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# Structural Assessment & Repair Techniques

Sushant Shelke, Student
M.Tech Construction Management
MITCOM, MIT ADT University, Pune, India

**Abstract:- Structures are meticulously designed to withstand predetermined loads throughout their lifespan. However, reinforced concrete (RC) structures, which have been widely employed worldwide for the past 50-60 years, are susceptible to a range of issues leading to varying degrees of damage. Factors such as material deterioration, construction techniques, workmanship quality, overloading, aggressive environments, and the fatigue and corrosion of embedded steel reinforcement contribute to the natural degradation of RCC. This deterioration is now evident in numerous concrete structures. In the current landscape of building research, the significance of repair and rehabilitation cannot be overstated. This is particularly crucial in developed countries where extensive rehabilitation efforts, especially for heritage buildings, are imperative due to their cultural and historical significance. Dealing with these challenges requires a systematic approach, encompassing thorough assessments, innovative repair strategies, and a commitment to sustainable solutions to ensure the longevity and resilience of our built environment.**

***Keywords:-*** *Repair – Rehabilitation – Damage Assessment – Maintenance.*

## I. INTRODUCTION

Existing structures approaching the end of their service life and displaying signs of deterioration necessitate technical intervention to enhance their longevity and prevent potential failures, whether triggered by seismic events or other structural issues. Degradation / Disintegration of buildings can result from, For Eg. weathering, fires, natural disasters like earthquakes, floods, tsunamis, cyclones, soil-structure interaction (such as settlement or soil failure), construction defects, and more. Following a comprehensive technical evaluation of these structures, a decision must be made regarding whether to repair or replace the structure or its components. This decision-making process should align with considerations of economic feasibility, construction viability, and adherence to the latest trends and techniques in the field.

➢ *Objective of Study:*

- To Know the terms used in Building repairs and rehabilitation of structures.
- To study various assessment procedure for structures
- To check the quality of concrete in RCC structures.
- To have knowledge about the strength of structures, surveys to be required to conduct.

## II. DETERIORATION OF STRUCTURES

Concrete deterioration is primarily influenced by several factors that is permeability, carbonation, chemical attacks, alkali-aggregate reaction, and physical wear and tear such as thermal expansion and contraction and abrasion. Typically, the degradation of concrete structures manifests through common signs like cracking and spalling. Among these factors, the corrosion of reinforcement is a critical contributor to the deterioration process. Despite advancements in building construction, all structures undergo degradation over time, with the rate of deterioration influenced by various factors, these factors are within the control of the occupants during the design and construction.

➢ *Damages in RC Structures:*

- Cracks
- Leakages
- Deflection
- Wear and tear
- Settlement
- Spalling
- Disintegration
- Delamination
- Over loading
- Environment
- Materials used for construction
- Corrosion

## III. DAMAGE ASSESSMENT OF STRUCTURES

### *A. Structural Audits:*

Structural audits are essential for the maintenance and repair of existing structures and it is compulsory for the buildings of 30+ years of age as per municipal Rules. After 15 years it is important to carry out structural audit and after that every 5 years of intervals the structural audit is mandatory. Aiming to prevent mishaps and safeguard human life. Many multi-storey concrete apartments constructed are now over thirty years old, exhibiting reduced strength due to structural deficiencies, deterioration of materials, overloading, and damages due to overloading. The continuous use of such damaged structures poses a potential threat to occupants and nearby habitation, emphasizing the need for proactive measures. Periodical structural audits are crucial for assessing the present

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serviceability and structural viability of buildings. Structural auditing facilitates the implementation of maintenance and repair work, extending the building's Durability and ensuring occupant safety. In India, numerous old buildings face strength reduction over time, and the persistent use of such structures may endanger lives. Responsible preemptive actions should include issuing notices by municipal corporations to buildings and co-operative societies over 30 years old, mandating structural audits and submission of audit reports. It underscores the importance of different repair and retrofitting measures post-audit, emphasizing the health and performance of a building. Structural audits, ensure the safety of buildings and recommend appropriate repairs and retrofitting measures. Conducted by experienced and licensed structural consultants, these audits address structural deficiencies, material deterioration, unexpected overloading, or physical damage. Premature material deterioration, often due to construction specification violations or exposure to harsh service environments, necessitates restoration through appropriate repair techniques to meet functional requirements. While the term 'repair' may imply small fixes, rehabilitation aims to restore distressed structures to their original durability.

