Journals Pub

International Journal of
Geological and Geotechnical Engineering

ISSN: 2581-5598
Volume 10, Issue 1, 2024
DOI (Journal): 10.37628/IJGGE

https://journalspub.com/journal/ijgge/

Case Study IJGGE

Structural Audit and Health Assessment of RCC Structure: A Case Study

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Abstract

In India, where rapid urbanization and seismic risks are prevalent, ensuring the safety and longevity of structures is paramount. Structural audits and health assessments of reinforced concrete cement (R.C.C.) buildings are mandated by municipal authorities to evaluate their integrity. The objective is to extend the lifespan of structures while mitigating risks to human life and neighboring buildings. Non-destructive testing (NDT) methods, including the rebound hammer test and ultrasonic pulse velocity test, are widely used for detailed evaluations. These techniques enable extensive assessments without harming the inspected structure. This study not only highlights the importance of structural audits in identifying weaknesses but also performing the structural health monitoring of RCC building.

Keywords: Structural health assessment, R.C.C. building, seismic risks, non-destructive testing

INTRODUCTION

Assessing structural integrity is essential in civil engineering to guarantee the safety and durability of concrete structures. As these structures age, evaluating their condition becomes paramount to mitigate risks and prioritize maintenance efforts. Traditional structural auditing combines destructive and non-destructive testing methods, but advancements in non-destructive testing (NDT) techniques offer more efficient and comprehensive evaluations without causing damage. This paper explores the evolving landscape of structural auditing, emphasizing the integration of advanced NDT methods and structural health monitoring (SHM) strategies. By examining principles and applications of NDT techniques like ultrasonic pulse velocity tests and rebound hammer tests, it aims to enhance assessment accuracy and efficiency. Additionally, the importance of real-time damage identification through SHM is addressed, emphasizing proactive maintenance for aging infrastructure. Through synthesis of literature and case studies, this study advocates for integrating advanced NDT and SHM approaches to improve safety and sustainability in civil engineering.

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Received Date: May 23, 2024
Accepted Date: June 06, 2024
Published Date: July 07, 2024

Citation: Sanket Kathane, Himanshu Gajbhiye, Jay Dhote, Bhushan Sathwane, Dhiraj Lonare, Nina R. Dhamge. Structural Audit and Health Assessment of RCC Structure: A Case Study. International Journal of Geological and Geotechnical Engineering. 2024; 10(1): 1–7p.

Structural health monitoring (SHM) is an essential discipline that significantly contributes to maintaining the safety, integrity, and durability of structures. By continuously monitoring the behavior and condition of structures, SHM enables early detection of damage, defects, or degradation, allowing for timely intervention and maintenance. The main objective of SHM is to provide accurate and reliable information about the structural health status, enabling engineers and stakeholders to make informed decisions regarding maintenance, repair, or retrofitting.

It encompasses the integration of diverse sensing technologies, data acquisition systems, and analytical tools to continuously monitor and evaluate the performance of structures. SHM has several key benefits. Firstly, it enhances safety by identifying and mitigating potential risks, reducing the probability of structural failure, and protecting human life. Secondly, it optimizes maintenance and repair strategies by enabling condition-based and proactive maintenance, minimizing downtime, and reducing overall costs.

LITERATURE REVIEW

The literature review on the structural audit and health assessment of RCC buildings provides a comprehensive understanding of the current state of research, methodologies, and findings in this field. By synthesizing existing knowledge and identifying gaps in research, the literature review serves as a foundation for further investigation and development of effective approaches to ensure the safety and longevity of reinforced concrete structure. Charles Charles R Farraret al. [1] carried out damage identification in conjunction with five closely related disciplines prognosis. John T. Petro et al. [2] performed experimental study to evaluate delamination in concrete using ultrasonic pulse velocity test.

