

An Experimental Investigation on Crack identification, Repairing Techniques and Preventive Measures in Reinforced Concrete Structures

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Abstract - Structural integrity is crucial for the longevity and safety of buildings and infrastructure. Cracks are common problems that compromise structural stability, durability, and functionality. This study investigates the causes, identification methods, repairing and preventive measures for cracks in structures. The research explores various factors such as material quality, environmental conditions, load variations, and construction techniques that contribute to crack formation and water infiltration. Different types of cracks, including structural and non structural cracks, are analyzed, along with modern techniques for their detection, such as visual inspections, rebound hammer test and ultrasonic testing, and infrared thermograph. The study also highlights the significance of proper material selection, construction practices, and maintenance strategies to mitigate these issues.

By understanding the root causes and implementing appropriate repair techniques, selecting the materials for repairing and preventive measures, this study aims to enhance the durability of structures, reduce maintenance costs, and ensure safety. The findings of this research contribute to improved construction practices and sustainable infrastructure development.

Keywords: Cracks, Structural Integrity, Identification, Repairing and Prevention, Maintenance

1.INTRODUCTION

Cracks in buildings are defined as physical discontinuities or separations in materials caused by stress, strain, or external influences. These can manifest as narrow fissures (hairline cracks) or wide openings, depending on the severity and cause. Cracks may occur in structural elements (e.g., beams, columns, and foundations) or non-structural elements (e.g., plastered walls and ceilings). They can vary in orientation, size, and depth, each reflecting specific causes and implications for the structure. Structural cracks affect the stability and integrity of the building and can occur due to excessive loads, foundation settlement, or seismic activity. Non-structural cracks are surface-level and do not compromise structural integrity but affect aesthetics and durability, such as shrinkage cracks and those due to temperature changes. Common causes of cracks include material shrinkage from drying concrete or plaster, thermal expansion and contraction due to temperature fluctuations, foundation movement from uneven ground settling,

overloading of structural components, poor construction practices, and environmental factors like moisture and chemical exposure.

Cracks can be classified as hairline cracks, which are thin and superficial; vertical cracks, typically from foundation settlement; horizontal cracks, indicating serious structural issues from lateral pressure; diagonal cracks from differential settlement or seismic activity; and stair-step cracks common in brick or masonry walls due to foundation movement. The implications of cracks include water ingress leading to mold and corrosion, structural weakening, aesthetic damage, and reduced property value. Preventive measures involve proper design and construction, regular maintenance and inspection, adequate drainage systems, control and expansion joints for material movement, and soil stabilization before construction.

The implications of cracks include water ingress leading to mold and corrosion, structural weakening, aesthetic damage, and reduced property value. Preventive measures involve proper design and construction, regular maintenance and inspection, adequate drainage systems, control and expansion joints for material movement, and soil stabilization before construction. Repair methods include filling and sealing (Zhang et al (2022)) with epoxy or polyurethane injections (Singh et al (2021)) for minor cracks, stitching with steel rods or wires to bridge and stabilize cracks, grouting with cement-based material to fill voids, reinforcement with additional support like steel beams, and surface coating to prevent moisture penetration.(Singh et al (2021)) Understanding the types, causes, and implications

1.3 Objectives of the Investigation
1. Identification and Classification:To categorize cracks based on their type, size, and orientation. This classification helps determine the severity and urgency of repair.
2. Understanding Causes:To determine the underlying reasons for crack formation, including structural, material, and environmental factors. This knowledge is vital for addressing root causes rather than symptoms.
3. Repair Development:To design effective and economical methods for repairing cracks and preventing recurrence. Techniques include epoxy injections, stitching, grouting, and reinforcement.

4. Enhanced Construction Practices: To use findings to improve building materials, designs, and construction techniques. Incorporating lessons from crack studies can lead to stronger and more resilient structures.

5. Maintenance Guidelines: To establish protocols for regular inspection, monitoring, and proactive maintenance of buildings. Routine checks ensure that cracks are identified and addressed early.

1.4 Formation of Cracks in Buildings: Cracks in buildings are caused by various factors affecting structural stability over time. Foundation settlement due to soil movement or moisture changes is a major reason for crack formation. Shrinkage of materials like concrete and plaster during drying can create hairline cracks. Temperature variations cause expansion and contraction, leading to stress and cracking

1.5 Causes of Cracks in Buildings

Cracks in buildings can be caused by various factors, often related to structural issues, environmental conditions, or poor construction practices. Some common causes include:

1.5.1 Improper Design: Structural or design flaws, such as inadequate reinforcement, incorrect placement of expansion joints, or poor load distribution, can lead to cracking over time.