*B. Non Destructive Evaluation Tests:*

Various non-destructive Tests (NDT) are available for assessing the in-situ strength and quality of concrete in structural members. It play a crucial role in evaluating the damage sustained by reinforced concrete structures exposed to corrosion, chemical attack, fire, and other environmental stressors. The term 'non-destructive' emphasizes that these tests do not compromise the intended performance of the structural elements under investigation. The field of non-destructive evaluation is broadly categorized into two main groups: 'in-situ field tests' and 'laboratory tests.' These categories encompass a range of techniques designed to provide valuable insights into the condition of concrete members without causing any harm to their structural integrity. This nuanced evaluation methodology is particularly beneficial in diagnosing issues related to durability, assessing the impact of environmental factors, and ensuring the ongoing reliability of concrete structures.

➢ *Rebound Hammer Test:*

The rebound hammer test provides a quick and simple way to estimate the strength of the concrete surface. It consists of a spring-loaded mass when released it impacts the surface of the concrete. The rebound distance of the hammer is measured and correlated to the concrete's compressive strength. Harder the concrete, the higher the rebound value. It is particularly useful in the field for assessing the uniformity of concrete strength across a structure or for identifying areas of potential concern. However, it's essential to note that the test provides only an estimate of the concrete strength at the surface and may not represent the overall strength of the entire structure.

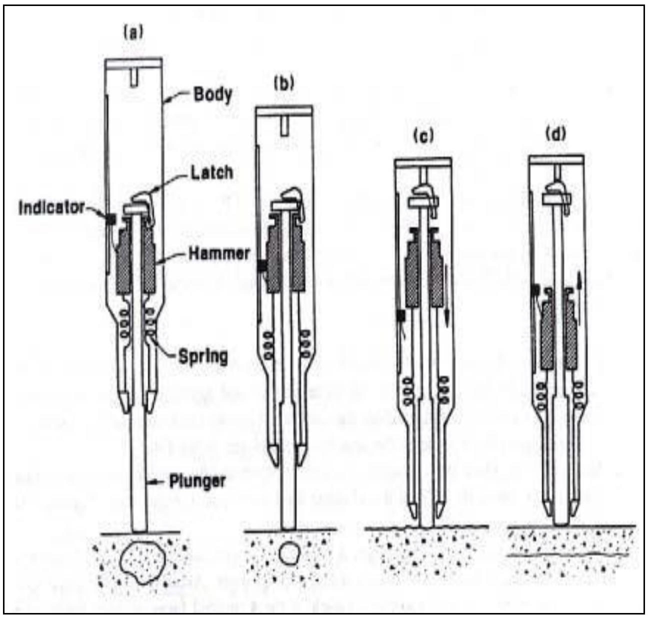


Fig 1: Rebound Hammer Test

Table 1: Quality of Concrete from Rebound Numbers

| Average rebound number | Quality of concrete |
|---|---|
| > 40 | Hard layer |
| 30 to 40 | Good |
| 20 to 30 | Fair |
| < 20 | Poor |
| 0 | Delaminated |

➢ *Ultrasonic Pulse Velocity (UPV) :*

The UPV test involves sending the ultrasonic pulses through the concrete using transducers. These pulses travel through the material, and their velocity is recorded. The speed of these pulses is influenced by the elastic properties and density of the concrete. Typically, sound waves travel faster in denser and more structurally sound concrete. Measuring the travel time, denoted as 'T,' of an ultrasonic pulse typically within the frequency range of 50-54 kHz. It is used to evaluate the quality and integrity of concrete

Table 2: Quality of concrete Using UPV as per IS 13311-1992

| Velocity | Concrete Quality |
|---|---|
| > 4.5 km/s | Very good |
| 3.5 to 4.5 km/s | Good to very good |
| 3.0 to 3.5 km/s | Satisfactory |
| < 3.0 km/s | Poor |

