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Study and Evaluation of Conditional Assessment of RCC Structures for Repair and Retrofitting Using NDT Modules

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Abstract - The structural integrity of Reinforced Cement Concrete (RCC) structures is crucial for ensuring long-term safety and performance in both residential and industrial applications. Over time, these structures are subjected to various environmental stresses and loadings that can lead to deterioration, compromising their safety and functionality. The conditional assessment of RCC structures plays a pivotal role in evaluating the extent of damage and determining the need for repair and retrofitting interventions. This study focuses on the evolution and advancements in Non-Destructive Testing (NDT) techniques used for assessing the condition of RCC structures. NDT methods, such as ultrasonic pulse velocity (UPV), and Rebound Hammer, provide essential data for evaluating concrete quality, detecting cracks, corrosion, and identifying hidden defects without causing damage to the structure.
The research explores how the integration of various NDT techniques has improved the accuracy and reliability of condition assessments, enabling better decision-making in repair and retrofitting strategies. By analysing case studies and experimental data, this paper examines the effectiveness of different NDT modules in diagnosing structural issues and the evolution of assessment methodologies in response to emerging challenges in civil engineering.
Ultimately, the findings of this study aim to highlight the importance of continuous monitoring and technological advancement in the field of RCC structural assessment, providing insights for engineers and researchers focused on improving the longevity and safety of civil infrastructure.

***Key Words**: Environmental Stresses, Assessments, Decision Making, Enabling, Corrosion, Longevity, Diagnosing, Retrofitting.*

1. Introduction

Every structure is important for any purpose in daily life. After using of the structure, some days it is subjected to several damages and various repairs. So, the main important of using these methods to improve the strength and durability and to make an impervious layer to the reinforced concrete structures to avoid the repairs. Now a days this importance is going to increase worldwide. The results are also good and acceptable for the reinforced concrete structures. In this project explains the importance of rehabilitation and also explains about some important retrofitting methods for the reinforced concrete structures. In this one thing is clearly understand about concrete is a universal material used for construction in reinforced concrete structures. day by day the usage of concrete in reinforced structures are increases. The main important thing we can understand about concrete is it is not a maintenance free material. so, the concrete structures are requiring regular inspections and maintenances to achieving more life span to the structures. In this project we are discussing Two different types of Structures like Building and Elevated Service Reservoir (ESR).

1.1. Building:

An existing building is a structure that is already constructed and in use, and understanding its details is crucial for various purposes, including energy efficiency, maintenance, and potential upgrades. Building is a structure, including a building, structure, or dwelling, that is physically present and ready for occupancy. These buildings serve various societal needs, providing shelter, security, living space, privacy, and storage. They can be categorized based on their usage, such as residential, commercial, or industrial.

Figure 1.1: *Building*

1.2. Elevated Service Reservoir (ESR):

An Elevated Service Reservoir (ESR) is a water storage structure constructed above ground level to store treated water and maintain pressure in a municipal or industrial water distribution system. Elevated to a certain height, these reservoirs use gravitational force to supply water at consistent pressure, even during peak demand periods or pump shutdowns. ESRs are critical in ensuring equitable distribution, emergency storage, and operational flexibility in water supply systems.

In India more than 68% of its total population lives in rural area. Domestic water is a major problem in these areas, so as to solve this problem innovative design and strategies and solution to existing problem is essential, hence for that study of Elevated Storage Reservoir (ESR) is undertaking. There are so

many case studies and report on failure during and post construction of ESR in recent years. R.C.C storage tanks used for small, medium and large capacity of storage. Large capacity storage tanks are also known as storage reservoir.

Figure 1.2: *Elevated Service Reservoir (ESR)*

2. Objectives

Aim: Study and Evaluation of Repair, Retrofitting and Rehabilitation Techniques for Strengthening of Various Existing Reinforced Concrete Structure.

- To perform nondestructive tests on the distressed building and ESR.
- To identify the need of retrofitting.
- To identify the problems of given structures with the help of N.D.T Techniques.
- To ascertain the structural soundness of the existing reinforced concrete administration building for the proposed additional floor by nondestructive testing/evaluation.
- To recommend suitable restoration / remedial measures for distressed and deficient individual reinforced concrete elements based on extent and amount of distress.

3. Methodology

3.1. Literature Review

• Conduct an extensive review of previous studies, standards, and guidelines related to:
• RCC (Reinforced Cement Concrete) structure deterioration.
• Non-Destructive Testing (NDT) techniques for condition assessment.
• Repair and retrofitting methodologies.
• Identify gaps in current practices and establish the need for the present study.