1.5.2 Overloading: Excessive weight or loads, such as heavy furniture, equipment, or additional floors, can stress the structure and cause cracks in load-bearing elements like beams and columns.

1.5.3 Vibration and External Forces: External forces like vibrations from nearby machinery, traffic, or construction work can cause cracks, particularly in older buildings or those with weak foundations.

1.5.4 Poor Construction Materials: The use of low-quality or substandard construction materials

1.5.5 Thermal Expansion and Contraction: Temperature fluctuations cause building materials like concrete, steel, and masonry to expand and contract

1.6 Tests on Cracks in Buildings

Several tests can be conducted to assess and analyze cracks in buildings to determine their cause, severity, and potential impact on structural integrity. Here are some common types of tests used to evaluate cracks in buildings:

1. Visual Inspection

Purpose: To identify the location, size, and pattern of cracks.

Process: A qualified engineer or technician examines the cracks visually, often using measuring tapes or markers to assess crack width and progression over time. This test helps in identifying whether the cracks are structural or cosmetic.

2. Crack Width Measurement

Purpose: To measure the width of cracks and track their development over time.

Process: A crack width gauge or caliper is used to measure the width of visible cracks. Regular

monitoring of crack widths can help in determining if the cracks are stable or widening, indicating ongoing structural movement or settlement.

3. Plaster or Paint Cracking Test

Purpose: To differentiate between superficial surface cracks (like those in plaster) and more serious

4. Ultrasonic Pulse Velocity (UPV) Test

Purpose: To assess the condition of concrete or masonry and detect hidden cracks or defects.

Process: High-frequency sound waves are passed through the concrete, and the time it takes for the waves to travel is measured. Variations in wave speed can indicate the presence of cracks, voids, or other defects in the material.

5. Rebound Hammer Test

Purpose: To evaluate the compressive strength and surface hardness of concrete, helping to detect cracks in structural elements.

Process: A rebound hammer is used to measure the surface hardness of concrete. The rebound value can give an indication of the concrete's strength and identify areas with surface cracks or weaknesses.

6. Penetrant Testing (Dye Penetrant Test)

Purpose: To detect surface cracks in non-porous materials like metal or concrete.

Process: A colored or fluorescent dye is applied to the surface of the material. The dye penetrates any cracks or voids, making them visible under ultraviolet light, allowing for precise identification of surface defects.

7. Infrared Thermography (Thermal Imaging)

Purpose: To identify cracks and moisture-related issues that may not be visible to the naked eye.

Process: Infrared cameras are used to capture heat patterns on the building surface. Temperature differences can indicate hidden cracks or water infiltration, as areas affected by cracks or moisture will often have a different thermal signature

2.1 LITERATURE REVIEW

Understanding Crack Formation

Bazant & Kaplan et al.,(1996) laid the foundation for understanding crack formation, emphasizing that thermal expansion and shrinkage are significant contributors to crack development. Their research helped explain why cracks occur due to the material behavior under various environmental conditions, a key factor in the study of building durability.

Crack Repair Techniques

Emmons & Sordyl et al.,(2006) explored epoxy injection as an effective method for repairing structural cracks, while recommending surface sealants for non-structural cracks. This classification of repair methods based on crack type improved repair efficiency and effectiveness by tailoring solutions to the specific nature of the crack.

Preventing Shrinkage Cracks

Neville (2011) focused on preventing shrinkage cracks by controlling the water-cement ratio and improving curing

conditions during concrete construction. This research provided valuable insights into preventive measures to minimize shrinkage-induced cracks, emphasizing proactive approaches rather than just repairs.

Self-Healing Concrete

Van Tittelboom & De Belie et al., (2013) introduced the concept of self-healing concrete, which uses bacterial agents to autonomously repair cracks in the structure. Although promising, they noted that the high initial costs of this material limited its widespread application in the construction industry

Strengthening with Fiber-Reinforced Polymers (FRPs)

Mehta & Monteiro et al., (2014) researched the use of Fiber-Reinforced Polymers (FRPs) to strengthen damaged structures. FRPs help restore tensile strength and provide long-term stability under dynamic loads, such as vibrations and seismic forces, enhancing the durability and resilience of buildings.