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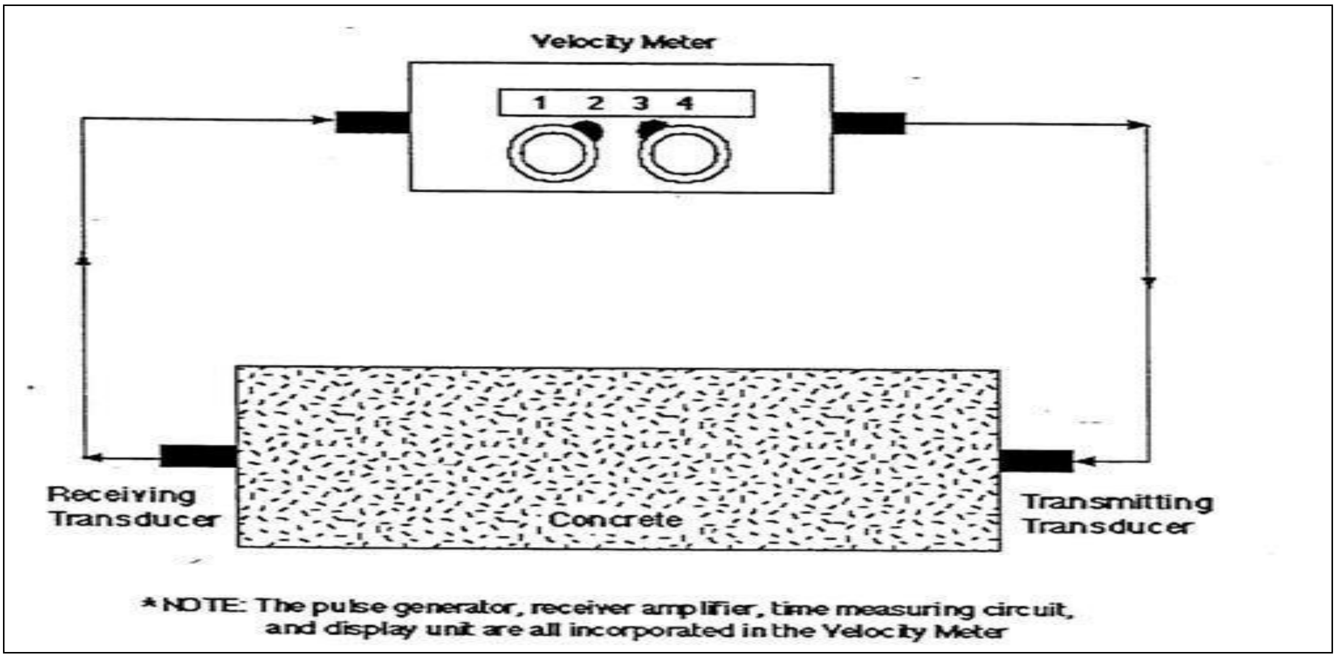


Fig 2: Ultrasonic Pulse Velocity Test

➢ *Core Sampling and Testing:*

Cores are typically precision-cut using a rotary Drill tool with diamond bits, resulting in cylindrical Sample. A detailed visual inspection and photographic documentation follow, with a specific focus on compaction, aggregate distribution, and the presence of steel. Subsequently, the cores undergo a meticulous process: soaking in water and capping with molten sulfur. This ensures that the ends become flat, parallel, and perpendicular. The final step involves compression testing under moist conditions, adhering to established standards.

➢ *Carbonation Test:*

A carbonation test is used to determine the depth of carbonation in RCC structures. It is a chemical reaction that occurs when carbon dioxide reacts with the hydrated cement minerals in concrete, leading to a reduction in the alkalinity of the concrete and potential corrosion of embedded steel reinforcement. This test is crucial for assessing the durability and potential long-term performance of concrete structures.

➢ *Half-Cell Potential Test:*

Half-cell potential measurements help assess the Probability of corrosion in reinforced concrete. A grid pattern is used to measure the corrosion potential of the rebar with a Cu/CuSO4 electrode. If the potentials are more positive than -0.2V, there's a 90% chance of no corrosion. Readings more negative than -0.35V indicate a 90% chance of active corrosion. Potentials between -0.2V and -0.35V suggest potential breakdown of passivity and the possibility of future corrosion. However, results may vary due to moisture, carbonation, and salt levels, making the method sometimes inconclusive.