3.2. Selection of Study Area / Structure

• Select existing RCC structures (buildings, bridges, etc.) that show visible signs of deterioration or have crossed their intended service life:
• Collect basic data.
• Age of structure.
• Structural drawings (if available).
• History of usage and maintenance.

3.3. Preliminary Visual Inspection

• Conduct visual surveys to:
• Identify distress symptoms (cracks, corrosion, spalling, deflection, discoloration).
• Document damages using photography and mapping.

3.4. Selection of NDT Techniques

• Choose appropriate NDT methods based on structure type and observed damages:
• Rebound Hammer Test (for surface hardness & compressive strength estimation).
• Ultrasonic Pulse Velocity Test (for internal flaws/crack detection).
• Carbonation Test (for assessing concrete durability).
• Chloride Contain (to determine the amount of chloride ions present)

3.5. Conducting NDT Tests

• Perform selected NDT Test on-site following standard procedures (ASTM/IS codes).
• Record and tabulate the data for all test points.
• Ensure tests are repeated at different locations to improve reliability.

3.6. Data Analysis and Interpretation

• Analyze test results to:
• Locate weak zones and extent of damage.
• Determine level of corrosion activity.
• Categorize structural components based on severity of damage (e.g., minor, moderate, major).

3.7. Condition Assessment Grading

• Based on NDT results, visual inspection and chemical test results grade the structural condition (e.g., Excellent, Good, Fair, Poor, Critical).
• Use a scoring or rating system for consistency.

3.8. Formulating Repair and Retrofitting Strategies

• Propose suitable repair/retrofitting techniques depending on the level of deterioration:
• Surface repairs (patching, crack filling).
• Structural strengthening (jacketing, FRP wrapping, steel plate bonding).

3.9. Validation / Recommendations

• If possible, validate findings by comparing with core test results or structural load tests.
• Suggest a monitoring plan post-repair for ensuring performance.
• Recommend a maintenance schedule based on the residual life estimation.

3.10. Documentation and Reporting

• Compile a detailed technical report summarizing:
• Structure background.
• Inspection and testing procedures.
• Observations, test results, interpretation.
• Proposed repair and retrofitting strategies.
• Provide drawings/photos/maps as annexures for better understanding.

4. Instrumentation

This study adopts a systematic approach to assess the condition of Reinforced Cement Concrete (RCC) structures using Non-Destructive Testing (NDT) methods.
Here are some Physical and Chemical Testing are as follow:

4.1 Physical Testing

4.1.1. Visual Inspection:

Visual inspection and Non-Destructive Testing (NDT) are crucial for assessing the condition of Reinforced Concrete (RCC) structures, enabling informed decisions about repair and retrofitting. Visual inspection identifies surface defects, while NDT provides deeper insights into structural integrity. This combined approach helps determine the extent and nature of damage, leading to effective rehabilitation strategies.

Fig 4.1. Corrosion of Concrete

Fig 4.2. Rusting of Concrete

4.1.2. Rebound Hammer Testing:

Rebound Hammer test is a Non-destructive testing method of concrete which provide a convenient and rapid indication of the compressive strength of the concrete. The rebound hammer is also called as Schmidt hammer that consist of a spring-controlled mass that slides on a plunger within a tubular housing. The operation of rebound hammer is shown in the fig. 4.1

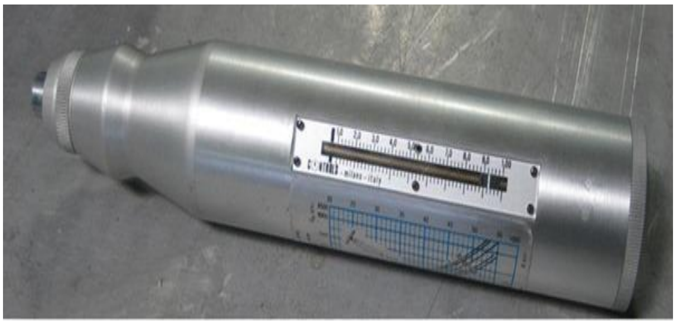

Fig 4.3. Rebound Hammer Test

4.1.3. Ultrasonic Pulse Velocity Test:

Ultrasonic pulse velocity test is an in-situ, non-destructive test to check the quality of concrete and natural rocks. In this test, the strength and quality of concrete or rock is assessed by measuring the velocity of an ultrasonic pulse passing through a concrete structure or natural rock formation.
This test is conducted by passing a pulse of ultrasonic through concrete to be tested and measuring the time taken by pulse to get through the structure. Higher quality indicated good quality and continuity of materials, while slower velocities may indicate concrete with many cracks or voids.