Challenges in Crack Detection

Kim et al. (2018) found that traditional Non-Destructive Testing (NDT) methods struggle with micro crack detection. They proposed hybrid techniques to improve accuracy. This research highlighted limitations in existing detection methods and suggested improvements.

3.1 METHODOLOGY

This chapter describes the types of cracks are available in the structure based various causes, Investigation on cracks, Depending upon the investigation data selecting the repair technique with suitable materials for crack repair

3.4 Stages in Repair and Rehabilitation Process

3.4.1 Structural Analysis (Assessment Phase)

The analysis phase aims to determine the extent, cause, and impact of deterioration on the structural performance.

3.4.1.1 A) Inspection and Assessment

By conducting an Visual Inspection for Detect the cracks, Spalling, rust stains, leakage, etc. In the Buildings.

3.4.1.1 B) Non-Destructive Tests (NDT):

Conducting the NDT on damaged structures for determining the following properties

- Rebound Hammer Test – surface hardness
- Ultrasonic Pulse Velocity (UPV) – internal defects
- Half-Cell Potential Test – corrosion activity
- Cover meter, core tests, carbonation depth, etc.

3.4.1.2 Structural Evaluation

Determine remaining load-carrying capacity
Perform structural analysis using the results of tests and material properties.

3.5 Repair and Rehabilitation Process of cracks

3.5.1 Structural Analysis (Assessment Phase)

3.5.1.1 Visual Inspection for Detect the cracks



Method 1: Using a Ruler Tools: A ruler (preferably with millimeter markings).

Procedure:

- 1. Align Ruler:** Place the ruler next to the crack.
- 2. Measure Width:** Use the ruler to visually estimate the width at the widest point of the crack. Ensure that the ruler is aligned properly for accurate measurement.
- 3. Small Cracks:** If the crack is very small, estimate the width in millimeters. For larger cracks, centimeters will be sufficient.

Method 2: Using Paper and Pencil

Tools:



Paper and pencil

Procedure:

- 1. Trace the Crack:** Place a piece of paper over the crack and trace its outline.
- 2. Measure the Width:** Use the pencil to mark the crack's edges on the paper. Measure the distance between these marks to determine the crack width.

3.5.2 Tests on Cracks

3.5.2.1 Rebound Hammer Test on Cracks in Buildings

3.5.2.2 Rebound Hammer Test Values

Table No: 3.5.2.2 Rebound Hammer Test Values

S.No	Location	Rebound Hammer Test Values					
		1	2	3	4	5	6
1	Room-1	21	19	25	22	21	23
2	Room-2	19	29	31	19	21	18
3	Room-3	12	22	18	21	21	20

Table No: 3.5.2.3 Evaluations of Rebound Hammer Test Values

S.No	Location	Rebound Hammer Test Values	
		Upper Limit	Lower Limit
1	Room-1	23.87	19.8
2	Room-2	28.5	17.6
3	Room-3	22.68	15.313

3.5.2.5.1 Crack Repairing With Cement Motor Minor/Non-Structural Cracks

These cracks are typically cosmetic or caused by minor settling, temperature changes, or drying shrinkage.

Purpose: To evaluate the compressive strength and surface hardness of concrete, helping to detect cracks in structural elements.

Materials: Acrylic-based fillers, gypsum plaster, or ready-made wall fillers.

Table No: 3.5.2.5.1A) RHTV Crack Repairing With Cement Motor

S.No	Location	Rebound Hammer Test Values					
		1	2	3	4	5	6
1	Room-1	24	22	28	24	24	26
2	Room-2	22	31	34	22	24	21
3	Room-3	15	25	21	24	24	23

3.5.2.5.2 Crack Repairing With Polymer modified Cement motor

S.No	Location	Rebound Hammer Test Values	
		Upper Limit	Lower Limit
01	Room-1	26.86	22.58
02	Room-2	31.01	20.20
03	Room-3	25.69	18.39

Concrete Patching:

Procedure: For larger cracks in concrete, patch the area with a strong concrete mix or polymer modified repair compound.

Materials: Concrete patching compounds, polymer-modified concrete, or mortar mix.

Process: Clean and prepare the crack, mix the repair material, and apply it to the crack. Smooth and

S.No	Location	Rebound Hammer Test Values					
		1	2	3	4	5	6
1	Room-1	26	25	31	27	26	28
2	Room-2	25	34	36	25	26	23
3	Room-3	17	27	23	26	26	25

finish it to match the surrounding surface

Table No: 3.5.2.5.2 A) RHTV Crack Repairing With Polymer modified Cement motor

4.1 RESULT ANALYSIS

This study evaluates the performance of Cement Mortar, Polymer Modified Cement Mortar, and PU50 Polyurethane Sealant in terms of strength, flexibility, adhesion, and durability.