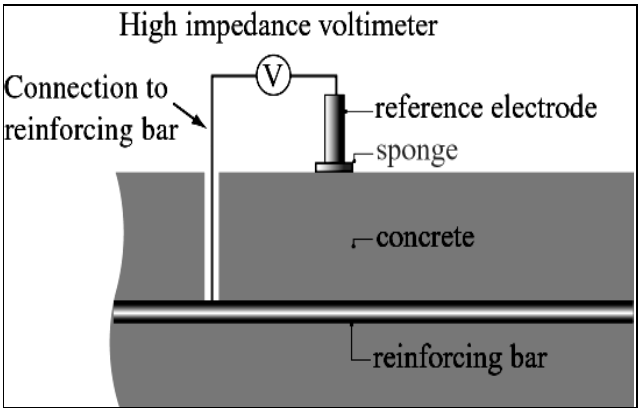


Fig 3: Half-Cell Potential Setup

Table 3: Corrosion Intensity based on Results

| Value | Corrosion Intensity |
|---|---|
| Less than 200 mv | 10% Corrosion |
| 200 mv to 350 mv | 50% Corrosion |
| Less than 350 mv | 90% Corrosion |

## IV. METHODOLOGY

### A. *Visual Inspection of Building*

Visual inspection is a fundamental process in assessing its overall condition, safety, and functionality of building. It involves examination of exterior and interior components of building, aiming for identifying any visible signs of damage, deterioration & potential issues.

➢ *Exterior Inspection:*

- Check for cracks, settling, or movement in the foundation, walls, and columns.
- Inspect the condition of load-bearing elements for signs of damage or stress.

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- Examine the roof for leaks, missing shingles, or damaged flashing.
- Assess the condition of exterior walls, windows, and doors for cracks, gaps, or water infiltration.
- Look for signs of water pooling around the foundation.
- Check for cracks or displacement in sidewalks, driveways, and other paved surfaces.
- Inspect utility connections, such as electrical, water, and gas, for any visible issues.
- Check the condition of outdoor HVAC units.

➢ *Interior Inspection:*

- Inspect walls, ceilings, and floors for cracks or signs of movement.
- Check for any visible damage to structural components.
- Examine the condition of wiring, outlets, and switches.
- Check the electrical panel for signs of overheating or corrosion.
- Look for leaks or water stains around plumbing fixtures.
- Inspect visible pipes for signs of corrosion or damage.
- Assess the condition of paint, wallpaper, and other interior finishes.
- Look for signs of water damage or mold growth.

*B. Photographic Record:*

It is essential for preliminary inspection of a distressed structure to capture necessary photographs of the affected areas and its components. Conducting a preliminary inspection and collecting relevant data is crucial for effective planning and subsequent condition surveys during field inspections. The observed signs of distress often correlate with the life of the structure. This preliminary data provides a understanding of the causes of damages.

*C. Collecting Basic Information:*

A Systematic program needs to be developed for acquring comprehensive information about a distressed structure, balancing the need for substantial details with considerations of cost and time efficiency. Consequently, a list outlining the required information from the owner or client must be compiled. While acknowledging that owners or clients may not have access to certain construction details or related information, every effort should be made to gather as much relevant information as possible during the Preliminary Site Visit.

➢ *For Example:*

- Date of Visit
- Name and address
- Building use
- Year of construction
- Number of floors
- Area
- Type of construction
- Builder / Owner
- Name of maintenance Company
- Environmental conditions
- Vibration (If any From nearby activities)
- Presence of chemicals in soil
- Presence of HVAC ducts
- Wind direction
- History of building Repairs, use or alterations
- Extensions or rebuilding carried out
- Any accident
- Type of concrete used (cement, sand, aggregate, use of admixture)

*D. Evaluation of Data:*

Identifying the Causes & Issues, understanding the probable Reasons, and determining the factors contributing to distress necessitate meticulous study and analysis of the information collected during the inspection stage. This data is systematically tabulated on a performa tailored to the available information for Evaluation. During the investigation, its crucial to document the conceivable factors. This comprehensive approach ensures that any features in the environment or within the concrete are noted, enabling the identification of key issues and the formulation of necessary solutions.

