



# A STUDY ON THE CRACKS BY USING MICROSCOPE, ULTRASONIC PULSE VELOCITY, REBOUND HAMMER, GROUND PENETRATING RADAR AND PREVENTION OF CRACKS

**K.Kiruthika,**

PG Student,

Department of Civil Engineering,  
Builders Engineering College, India

**Abstract:** Cracks affect the strength and appearance of the structure and can demonstrate potential shortcomings or disappointments in materials. There are different types of cracks arrive in structural or non-structural structure due to weather changes, temperature conditions, improper curing, setting, loading conditions and etc., Understanding crack behaviour is crucial for developing effective repair methods such as Epoxy injection, Additional reinforcement, column jacketing, crack stitching, etc., In this paper, the cracks are analysed using a Microscope and rectify these problem. The study of cracks not only identifies the immediate issues but also provides insights into the structure's overall health, guiding long-term durability strategies delaying costly reconstruction. Timely detection and repair of cracks reduce maintenance costs and prevent expensive large-scale repairs or replacements. Cracks in structural elements significantly impact the durability, safety, and functionality of buildings and infrastructure. This study investigates the detection, characterization, and prevention of cracks using a combination of advanced non-destructive testing (NDT) techniques and preventive methodologies. Microscopic analysis provides a detailed understanding of crack morphology and propagation at a microstructural level. Ultrasonic Pulse Velocity (UPV) evaluates the material integrity by identifying internal flaws through variations in wave velocity. The Rebound Hammer test assesses surface hardness and potential crack susceptibility, while Ground Penetrating Radar (GPR) offers subsurface imaging to detect hidden cracks and voids. The integration of these techniques enables a comprehensive evaluation of crack formation, size, orientation, and depth. Additionally, strategies for the prevention of cracks are explored, including material selection, structural design improvements, and environmental control measures. The study aims to establish a multi-disciplinary approach to crack assessment and prevention, providing a robust framework for maintaining structural health and ensuring long-term performance.

**Index Terms – Cracks, NDT, UPV, GPR.**

## 1. Crack Assessment and Monitoring

**Visual Inspection:** Initial identification through visual checks for length, width, and depth.

**Crack Monitoring Devices:** Instruments like Ultrasonic Pulse Velocity (UPV), Rebound hammer, Microscope and Ground Penetrating Radar (GPR) etc.,

**Ultrasonic Testing:** Identify the cracks, voids, changes in structure for plain, reinforced and prestressed concrete whether it is precast or cast in-situ.

**Rebound Hammer:** Identify the compressive strength, uniformity and quality of concrete.

**Microscope:** Measure the width of cracks in concrete, masonry walls and also used to measure in fresh and hardened concrete.

**Ground Penetrating Radar (GPR):** To detect subsurface cracks in concrete or masonry.

## 2. Types of Cracks

Cracks can form for various reasons, such as:

- i. **Structural Cracks:** Result from external loads, shear stress, or bending.
- ii. **Non-Structural Cracks:** Due to shrinkage, expansion, or settlement.
- iii. **Thermal Cracks:** Caused by temperature fluctuations.

iv. **Corrosion-Induced Cracks:** From rusting of embedded materials like steel.

## 2. A. Structural Cracks

Structural cracks are cracks in a structure's foundation, walls, bottoms, or ceilings that can affect the structure's stability and integrity. They can be caused by a number of factors, including

- a) Soil issues: Wet or dry soil, poor soil bearing, or extensive voids under the concrete
- b) Overloading: Extreme weight on the foundation
- c) Construction issues: Poor design and mixing, Poor Quality of material, Poor knowledge in construction practices
- d) Climate changes: Construction materials of steel, wood, cement and etc. are affected by the seasonal changes. For example, wood can expand or shrink when the seasons change and cement affected by air content, steel like rusting.
- e) Landscaping: Grading that encourages water retention or landscaping features like concrete quadrangles can beget uneven soil movement

Structural cracks are more serious than non-structural cracks and can pose serious pitfalls if left unaddressed. They're frequently wider, deeper, and more irregular in shape. Some signs of structural cracks include

- f) Stair- step cracks
- g) Cracks on foundation
- h) Cracks measuring 1/8 " in range
- i) Cracks on walls

## 2. B. Non-Structural Cracks

This cracks do not affect the structural integrity of the building and are usually less than 3 millimeters in width.