Two slab specimens with dimensions of 150 mm by 300 mm in thickness, each containing delamination's of varying sizes, are used for the tests. Suryawanshi Sanket Sanjay et al. [3] concluded that structural members or components are suffering from class 3 damage. According to the Central Public Works Department (CPWD), class 3 damage includes observations, such as spalling of the concrete cover and structural cracks, indicating the need for principal repairs. Kamal Kant Jain et al. [4] characterized working details of visually inspect, tools to carry out visual inspection and various process which are involved in the visual inspection they provide guidelines about performing the visual inspection work. This paper primarily discusses the defects occurring in earthquake-prone zones and provides detailed insights into these issues. Douglas E. Ellsworth et al. [5] confirmed that increasing the bearing capacity of strengthened reinforced concrete (R/C) frames can be achieved by introducing epoxy sealant grouting to fill selected bays for rehabilitating damaged building elements. Maria Valeria Piras et al. [6] outlined the parameters used for visual inspection. Visual inspection is carried out using the expertise of the engineer and informed by various research articles published in the field of structural building auditing. The visual inspection process begins with the evaluation of cracks, spalling on the surface of walls, columns, slabs, and all other structural and non-structural components of the building. It also involves measuring the moisture content on walls and other elements. During the visual inspection, potential causes of the observed issues are also documented. Malcolm k. Lim, Hanggang Cao [7] this provided insight into the different test methods and provided case history whereby combining different non-destructive test methods were used in the evaluation. Mr. Jolly [8] reviewed various non-destructive testing (NDT) techniques and compared their characteristics and applicability to composite materials. The review provided an overview of several NDT methods, including ultrasonic testing, thermography, and radiography. Although CT equipment is significantly more expensive than UT and thermography equipment, it is a proven system with high reliability and superior traceability. Experimental results demonstrated that delamination can be clearly detected using CT, making it the preferred technique for analyzing thick-walled composite components. Eiichi Sato and Mitsuhiro Shiwa [9] devised flaws, thereby validating the newly developed technique. This approach has been formalized as JIS Z 2356, titled "Method of Automatic Ultrasonic Inspection for Graphite Ingot." Gabriel Dan et al. [10] introduced a non-destructive evaluation process designed to detect cracks and delamination beneath the surface in titanium parts, especially those with complex shapes. The ultrasonic data provide deeper insights into the failure mechanisms of this material.

STRUCTURAL HEALTH MONITORING

Implementing a damage identification strategy for mechanical, civil, and aerospace engineering infrastructure is called structural health monitoring (SHM). Damage is defined in this context as modifications to the structural and/or these systems' geometric properties, such as altered boundary conditions and system connectivity, have an adverse effect on the system's performance. For such monitoring, a wide range of highly efficient local non-destructive evaluation tools are available.

However, the majority of SHM research done over the past 30 years has sought to identify structural damage more broadly. Research on SHM has grown significantly over the past ten years, as evidenced by the significant rise in papers published on the topic. The demand for this theme issue has been driven by the growing interest in SHM and its potential to have significant positive effects on both life safety and the economy. SHM has several key benefits. Firstly, it enhances safety by identifying failure and gating potential risks, reducing the probability of structural failure, and protecting human life. Secondly, it optimizes maintenance and repair strategies by enabling condition-based and proactive maintenance, minimizing downtime, and reducing overall costs.

NON-DESTRUCTIVE TESTING (NDT)

NDT's primary objective is to find flaws, irregularities, or structural changes in a component or material that could compromise its functionality or safety. NDT is a crucial tool for ensuring the safety, reliability, and longevity of equipment and structures, and its importance will continue to grow as industries demand higher levels of performance and safety.

Non-destructive testing (NDT) techniques, including the rebound hammer test and ultrasonic pulse velocity test, are commonly employed for thorough evaluations.

The ultrasonic pulse velocity (UPV) test, according to IS 13311 (Part 1) 1992, measures the time taken for the initial part of an ultrasonic pulse to travel from a point on the material's surface to a receiving transducer. Figure 1 illustrates the ultrasonic pulse velocity test (Table 1).

The Rebound Hammer Test (RHT), in accordance with IS 13311 Part II, utilizes the Schmidt rebound hammer as a surface hardness tester. The rebound and surface hardness are considered indicative of the compressive strength of concrete. The rebound number is read along a graduated scale and serves as a measure of the rebound. Figure 2 depicts the rebound hammer test (Table 2).

Table 1. Ultrasonic pulse velocity.

S.N.	UPV (km/sec.)	Quality of Concrete
1	Above 4.5	Excellent
2	3.5 to 4.5	good
3	3 to 3.5	medium
4	Below 3 m/sec	Doubtful

Figure 1. Ultra sonic pulse velocity test (upv).

Table 2. Rebound hammer.

S.N.	Average Rebound	Quality of Concrete
1	>40	Very good
2	30-40	Good
3	20-30	Fair
4	<20	Poor

Half-Cell Test (is 13311 (part II) 1992)

This test is used to determine the condition of reinforcement from structural element. The device evaluates both the potential and electrical resistance between the reinforcement and the surface to analyze corrosion activity and determine the current condition of the cover layer during testing (Figure 3).

Figure 2. Rebound hammer test (RHT).