## V. RESULTS AND OBSERVATION

*A. Case Study 1: A Three Storied RCC Framed Residential Building at Virar, Maharashtra*

Image 1: Residential Building

➢ *Salient Features*

- Year of Construction : 1998
- Date of Inspection : August 2023
- Type Of Structure : RCC Framed Structure
- Type Of Footing : No Data Available
- Number Of Flats : 32
- Number Of Shops : 3
- Repair History/Any : No Data Available
- Alterations

➢ *Visual Observations*

- Minor to Major cracks observed in Columns, beams, slabs & walls
- Plumbing and Drain lines are having leakages
- Reinforcement was exposed and Heavily Corroded also small portion of slab was collapsed

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- Waist slab of staircase and soffit of beams exhibited delamination over 20%
- In few flats loft slab are been seen sagging

➢ *Non-Destructive Test:*

- The field testing / laboratory testing of structural members and reinforcements taken, for validating the observations of visual inspection.
- If observations of the visual inspection conclude that the NDT test results may fail Hence it was aborted.
- It may not be feasible for the client/owner of the distressed Building.

*B. Case Study 2: A two storied RCC Framed Industrial Building at Vasai*

Image 2: Industrial Building

➢ *Salient Features*

- Year of Construction : 1997
- Date of Inspection : November 2022
- Type Of Structure : RCC Framed Structure
- Type Of Footing : No Data Available
- Repair History/Any Alterations : Errection of Shed on Terrace

➢ *Visual Observations*

- Minor to Major cracks observed in Columns, beams, slabs & walls
- Minor cracks are observed on wall in common area.
- Plumbing and Drain lines are having Heavy Leakages & seepages
- At some places reinforcement was exposed and corroded.
- Cracks are observed & stagnant water is observed which is unhygienic & cause further structural damage
- Vegetation was observed

➢ *Non-Destructive Test:*

- *Rebound Hammer Test*

✓ The Rebound numbers measured are less than 15 MPA
✓ Cost of test is high.
✓ Solution of these issues are not life time.
✓ It's feasible for this case study.

- *Ultrasonic Pulse Velocity Test*

✓ Values of pules velocity varied in the range of 3.0 km/sec to 4.8km/sec.
✓ It's feasible for this case study.

- *Carbonation Test*

✓ Carbonation was taken beyond the reinforcement level.
✓ It's feasible for this case study.

- *Core Sampling and Testing*

✓ Strength and density determination of concrete failed.

*C. Case Study 3: A Three Storied RCC Framed Residential Building with Shop line at Vasai*

Image 3: Residential Building

*A. Salient Features*

- Year of Construction : 1990
- Date of Inspection : November 2023
- Type Of Structure : RCC Framed Structure
- Type Of Footing : No Data Available
- Number Of Flats : 28
- Number Of Shops : 10
- Repair History/Any Alterations : No Data Available

*B. Visual Observations*

- Minor to Major cracks observed in Columns, beams, slabs & walls
- Plumbing and Drain lines are having Heavy Leakages & seepages
- Cracks are observed on column, beam & Staircase waist slab exhibited delamination over 30%
- Reinforcement was exposed and heavily Corroded at Some Places.
- In few flats loft slab are been seen sagging
- Vegetation was observed

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*C. Non-Destructive Test:*

➢ *Rebound Hammer Test*

- The rebound numbers measured on concrete surface
- Solution of problem is not life time.
- Cost of test is high. And it's not feasible for this case study.

➢ *Ultrasonic Pulse Velocity Test*

- It's not feasible, Hence aborted

➢ *Carbonation Test*

- Carbonation has taken place at the reinforcement level.
- Solution of problem is not life time.
- Cost of test is high and it's not feasible for this case study.

➢ *Core Sampling and Testing*

- It's not feasible for this case study.

This Building was Concluded to be Demolished.

## VI. CONCLUSION

The rehabilitation of structures involves the application of advanced technology, sophisticated skills, and intricate calculations. The Structural repairs include polymer treatment to columns & beams, re-casting of slabs, Epoxy grouting, Waterproofing, strengthening of Overhead water tank, plastering etc. It is a highly responsible task aimed at preventing the Major failure of RCC structures due to deterioration. Rehabilitation becomes imperative for old buildings displaying symptoms of decay, playing a crucial role in safeguarding human lives from potential structural failures. It meticulously reviews existing problems and their reported solutions. Through a thorough examination, an effective solution for the identified issues is formulated, taking into account a careful Measures which are economical, expected life, and adaptability of the solutions. The paper extends its utility to individuals with the objective of undertaking the repair and rehabilitation of civil structures, offering valuable insights and guidance in this specialized field.

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