4.1.1 Cement Mortar: A conventional material used for crack filling, offering good compressive strength but prone to shrinkage and limited flexibility.

4.1.2 Polymer Modified Cement Mortar: An improved version of cement mortar, where basalt fibers enhance tensile strength, reduce cracking, and improve durability.

4.1.3 PU50 Polyurethane Sealant: A flexible, adhesive-based crack filler that provides superior elasticity and water resistance, making it ideal for dynamic cracks.

4.2 Analysis of Results Rebound Hammer Test Values

When a concrete structure develops cracks, its compressive strength can drop by 20–50% depending on crack width, depth, and propagation.

Wider cracks cause greater strength reduction, as stress cannot be evenly distributed across the structure

4.2.1 Cracks without repair

S.No	Location	Rebound Hammer Test Values	
		Upper Limit	Lower Limit
01	Room-1	23.87	19.80
02	Room-2	28.50	17.60
03	Room-3	22.680	15.313

4.2.2 Cracks Repaired with Cement Mortar

4.2.3 Cracks Repaired with Polymer Modified Cement Mortar

S.No	Location	Rebound Hammer Test Values	
		Upper Limit	Lower Limit
01	Room-1	27.45	23.36
02	Room-2	32.25	21.65
03	Room-3	27.25	20.12

4.2.4 Crack Filling With Polyurethane Epoxy Injection

S.No	Location	Rebound Hammer Test Values	
		Upper Limit	Lower Limit
01	Room-1	34.56	27.80
02	Room-2	36.50	26.16
03	Room-3	30.69	27.22