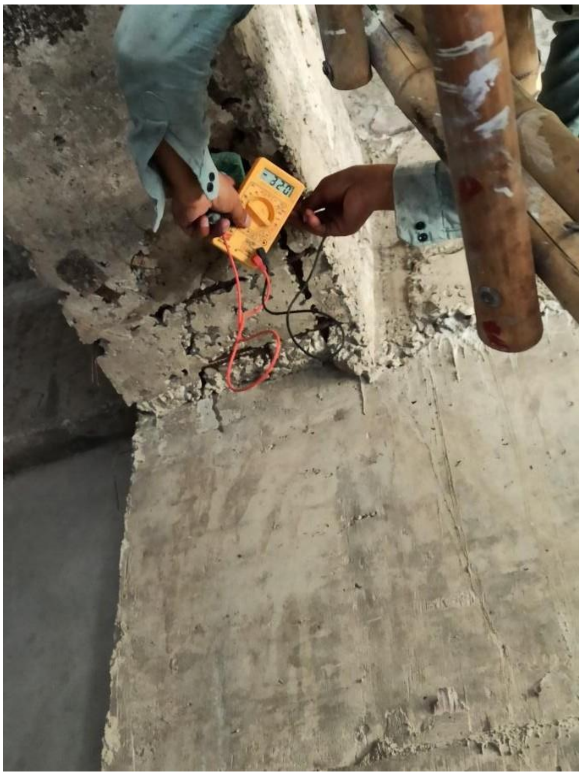

Figure 3. Half-cell test.

TESTING RESULT AND DISCUSSION

Ultrasonic Pulse Velocity Test Result

Table 3 shows readings of the UPV test conducted on a RCC structure.

The ultrasonic pulse velocity results with direct, indirect and semi-direct method indicate that out of total number of UPV 384 points, 1.04 % readings are excellent, 36.20% readings are good, 53.91% readings are medium, 8.85% readings are doubtful. According to IS 13311 (Part 1) 1992, "Non-destructive testing of concrete - Methods of test - Ultrasonic pulse velocity," the ultrasonic pulse velocity readings obtained through the indirect method typically yield lower values compared to direct methods, usually by approximately 1 unit. km/sec and readings given in the report are factored.

Table 3. UPV Test results.

S.N.	Description	Type of Test	Transit Time in Microseconds (t)	Path Length (l) (mm)	Velocity v=(l/t) (in km/sec)	Factored Value of UPV (km/sec)	Quality of Concrete
Ground floor							
1	Column c – 59 ground floor	Indirect	123.8	200	1.62	2.62	Doubtful
		Indirect	116.3	200	1.72	2.72	Doubtful
		Indirect	89.6	200	2.23	3.23	Medium
		Indirect	98.3	200	2.03	3.03	Medium
		Indirect	73.5	200	2.72	3.72	Good
		Indirect	79.6	200	2.51	3.51	Good
2	Column c – 54 ground floor	Indirect	98.6	200	2.03	3.03	Medium
		Indirect	94.4	200	2.12	3.12	Medium
		Indirect	90.1	200	2.22	3.22	Medium
		Indirect	93.2	200	2.15	3.15	Medium
		Indirect	84.6	200	2.36	3.36	Medium
		Indirect	87.6	200	2.28	3.28	Medium
3	Column c – 57 ground floor	Indirect	89.4	200	2.24	3.24	Medium
		Indirect	92.6	200	2.16	3.16	Medium
		Indirect	76.3	200	2.62	3.62	Good
		Indirect	88.5	200	2.26	3.26	Medium
		Indirect	79.6	200	2.51	3.51	Good
		Indirect	91.6	200	2.18	3.18	Medium

Rebound Hammer Test Results

Table 4 shows the readings of rebound hammer test. From rebound hammer rebound numbers can be calculated, taking average of all number’s strength can be calculated from the graph given in is code. As per the rebound hammer test reading maximum readings are confirming to m21 to m59 grade of concrete.

Table 4. Rebound number test result.

S.N.	Particulars	Rebound No.	Average	Probable Compressive Strength (n/mm^2)
Ground floor				
1	Column c - 59	42,48,46,44,40,42	43.67	51.00
2	Column c - 54	44,40,42,40,44,36	41.00	46.00
3	Column c - 57	42,44,40,38,34,38	39.33	43.00
4	Column c - 9	46,42,46,44,42,42	43.67	51.00
5	Column c - 32	46,46,44,48,46,46	46.00	55.00
6	Column c - 27	44,46,46,46,44,48	45.67	55.00
7	Column c - 32	46,38,42,44,42,44	42.67	49.00

Half-cell Test Results

Table 5 represents the reading of half-cell potentiometer test. As per half- cell potentiometer test results maximum readings are in between --254 and --372 which indicates that there is severe corrosion found at most of the location.

pH Test and Chemical Analysis Test Result

Table 6 represents the reading of potential mv, pH, chloride content in ppm, sulphate content in ppm and depth of carbonation (mm). Based on the pH and carbonation test results conducted on concrete, it is noted that the pH of the concrete cover has decreased, while the passive layer over the reinforcement remains intact. Additionally, the pH of the core concrete falls well within the acceptable limits. The carbonation depth has not crossed the reinforcement level at maximum locations. As per chemical analysis of concrete, chloride & sulphate attack has not been observed and well within the acceptable limits.