Fig 4.4. Ultrasonic Pulse Velocity

4.2. Chemical Testing

4.2.1. Carbonation:

A carbonation test determines the depth of carbonation in concrete, a process where atmospheric carbon dioxide reacts with concrete, reducing its pH and potentially causing corrosion of steel reinforcement. The test typically involves spraying a phenolphthalein indicator solution on a freshly exposed concrete surface, which turns pink in areas where the pH is above 8.6, indicating the presence of uncarbonated concrete.

Fig 4.5. Carbonation

4.2.2. Chloride Contain:

Chloride (Cl-) is a negatively charged ion formed when chlorine gains an electron. It is a crucial electrolyte, essential for maintaining fluid balance, pH levels, and nerve and muscle function. Chloride is primarily found in salt (sodium chloride, NaCl), and it's also present in various foods like vegetables and seaweed.

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4.2.3. pH Test:

A pH test strip is a strip of litmus paper with which you can measure the pH value of a liquid. The substance in the paper causes the paper to show a different color at different acidities. The official pH scale is from 0 to 14, where 0 is very acidic and 14 is very alkaline.

Fig 4.6. pH Meter

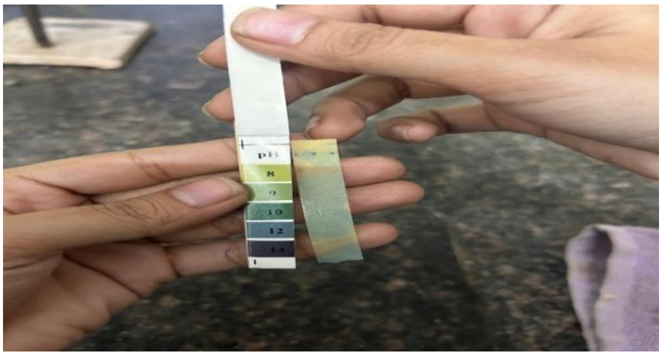


Fig 4.6. Litmus Paper

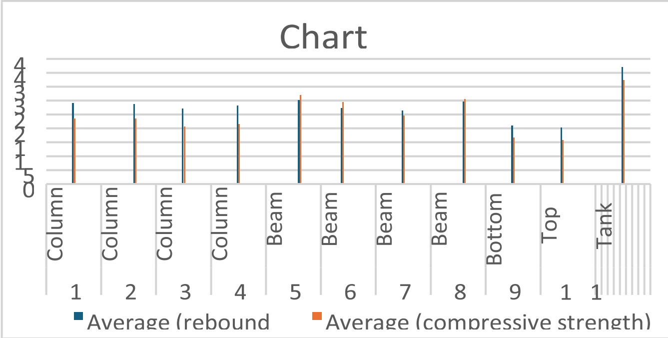
5. Results

5.1 General:

ESR is a Elevated Service Reservoir used to store water. It is located at Takali Jahangir village. It is constructed by local authority in 2000. It is used to supply water in the village.

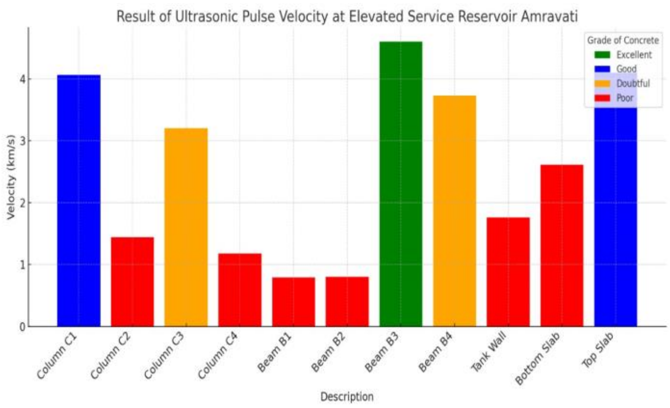
5.1.1. Rebound hammer test situated at Elevated Service Reservoir, Amravati.