### Appearance

Non-structural cracks are fragile and have no regular shape or size. They can be vertical or diagonal.

### Causes

Non-structural cracks can be caused by a number of factors, including:

- a. **Surface drying:** Improper of curing, the surface leads dehydration and drying shrinkage, it forms the surface as dry condition.
- b. **Temperature changes:** Due to changes of weather condition leads cracks.
- c. **Moisture:** Moisture content can cause cracks
- d. **Crazing:** Crazing cracks occur when the top of a concrete slab loses moisture too quickly

## 2. C. Thermal Cracks

Thermal cracking can refer to a process that breaks down organic substances or to cracks that form in concrete and glass due to temperature changes:

### Thermal cracking of organic substances

A process that uses high temperatures to break down organic substances into shorter-chained hydrocarbons. This process can produce biodiesel, char, and gas.

### Thermal cracking in concrete

Cracks that form in concrete when the tensile stress of the concrete exceeds its tensile strength. This can happen when there are differences in temperature between the surface and core of the concrete.

### Thermal cracking in glass

Cracks that form in glass when there is a rapid change in temperature, causing the glass to expand or contract quickly. This can happen when direct sunlight heats glass or cold air from air conditioning hits hot glass.

Here are some things to know about thermal cracking in concrete:

### External restraint

When concrete is restrained on one face, like when a concrete slab is on the ground, it can create tensile strain and lead to cracking.

### Repairing

Fine hairline cracks may not need repair, but wider cracks may need to be sealed with epoxy injection and a seal coating. Inappropriate repair techniques can cause more damage.

## 2. d. Corrosion-induced crack

Corrosion-induced cracking is a major cause of deterioration in reinforced concrete structures. It occurs when the corrosion products of steel expand and cause tensile stresses on the concrete, which eventually leads to cracking.

Here are some things to know about corrosion-induced cracking:

### Stages

The cracking process can be divided into two stages:

Stage I: The number of cracks is directly related to the total area of the cracks.

Stage II: A single penetrating crack becomes the main crack.

### Crack shape

The shape of the crack changes as the corrosion degree increases. The crack starts as a triangle, then becomes a rectangle, and finally a trapezoid.

### Corrosion products

The corrosion products are about 2–6 times the volume of the original steel.

### Crack propagation

Once the cracks penetrate the concrete cover, aggressive agents can quickly reach the reinforcement, which accelerates the corrosion process.

### Prediction

Research on corrosion-induced cracking can help predict the durability and serviceability of reinforced concrete structures.

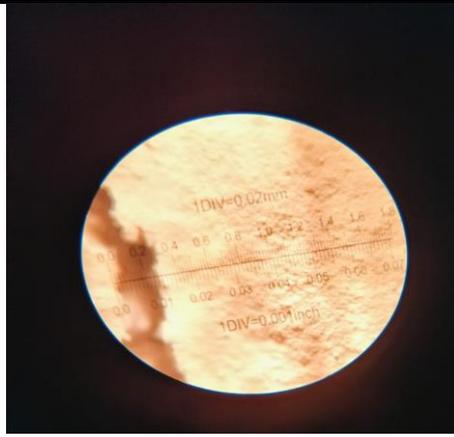
## 3. Classification of Cracks under microscope

Cracks are classified based on their width.

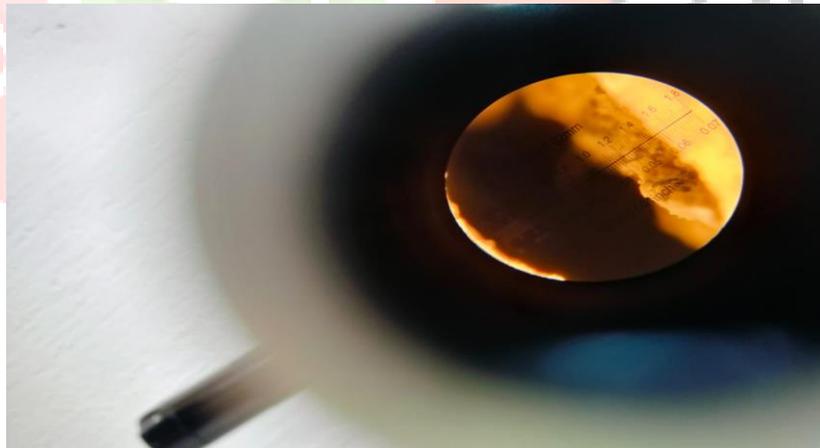
- **Hairline Cracks:** The cracks width less than 0.1mm. The crack does not affect the structural strength but leads to leakage. It occurs improper curing, shrinkage. In plastering lack of water, light weight bricks used. In concrete improper curing, improper water cement ratio, poor design. In walls due to temperature fluctuations, humidity changes.



