairs time.
4) Encourages the use of innovative materials.
5) Minimizes maintenance costs by enabling predictive maintenance.
6) Reduces risks of catastrophic failures and ensures public safety.

B. Purpose of SHM

1) Improve performance (safety and functionality) of existing structures.
2) Structural monitoring and assessment are essential for on-time and cost-effective maintenance. So, it reduces construction work and increases maintenance activities.

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3) The SHM process collects data on the realistic performance of structures. This data can help design better structures in the future.

4) SHM provides real-time or near real-time information about the structural condition, enabling data-driven decision-making for maintenance, repair, and retrofitting.

II. TOOL AND EQUIPMENT

Rebound Hammer

The rebound hammer, also known as the Schmidt hammer, is a non-destructive testing (NDT) device used to assess the compressive strength of concrete. It consists of a spring-loaded hammer that impacts the concrete surface, and the rebound distance of the hammer is measured on a scale to determine the surface hardness. This measurement correlates with the concrete's strength, providing a quick and easy way to estimate its quality. The rebound hammer is commonly used in construction and quality control to evaluate uniformity, detect weak spots, and monitor the concrete's aging process. However, factors such as surface roughness, moisture content, and the type of aggregate can affect the accuracy of the readings, requiring calibration and careful interpretation of results.

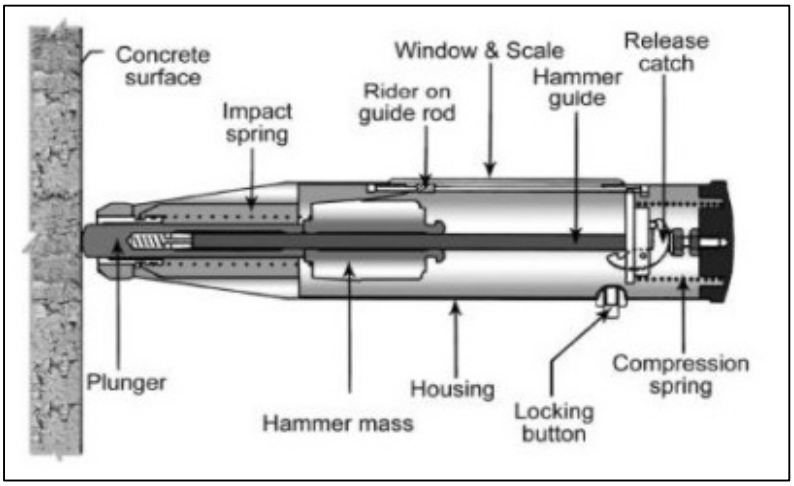


Fig.1) Schematics of Rebound Hammer

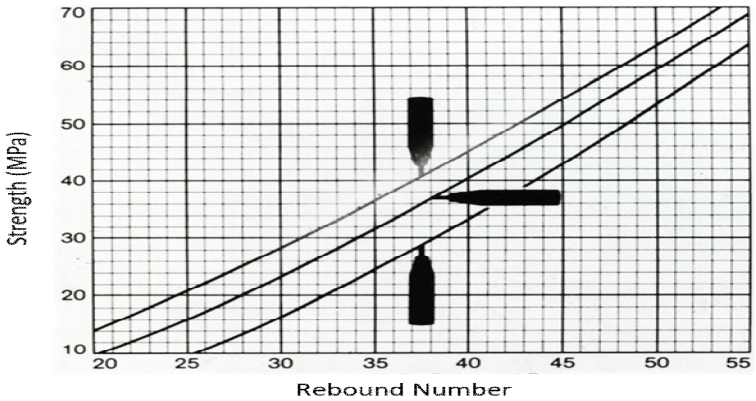


Fig.2) Graph of Average Rebound Number VS Strength (MPa)

III. METHODOLOGY

1) Site Selection:

Selecting a residential building based on parameters such as a) structural type, e.g., concrete or steel b**)** Age and condition of the building.

We have selected a G+3 residential building, having the ground floor and first floor fully functional and well maintained, but the second and third floors left framed after construction of the columns, beams, and slabs.

The age of the building is around 12 years old.

2) Structural Baseline Assessment:

Conduct an initial inspection to identify pre-existing issues (e.g., cracks, deformation).