Sr. No.	Description	Average (Rebound Number)	Average (Compressive Strength) N/mm2
1	Column C1	29	23.53
2	Column C2	28.7	23.53
3	Column C3	27.1	20.59
4	Column C4	28.2	21.57
5	Column C5	30.2	31.88
6	Column C6	27.3	29.49
7	Column C7	26.3	24.51
8	Column C8	29.6	30.4
9	Column C9	21	16.67
10	Column C10	20.2	15.69
11	Column C11	42	37.26



5.1.2. Result of Ultrasonic Pulse Velocity at Elevated Service Reservoir Amravati

Sr. No.	Description	Velocity	Grade of Concrete
1	Column C1	4.06	Good
2	Column C2	1.44	Poor
3	Column C3	3.2	Doubtful
4	Column C4	1.18	Poor
5	Beam B1	0.79	Poor
6	Beam B2	0.8	Poor
7	Beam B3	4.6	Excellent
8	Beam B4	3.73	Doubtful
9	Tank Wall	1.76	Poor
10	Bottom Slab	2.61	Poor
11	Top Slab	4.10	Good



5.1.3. Combine condition index result

Sr. No.	Description	Combined Conditional Index	Condition of Member
1	Column C1	0.817	Good
2	Column C2	0.522	Fair
3	Column C3	0.702	Fair
4	Column C4	0.486	Poor
5	Beam B1	0.467	Poor
6	Beam B2	0.432	Poor
7	Beam B3	0.851	Good
8	Beam B4	0.793	Good
9	Tank Wall	0.462	Poor
10	Bottom Slab	0.594	Fair
11	Top Slab	0.99	Excellent

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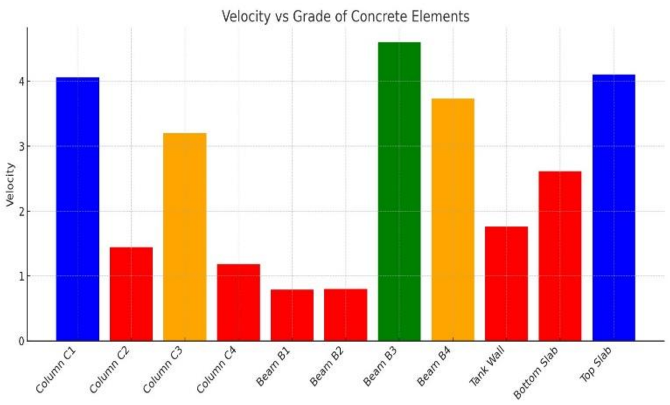
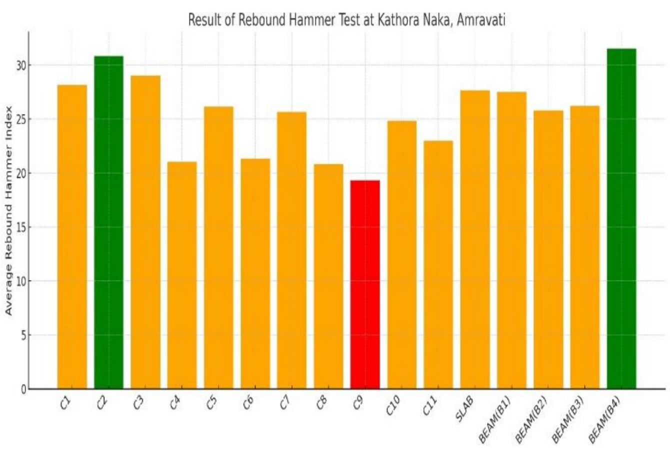


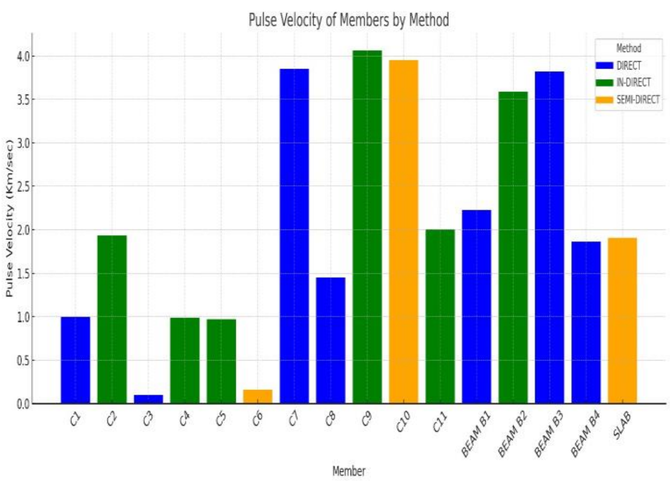
5.1.5. Result of rebound hammer test situated at kathora Naka, Amravati.