- **Fine Cracks:** It can be caused by poor quality of materials, poor design, climate changes, structural design, shrinkage, water leaks, and precast walls. The cracks width between 0.1mm and 1mm.



- **Medium Cracks:** It can be caused by temperature changes, improper concrete strength, too much of water added, lack of control joints. The cracks width between 1mm to 2mm.



- **Wide Cracks:** The width crack Greater than 2mm. This crack may cause serious effect on structure.

#### 4. Cracks under UPV

Ultrasonic Pulse Velocity (UPV) is a widely used Non-Destructive Testing (NDT) method for evaluating the quality and structural integrity of materials, especially concrete. It is based on measuring the travel time of ultrasonic pulses through a material and calculating their velocity. This method provides insights into the material's properties, such as density, uniformity, and the presence of internal flaws like cracks or voids.

#### 4. A. Types of Method using UPV

##### i. Direct Transmission (Cross Probing) through Concrete

The direct transmission method of Ultrasonic Pulse Velocity (UPV) testing involves placing the transmitting and receiving transducers on opposite sides of the material being tested. This setup allows the ultrasonic pulse to travel directly through the entire thickness of the material, providing a clear and accurate measurement of the pulse velocity. Since the wave travels along a straight path, this method yields reliable results and is highly effective in assessing the material's uniformity, density, and structural integrity. The pulse velocity is calculated by measuring the time it takes for the ultrasonic wave to travel the known distance between the transducers. This method is especially useful for detecting internal defects such as cracks, voids, and inconsistencies that could affect the material's performance. However, it requires that both sides of the material be accessible, which may not always be possible for structures like walls or reinforced concrete where access is limited. Despite this limitation, the direct transmission method is considered the most accurate and dependable technique for UPV testing.

##### ii. Semi-direct Transmission through Concrete

The semi-direct transmission method of Ultrasonic Pulse Velocity (UPV) testing involves placing the transmitting and receiving transducers on adjacent faces of the material, typically at a corner or edge. The ultrasonic pulse travels diagonally through the material, rather than directly across its thickness as in the direct transmission method. It can be used when access to opposite sides of the material is not possible, such as in walls, columns, or structural corners. While the pulse path is less straightforward than in direct transmission, it still offers relatively reliable results for assessing the material's uniformity, density, and the presence of internal defects.

##### iii. Indirect Transmission (Surface Probing) through Concrete

The indirect (or surface) transmission method of Ultrasonic Pulse Velocity (UPV) testing involves placing both the transmitting and receiving transducers on the same surface of the material. In this method, the ultrasonic pulse travels along the surface or through the near-surface regions of the material, rather than penetrating through its full thickness. This makes the indirect transmission method particularly useful when only one side of the material is accessible, such as in pavements, walls, or slabs where the opposite side cannot be reached. While the method allows for testing in situations with limited access, it is the least accurate of the three UPV methods due to the effects of surface roughness, scattering, and wave dispersion, which can distort the pulse and affect the measurement of velocity. The indirect method is best suited for detecting surface or near-surface cracks, voids, and other discontinuities, but its results are more susceptible to environmental factors and material inhomogeneity compared to the direct or semi-direct methods.

#### 5. Ground Penetrating Radar (GPR)

The Ground Penetrating Radar (GPR) is based on the use of high-frequency electromagnetic waves to penetrate the ground or other materials and detect subsurface structures or anomalies. GPR is a non-destructive testing (NDT) technique that provides real-time imaging of the internal structure of materials. Using Ground Penetrating Radar (GPR) for measuring and analyzing cracks in concrete, asphalt, or other materials involves a systematic process of scanning and interpreting the results.