Table 5. Half-cell potentiometer test result.

S.N.	Particulars	Half Cell
1	Lower ground floor column-05	-343
		-348
		-317
		-312
		-272
		-289
2	Lower ground floor column-06	-332
		-317
		-289
		-288
		-312
		-317

Table 6. pH Test and Chemical Analysis Test Result.

S.N.	Particulars	Potential mv		Ph	Chloride Content in Ppm	Sulphate Content in Ppm	Depth of Carbonation (mm)
		40mm	*80mm*				
Ground floor							
1	Column c - 57	-110	-122	10.25 to 11.04	280	400	Less than 20 mm
2	Column c - 9	-107	-126	10.09 to 11.10	250	450	Less than 15 mm
3	Column c - 32	-137	-140	10.14 to 11.15	270	410	Less than 25 mm
4	Column c - 27	-156	-142	10.00 to 11.07	320	430	Less than 19 mm

CONCLUSION

Non-destructive test is a crucial tool for guaranteeing the dependability and integrity of equipment and structures in numerous industries, including aerospace, automotive, building, manufacturing, and many others. Each Non-destructive test technique has its strengths and limitations and can be used for different types of materials and applications. Based on the results of all non-destructive tests, it is advised to address damaged areas according to their specific locations. Carbonation is detected on multiple columns, with a reduction in the pH of the concrete cover and the absence of an intact passive layer over the reinforcement observed. Half-cell potentiometer testing was conducted to assess potential corrosion in the reinforcement, revealing severe corrosion in numerous column locations.

REFERENCES

1. Lim MK, Cao H. Combining multiple NDT methods to improve testing effectiveness. 2013 [cited 2024 Jun 4]. Available from: https://www.infona.pl/resource/bwmeta1.element.elsevier-c6eddc61-ee9a-35f7-9205-9f9fe6d532d5
2. Jolly R, Prabhakar A, Sturzu B, Hollstein K, Singh R, Thomas S, Foote P, Shaw A. Review of non-

destructive testing (NDT) techniques and their applicability to thick, walled composites. 2015 [cited 2024 Jun 4]. Available from: https://pdf.sciencedirectassets.com/282173/1-s2.0-s2212827115x0014x/1-s2.0-s2212827115008021/main.pdf?x-amz-security-

3. Sato E, Mitsuhara S, Shiwa M, Nagawa O, Takakashiida O. Ultrasonic testing method for detection of planar flaws in graphite material. 2007 [cited 2024 Jun 4]. Available from: https://www.researchgate.net/publication/250155660_ultrasonic_testing_method_for_detection_of_planar_flaws_in_graphite_material
4. Dan G, Amza G. Research regarding ultrasonic examination of complex parts. 2012 [cited 2024 Jun 4]. Available from: https://www.scientificbulletin.upb.ro/rev_docs_arhiva/full53f_604990.pdf
5. Mandal T, Tinjum JM, Edil TB. Non-destructive testing of cementitiously stabilized materials using ultrasonic pulse velocity test. 2015 [cited 2024 Jun 4]. Available from: https://www.researchgate.net/publication/282433514_non-destructive_testing_of_cementitiously_stabilized_materials_using_ultrasonic_pulse_velocity_test
6. Tschelisnig P. Acoustic emission testing (AET) an integral non-destructive testing method. Int J Mater Prod Technol. 2001;3(3/4):267–275. Available from: https://www.inderscienceonline.com/doi/abs/10.1504/IJMPT.1988.036708
7. Crostack HA, Reimers W. Evaluation of component integrity by nondestructive testing. Int J Mater Prod Technol. 2001;3(2):147–162. Available from: https://www.sciencedirect.com/science/article/abs/pii/S2214785317328936
8. Zahran OS, Shihab S, Al-Nuaimy W. Recent developments in ultrasonic techniques for rail track inspection. NDT 2002, Southport, The British Institute of NDT. 2002 [cited 2024 Jun 4]. Available from: https://www.researchgate.net/publication/275656546_Recent_Developments_in_Ultrasonic_Techniques_for_Rail-track_Inspection.
9. Mori K, Spagnoli A, Murakami Y, Kondo G, Torigoe I. A new non-contacting non-destructive testing method for defect detection in concrete. NDT E Int. 2002 Sep;35(6):399–406. Available from: https://www.sciencedirect.com/science/article/abs/pii/S0963869502000099
10. IS 13311-1(1992): Method of non-destructive testing of concrete, Part 1: Ultrasonic pulse velocity [CED 2: Cement and Concrete]. 1992 [cited 2024 Jun 4]. Available from: https://law.resource.org/pub/in/bis/S03/is.13311.1.1992.pdf