3) Initial Visual Inspection:

Detected visible defects in structural elements and identified the locations of damages in the structure for detailed monitoring or instrumentation.



Photo 1) Reinforcement came out of concrete



Photo 2) Spalling of concrete from Column

4) Test on the Structure:

Perform various tests on the structure for any damage and defects in the structure, tests including;

Non-Destructive Testing (NDT): NDT methods allow the structural evaluation without damaging the structure .

- Rebound Hammer Testing:

The rebound hammer test assesses the surface strength of the concrete; it evaluates the compressive strength of concrete.

Following are a few images showing the implementation of the rebound hammer test on the surfaces of different structural members of the building for determining the surface strength of concrete.





Photo 3 & 4) Rebound hammer testing on column surfaces

- Corrosion Testing on Concrete: Corrosion testing in concrete structures is critical to ensure the longevity and safety of reinforced structures.

We were decided to perform a carbonation test on concrete with the help of a phenolphthalein indicator for determining the corrosion in the structure, but with thorough visual inspection, we found severe corrosion in the different structural members present due to the harsh environmental conditions. Because the building is exposed freely to the environment.

5) Documentation and Reporting:

- Damage Mapping: Create a damage map highlighting the location and type of damage.
- Photographic Evidence: Capture clear images of damages (with scale markers for reference).

- Measurement Logs: Record crack dimensions (width, length, location) and note any progression signs.
- Severity Classification: Classify damage into categories:
  - Minor
  - Moderate
  - Severe

6) Inspection Report:

Summarize findings in a report, including:

- Observe damages with descriptions.
- Locations and photographs.

7) Suggesting the Treatment :

Suggesting the suitable repairs to the structures according to the severity of the damage in the structure.

IV. RESULT AND DISCUSSION

The following are the observations obtained after the rebound hammer test on different structural members in the building structure.

Table 1. Beam (Horizontal)

Sr.no.	Rebound no.	Average Rebound No.	Strength (MPa)
1	24	215/9 = **23.9**	**14.4 MPa**
2	26		
3	23		
4	24		
5	20		
6	25		
7	26		
8	22		
9	25		

Table 2. Slab-1 (Vertically Downward)

Sr.no.	Rebound no.	Average Rebound No.	Strength (MPa)
1	21	205/9 = **22.8**	**18 MPa**
2	22		
3	24		
4	21		
5	21		
6	24		
7	25		
8	24		
9	25		

Table 3. Slab-2 (Vertically Upward)

Sr.no.	Rebound no.	Average Rebound No.	Strength (MPa)
1	33	298/9 = **33.123**	**21.5 MPa**
2	35		
3	36		
4	32		
5	33		
6	32		
7	31		
8	33		
9	32		

Table 4. Column-1 i.e. Visibly good (Horizontal)

Sr.no.	Rebound no.	Average Rebound No.	Strength (MPa)
1	24	224/9 = **24.9**	**16 MPa**
2	26		
3	25		
4	23		
5	25		
6	26		
7	24		
8	26		
9	25		

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Table 5. Column-2 i.e. Visibly Poor (Horizontal)

Sr.no.	Rebound no.	Average Rebound No.	Strength (MPa)
1	**20**	187/9 = **20.78**	**11 MPa**
2	**19**		
3	**22**		
4	**21**		
5	**22**		
6	**20**		
7	**22**		
8	**20**		
9	**21**		