##### 5. A. Preparation for GPR Survey

**Select the Area for Inspection:** Choose the surface or structure (such as concrete slabs, pavements, or walls) where cracks are suspected. Clear any debris, dirt, or obstacles from the surface, as these can affect GPR signal penetration. **Positioning the GPR Equipment:** Place the GPR antenna on the surface to begin the survey. The choice of antenna frequency (e.g., low or high frequency) depends on the material being tested and the required depth of penetration.

##### 5. B. Scanning the Area

The GPR device is moved across the surface, sending high-frequency electromagnetic waves (radar signals) into the material. These signals travel through the material and bounce back when they encounter a boundary between different materials, such as a crack or void. For crack detection, the GPR system monitors the reflections of the waves. A crack will cause a distinct reflection, as it represents a change in material properties compared to the surrounding intact material.

##### 5. C. Data Collection

As the GPR antenna moves, it collects reflected signals and transmits them to a computer or display unit for processing. The GPR device typically generates a time-domain signal or a radargram that visualizes the reflections from the subsurface. The GPR radargram displays the reflections as vertical lines (representing depth) and horizontal lines (showing the length of the scan). A crack will appear as a break or distortion in the radar signals, indicating a discontinuity in the material.

## 5. D. Crack Location and Size Estimation

### Cracks and Voids:

Reflection patterns: Cracks or voids appear as sharp discontinuities or breaks in the radar signal. The reflection from a crack may vary depending on whether it's filled with air, water, or other materials.

Location and Depth: The location of a crack is indicated by where it shows up on the radargram. The depth can be estimated from the travel time of the radar waves—longer times indicate deeper features.

### Reinforcement Bars (Rebar):

In concrete structures, reinforcement bars (rebar) can be detected as hyperbolic reflections in the radargram. These reflections come from the steel reinforcement that causes a distinct change in the radar signal. The size of the reflection can provide information about the diameter of the bars, and the spacing between bars can also be estimated.

### Layer Boundaries:

When GPR is used to detect subsurface layers (in soil, concrete, or asphalt), the boundaries between different materials appear as sharp reflections. For instance, the transition from soil to rock, or from one layer of concrete to another, will produce a noticeable reflection at the layer interface.

### Delamination:

Delamination in concrete (when layers of concrete separate) can be identified by a distinct break or change in the radar signals. The GPR may detect a separation between layers, and the extent of delamination can be estimated from the reflection patterns.

### Water Content:

GPR can detect moisture within materials. Water-filled cracks or voids produce stronger reflections than dry ones, allowing you to identify areas where water has infiltrated or where moisture is present in the material.

### Corrosion or Damage in Concrete:

GPR can help identify corrosion in reinforcement bars. Corrosion products, which alter the conductivity of concrete, produce different reflection patterns. The test can help detect areas where the rebar has corroded, which might be hard to spot visually.

## 5. E. Reporting and Results:

Once the data is collected and analyzed, a report can be generated showing the location, depth, width, and extent of the cracks. The report may also include images of the radargrams or visual representations of the crack features. The information is useful for maintenance planning, repair strategies, and structural assessments.

## 6. Effects of cracks on Structural Strength

The rebound hammer (also known as the Schmidt Hammer) is a widely used, non-destructive testing (NDT) device that measures the surface hardness of materials, particularly concrete. Developed by Ernst Schmidt in 1950, the rebound hammer is designed to give an indirect estimate of the compressive strength of concrete. The rebound hammer is used to evaluate the quality and uniformity of concrete, and it can help identify areas that may need further inspection, such as zones with cracks, weak spots, or inconsistent curing. It is a simple and effective tool in structural engineering, especially in the inspection, quality control, and maintenance of concrete structures.

Crack identification using a rebound hammer is indirect and not precise. The device does not directly detect or locate cracks but highlights areas where further investigation is needed. It can be useful in identifying areas with reduced surface strength, which may correlate with the presence of cracks or other internal damage. Lower rebound values in certain regions suggest possible cracks or deterioration, prompting further investigation to determine the exact nature of the problem. The rebound hammer is more effective as a screening tool for quality control and monitoring than as a direct method for crack detection.