Sr. No	Location	Average Rebound Hammer Index	Mean Compres-sive Strength N/mm2	Quality of Concrete
1	Column C1	28.17	20	Fair
2	Column C2	30.83	25	Good Layer
3	Column C3	29.00	22	Fair
4	Column C4	21.00	11	Fair
5	Column C5	26.17	18	Fair
6	Column C6	21.33	11	Fair
7	Column C7	25.67	17	Fair
8	Column C8	20.83	11	Fair
9	Column C9	19.33	Below 10	Poor
10	Column C10	24.83	16	Fair
11	Column C11	23.00	14	Fair
12	Slab	27.67	20	Fair
13	Beam B1	27.50	20	Fair
14	Beam B2	25.80	17	Fair
15	Beam B3	26.23	18	Fair
16	Beam B4	31.50	27	Good Layer



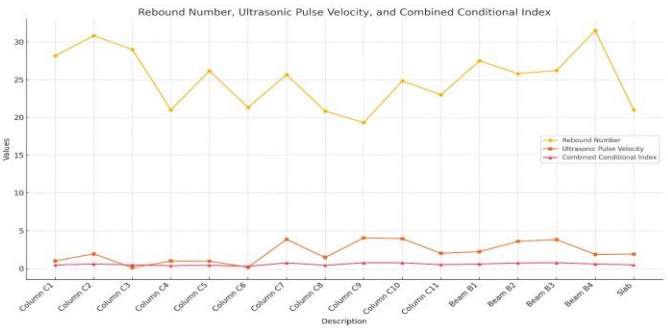
5.1.6. Result of Ultrasonic Pulse Velocity at Location Situated at Kathora Naka Site, Amravati.

Sr. No.	Member	UPV	Quality of Concrete
1	Column C1	1.001	Poor
2	Column C2	1.934	Poor
3	Column C3	0.1028	Doubtful
4	Column C4	0.991	Doubtful
5	Column C5	0.973	Doubtful
6	Column C6	0.163	Doubtful
7	Column C7	3.85	Good
8	Column C8	1.45	Poor
9	Column C10	4.06	Good
10	Column C11	3.95	Good
11	Column C12	2.006	Poor
12	Beam 1	2.23	Poor
13	Beam 2	3.59	Good
14	Beam 3	3.82	Good
15	Beam 4	1.86	Doubtful
16	Slab	1.908	Doubtful



5.1.7. Combine condition index result

Sr. No	Description	Combined Conditional Index	Condition of Member
1	Column C1	0.46	Poor
2	Column C1	0.60	Fair
3	Column C1	0.47	Poor
4	Column C1	0.37	Very Poor
5	Column C1	0.43	Poor
6	Column C1	0.28	Very Poor
7	Column C1	0.75	Fair
8	Column C1	0.42	Poor
9	Column C1	0.76	Good
10	Column C1	0.75	Fair
11	Column C1	0.51	Fair
12	Beam B1	0.59	Fair
13	Beam B2	0.73	Good
14	Beam B3	0.76	Good
15	Beam B4	0.60	Fair
16	Slab	0.47	Poor



5.1.8. Ph Test Results Carried Out on Residential house at kathora Naka

Sr. No.	Sample	pH Test	Nature
1	Column	14.02	Alkaline
2	Column	12.3	Alkaline
3	Beam	8.6	Alkaline
4	Beam	6	Alkaline

6. Conclusion

- This paper successfully assessed structural damage using visual inspection and Non-Destructive Testing (NDT) methods, including the Rebound Hammer and Ultrasonic Pulse Velocity (UPV) tests. These tests provided insights into the condition of RCC structures in two case studies: a building at Kathora Naka and an Elevated Service Reservoir in Amravati.
- At Kathora Naka, 46% of members were in poor or very poor condition, requiring immediate attention, especially Columns C4 and C6. Only 20% were in good condition. Columns showed more deterioration than beams, with Beams B2 and B3 performing well.
- In the reservoir, most members were in fair to poor condition, with C1, B3, B4, and the Top Slab in good or excellent condition. About 36% were rated poor, and 36% good or excellent. Critical repairs are needed for poor-rated elements like beams and tank walls.
- Overall, NDT techniques proved effective for evaluating structural health, offering reliable, non-invasive means of identifying damage and guiding repair and retrofitting strategies.

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