V. GRAPHICAL REPRESENTATION OF RESULLS

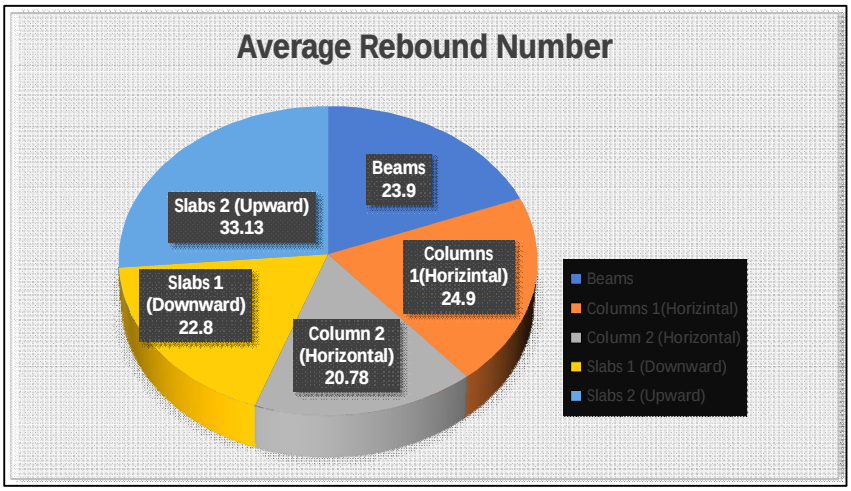


CHART 1. Pie - Chart Showing Average Rebound Number for different Structural Member of Building

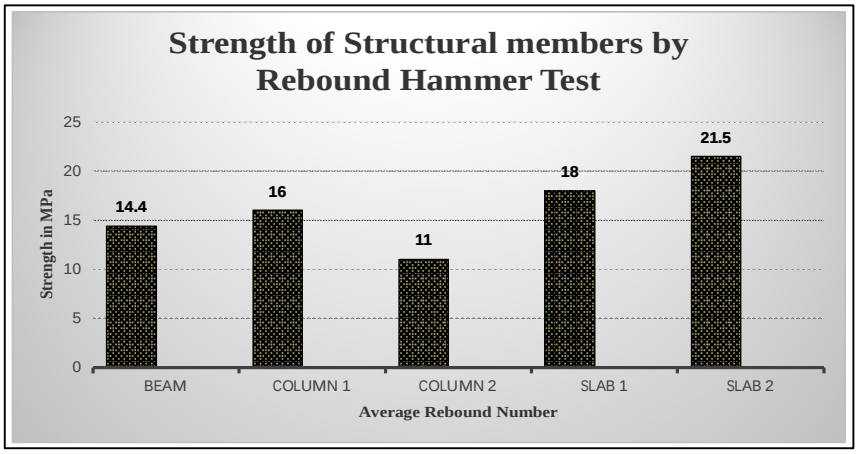


CHART 2. Graph Showing Strength of Structural Members

During the structural health monitoring of the residential building, several key observations were made that indicate signs of distress in the structure.

1) Corrosion in Structural Elements : Corrosion was observed on exposed reinforcement bars in various parts of the structure. This is a serious concern as corrosion leads to the expansion of steel, which causes cracks and weakens the bond between concrete and steel. Over time, this can significantly reduce the load-carrying capacity of the structural elements.
2) Spalling of Concrete from Columns: Spalling of concrete was noted in some of the columns. This typically occurs when the concrete cover is compromised, often due to corrosion of reinforcement. Spalling reduces the cross-sectional area of the columns, which may affect the stability and strength of the building. It also exposes the reinforcement to environmental conditions, further accelerating corrosion.
3) Non-destructive testing using the rebound hammer showed that the strength of the concrete in most structural members ranged from average to moderate. While this suggests that the concrete has not completely deteriorated, it also indicates that the structure is not in optimal condition. Continuous monitoring and possible retrofitting may be necessary to ensure safety and serviceability.

VI. DISCUSSION

The combined effect of corrosion, spalling, honeycombing, and moderate strength indicates a deterioration trend in the structural health of the building. These signs point towards aging and environmental effects on the building materials. Although the structure may still be safe for occupancy, preventive maintenance and localized repairs are recommended. If left unattended, these issues could worsen over time, potentially leading to more serious structural damage or safety hazards.

Regular inspections, especially in high-risk areas, and corrective actions like anti-corrosion treatment, recasting of damaged members, and surface protection can help in extending the life of the building.

VII. CONCLUSIONS

This study emphasizes the importance of structural health monitoring (SHM) systems for infrastructure safety, reliability, and longevity. The structural health monitoring conducted has provided important insights into the current condition of its structural elements. Through visual inspection and non-destructive testing, several signs of deterioration were observed. One of the major concerns is corrosion in the reinforcement. In addition, spalling of concrete was noticed in some of the columns, which may be the result of ongoing corrosion, poor-quality concrete, or environmental exposure.