## 7. Effects of cracks on Structural Strength

Cracks can significantly affect a structure's strength:

- **Tensile Strength:** Cracks reduce the tensile capacity, especially in reinforced concrete structures.
- **Compressive Strength:** Concrete's compressive strength might not be severely impacted unless cracks are large and deep.
- **Shear Strength:** Cracks can propagate through areas experiencing shear, leading to potential failure.

## 8. Repair and Rehabilitation

- **Epoxy Injection:** Filling small and medium cracks with epoxy to restore structural integrity.
- It is easy to fill the cracks in vertical, horizontal and overhead positions. It is a simple application process. It looks like a glue and help to return the structure into original stage.
- **Reinforcement:** Adding additional reinforcement (e.g., steel) to prevent further crack growth.
- To determine the cause of cracks by evaluating the factors of overload, Environmental factors and material degradation. Clean the surface to remove dirt, grease, rust, and loose material. Chisel out deteriorated concrete to expose the steel reinforcement. Treat the exposed steel reinforcement with anti-corrosion agents. To decide the which type of reinforcement required for corresponding damage like additional reinforcement additional rebar, steel plates, fiber-reinforced polymer (FRP), etc. Design the reinforcement details along with structures. Fill the gap by grouting, FRP Wrapping, Jacketing methods.
- **Crack Stitching:** Placing steel bars or staples across cracks to hold them closed. Initially clean the surface and marks the surface for stitching for 20 – 30cm intervals along with the crack. Ensure stitching bars at angle of 45 – 60 degree. Drilling and ensure the groove depth for adhesive purpose. Place and apply the epoxy adhesive or grouting inside the grooves. Place stitching bars and filling the remaining gaps with non-shrink grout or mortar. Smooth and even the surface. Allow sufficient curing time for setting.
- **Overlay or Jacketing:** Applying an additional layer of material to strengthen the cracked structure. To clean the surface avoid debris and roughen the surface for better bonding. In required place add the longitudinal stirrups and bars. Use dowels for connection to the old structure and new structure for develop bonding. Create a formwork around the column or beam. Use high strength concrete for ensure strength and durability of the structure. To attain proper compaction and curing. Remove the formwork, repair surface defects and apply protective coating.

## 9. Conclusion:

In this study, observe the cracks are analysed by microscope, types of cracks and various prevention methods provided. Cracks serve as critical indicators of structural health, often signaling underlying issues such as excessive loading, environmental effects, material deficiencies, or construction errors. Through comprehensive analysis, engineers can identify the causes, progression, and potential impacts of cracks, enabling informed decisions for maintenance, repair, and prevention. This research highlights the importance of early detection and systematic evaluation of cracks using visual inspection and advanced monitoring tools. Understanding crack behavior not only prevents catastrophic failures but also extends the lifespan of structures, reduces repair costs, and promotes sustainable construction practices.

## 10. Reference:

1. Shailendra kumar vimal, Digambar, Study on types of cracks on concrete and their causes & preventive measures on ISSN NO: 0776-3808
2. Kishor Kunal, Namesh Killemsetty, Study on control of cracks in a Structure through Visual Identification & Inspection. Volume 11, Issue 5 Ver. VI (Sep-Oct. 2014), PP 64-72.
3. Syed Mohd Mehndi, Prof. Meraj Ahmad Khan & Prof. Sabih Ahmad. Causes and evaluation of cracks in concrete structures. Volume 2, Issue 5 (Sep-Oct 2014), PP. 29-33.
4. P. Dickinson, N. Thornton, Cracks Caused By Foundation Movement, BRE, ISBN: 978-1-86081-097-8.
5. Chung, H.W. 1981. "Epoxy Repair of Bond in Reinforced Concrete Members", Journal, American Concrete Institute, Proceedings, Vol. 78, No. 1, pp. 79
6. FIP Guide. "Repair and Strengthening of Concrete Structures", Thomas Telford.
7. Grishma Thagunna. "Building cracks – Causes and Remedies". 3rd World Conference on Applied Sciences, Engineering and Technology at Basha Research Centre.
8. Pirro, R. (2012). "Concrete Evaluation and Repair Techniques." Professional lecture, Sept. 2012.