4.3 Comparison of Rebound Hammer Test Results

4.3.1 Lower limit Rebound hammer Test Results

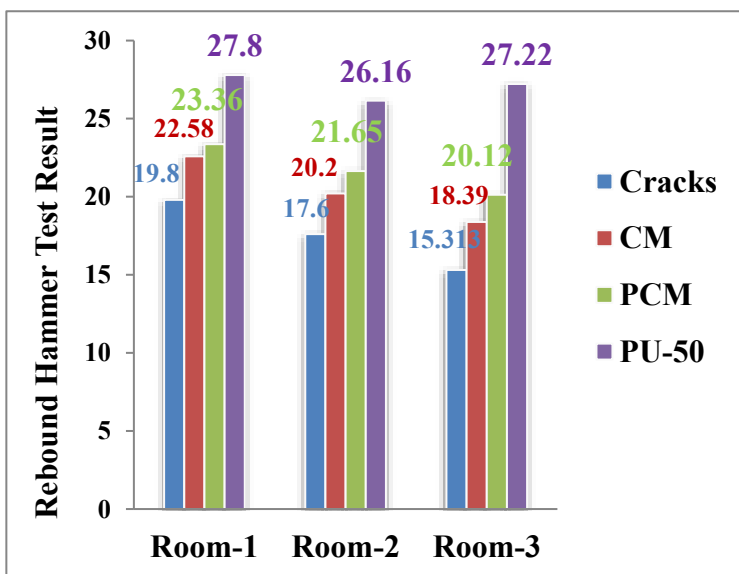


Fig. No: 4.3.1 Lower limit Rebound hammers Test Results

4.3.2 Upper limit Rebound hammer Test Results

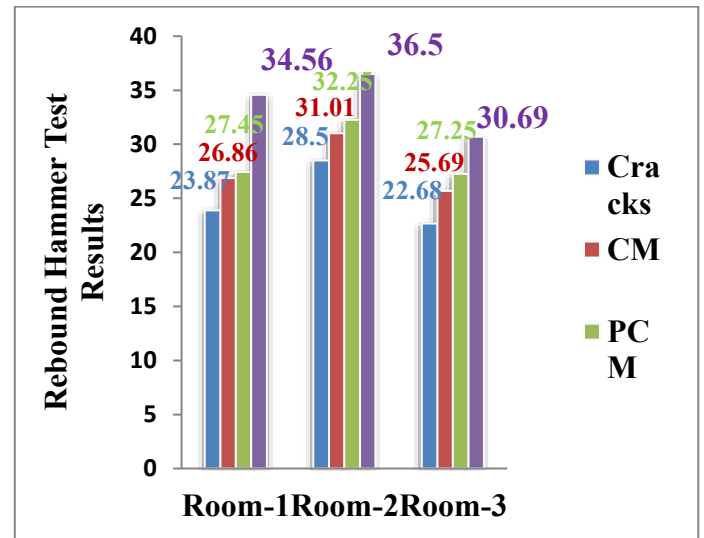


Fig. No: 4.3.2 Upper limit Rebound hammer Test Results

4.4 Results comparing with IS 3311

Table No: 4.4 IS 13311 Rebound Hammer Number

Rebound Hammer Number (IS: 13311 Part-2)				
S.No	Avg. Rebound Hammer Number	Quality of Concrete	Observed Values	Remarks
1	> 40	Very Good Hard layer		
2	30 -40	Good layer	34.56, 36.50, 30.69	After Repair
3	20-30	Fair		
4	<20	Poor	15.313, 17.60, 19.80	Before Repair

5.1 Conclusion

Cracks in concrete reduce compressive strength by around up to 30%, requiring effective repair methods and materials for strength recovery and integrity

Cement Mortar restores about 5% of lost strength, making it a basic but less effective solution.

Polymer modified Cement Mortar improves strength recovery by up to 10 %, offering better durability and crack resistance.

PU50 provides the highest recovery up to 12 %) but is more suitable for flexible and dynamic crack applications rather than load-bearing repairs.

Choosing the right filler depends on whether strength restoration (cement mortar / Polymer modified Cement Mortar) or flexibility (PU50) is the priority.

5.1.1 Conclusion Table

Table No: 5.1.1 Conclusion Table

S.No	Condition	Initial Strength	Crack Strength	Final Strength After Repair
		Loss (%)	Recovery (%)	(%)
1	Cracked Concrete (Untreated)	30%	0%	70%
2	Crack Filled with Cement Mortar	30%	5%	75%
	(5% Gain)			
3	Crack Filled with Polymer Mortar	30%	8%	78%
	(8% Gain)			
4	Crack Filled with PU50 (12% Gain)	30%	12%	82%

5.2 Future Scope

5.2.1 Advanced Materials for Reaping Tools

- High-strength lightweight alloys (aluminum-magnesium, titanium blends)
- Wear-resistant composite blades (carbon fiber reinforced polymers)
- Self-sharpening and coated blades (ceramic, nano-coatings)

5.2.2 Smart & Sustainable Materials

- ✓ Shape memory alloys for adaptive cutter mechanisms
- ✓ Bio-based and recyclable polymers for tool housings
- ✓ Corrosion-resistant materials for humid and saline environments

References

[1] Oh, K. (2010) – Repair Guidelines for Water-Leakage Cracks in Concrete Structures. Investigated polymer-based sealants for mitigating water infiltration and improving crack resistance.

[2] Chung et al. (2015) – Polymer-Based Waterproofing Membranes: A Comparative Study Evaluated different polymer formulations for long-term durability.

[3] Bastani et al. (2016) – Hydrophobic Surface Treatment for Cement-Based Materials. Studied the effectiveness of surface coatings in reducing water penetration.

[4] Mydin et al. (2017) – Waterproofing Failures in Concrete Buildings: Causes and Solutions. Found that improper sealant application and material degradation contribute to leakage

[5] Rahman et al. (2017) – Long-Term Durability of Water-Repellent Concrete Coatings. Investigated the sustainability of hydrophobic coatings over a 5-year period.

[6] Reddy et al. (2018) – Effectiveness of Basalt Fiber in Crack Healing. Examined the role of basalt fiber reinforcement in minimizing crack propagation.

[7] Oh et al. (2018) – Artificial Crack Behavior and Water Leakage Repair Materials in Concrete Showed that hydrophobic coatings significantly enhance moisture resistance.

[8] Liu et al. (2018) – Impact of Crack Size on Water Penetration in Reinforced Concrete. Provided empirical data on crack width and corresponding leakage rates

[9] Wang et al. (2019) – Self-Healing Materials for Cracks in Engineered Cementitious Composites. Demonstrated self-healing mechanisms improving structural longevity.

[10] Taha et al. (2019) – PU 50 Crack Sealant Performance Under Extreme Weather Conditions. Tested the resistance of polyurethane-based sealants against temperature variations.

BIOGRAPHIES (Optional not mandatory)



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