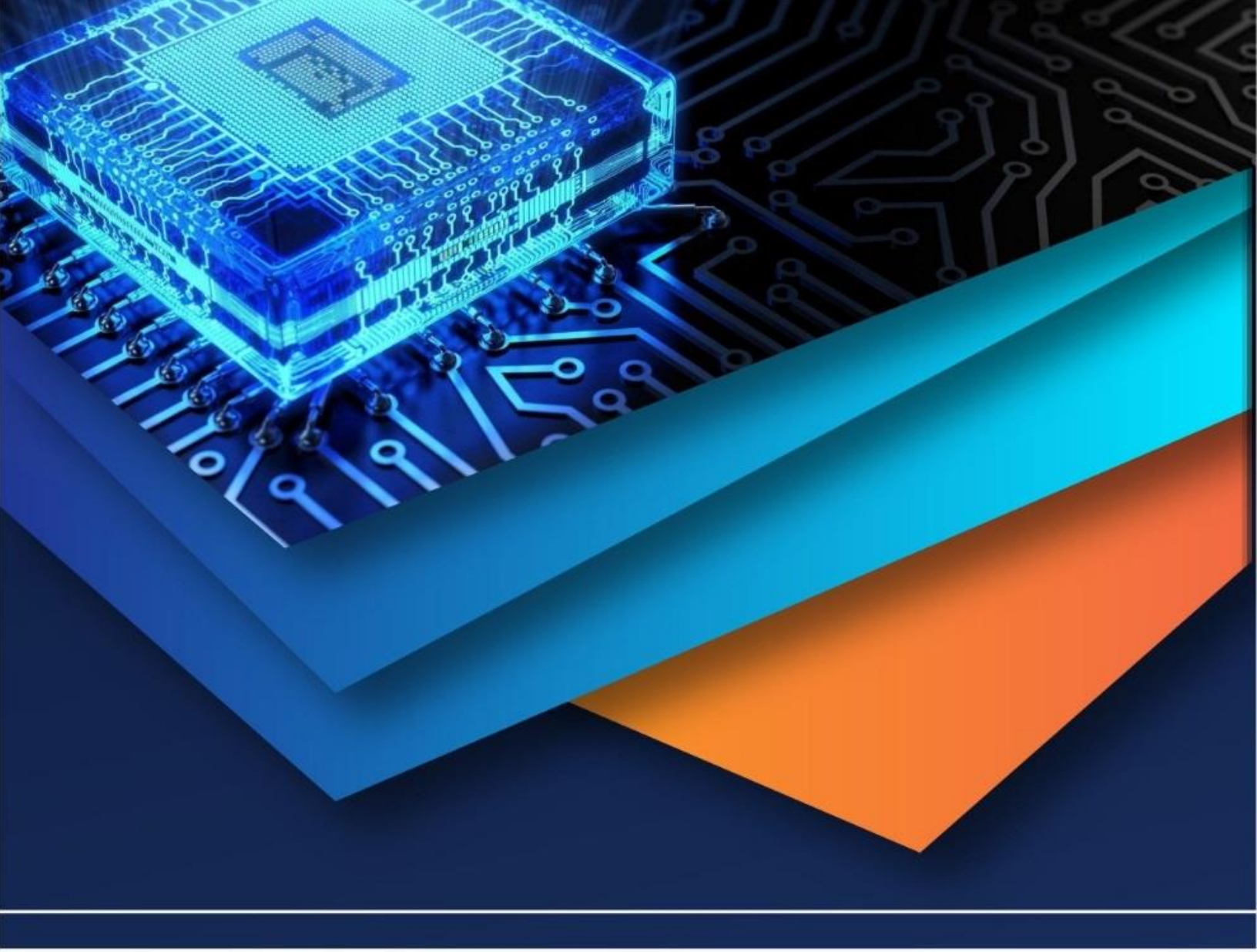
The rebound hammer test results showed that the concrete strength in the structural members is in the average to moderate range. While this does not indicate an immediate risk of failure, it suggests that the structure may not perform well under extreme loading conditions such as earthquakes or additional loads beyond its original design.

Based on these observations, it is recommended that maintenance and repair measures be taken immediately, especially in areas showing visible damage and corrosion. Further detailed assessment, such as core testing or ultrasonic pulse velocity, may also be beneficial to gain a more accurate understanding of the structural integrity. Regular monitoring should continue to ensure the safety and durability of the building.

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