

# AN EXPERIMENTAL STUDY OF CRACK PATTERNS ON REINFORCED CONCRETE BEAM

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**Abstract** - Concrete cracks are caused by overloading, corrosion, shrinkage or poor workmanship. When looking at a specific cracking pattern or defect in concrete, sometimes the causes can be attributed to a specific reason other times the pattern may have multiple causes leading to its current state. In better understanding some of the causes of concrete cracks as well as different cracking pattern types, engineer, construction managers, and other may be able to avoid major structural catastrophes. In this experimental study, around 6 beam specimens of M20 is cast, Beam size of 1500 x 100 x 200 millimeter. During loading the pattern of cracks i.e., initial cracks and the crack propagation is studied. Flexure and Shear crack is studied. The ultimate capacity of beam is also studied.

**Key Words:** Flexure, Shear, Corrosion, Shrinkage, Overloading, Crack propagation, Catastrophes.

## 1. INTRODUCTION

Concrete cracks, in fact, it is designed to crack to be able to fully engage the reinforcing steel. Concerns with concrete cracking come up when owners are maintenance workers and unsure of what to look for or are unaware of the implications of certain cracks. Some types of cracking indicates a structural issue, when others do not indicate any type of issue, when others do not indicate any type of issue other than normal weathering. There are many different causes of cracks, which can lead to different type of crack patterns. Each type of cracking pattern can be associated with a likely cause. If this cause is recognized, it can be identified as structurally vital or non-vital. It is of particular interest in discerning between these two so that the failures and damage of these can be avoided or at least predetermined to minimize economic damage, future deterioration, and in severe cases the loss of human life. The occurrence of various crack patterns in the building mostly takes place during construction and/or after completion. A building component develops cracks whenever the stress in the components exceeds its strength. Stress in the building component is caused by externally applied forces/loads. Almost all the types of cracks in Reinforced Concrete Beams are fundamentally defined by the principle cause or mechanism associated with the function of cracks. An occurrence of the cracks is often a subject that raises numerous questions. Cracks may appear in structures, either at the initial stage or with time. It should first of all be

accepted that cracks of some type are unavoidable in any structure. Cracks may be only at the surface or may extend to more than one layer of materials such as paint, plaster, walls, or through cracks, etc., Cracks due to different causes have varying characteristics and by the careful observations of these characteristics, one can diagnose the cause of cracking for adopting the appropriate remedial measures.

Allowable crack width as per IS: 456 - 2000 varies according to climatic conditions from 0.1 mm to 0.3 mm.

## 1.1 Scope of the Investigation

To know the different types, nature and effects of cracks in structure, in order to avoid major structural catastrophes and loss of life.

## 1.2 Classification of Cracks - Nature Wise

**1.2.1 Structural Cracks:** These cracks occur due to incorrect design, faulty construction or overloading and these may endanger the safety of building. Example: Extensive cracking of RCC column of any structural element.



**Fig -1:** Structural Cracks

**1.2.2 Non-Structural Cracks:** These occur mostly due to internally induced stresses in building materials and do not endanger the safety of a building but may look unsightly, or may create an impression of faulty work or may give a feeling of instability. In some situations due to penetration of moisture through them, non-structural cracks may spoil the

internal finishes thus adding to the cost of maintenance, or corrode the reinforcement, thereby adversely affecting the stability of the structure in long run.

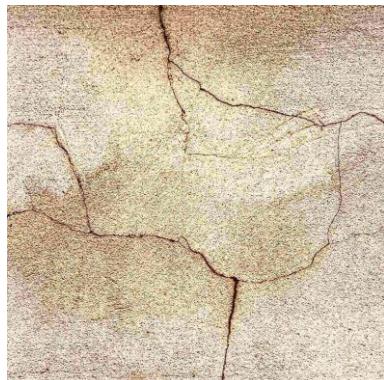


**Fig -2:** Non-Structural Cracks

### 1.3. Classification of Cracks - Width Wise:

Cracks may appear in the structure either at the initial stage or with the time. Some cracks are unavoidable in structure and subjected to numerous questions. Cracks may appreciably vary in width from very thin hair crack barely visible to the naked eye (about 0.01mm in width) to gaping cracks 5mm or more in width.

#### 1.3.1 Thin Crack: Less than 1mm width



**Fig -3:** Thin Crack

#### 1.3.2 Medium Crack: 1 mm to 2 mm in width



**Fig -4:** Medium Crack

#### 1.3.3 Wide Crack: More than 2 mm width



**Fig -5:** Wide Crack

#### 1.3.4 Crazing: The occurrence of closely spaced fine cracks at the surface of a material



**Fig -6:** Wide Crack

### 1.4. Classification of Cracks - Shape Wise:

Cracks may appreciably vary in width from very thin hair crack barely visible to the naked eye to gaping crack. Vice versa cracks can be of uniform width throughout or may be narrow at one end gradually widening at the other. Crack depending upon its shape can be classified as following:

#### 1.4.1 Straight:



**Fig -7:** Straight

#### 1.4.2 Toothed:



Fig -8: Toothed

#### 1.4.3 Stepped:



Fig -9: Stepped

#### 1.4.4 Map Pattern or Random type:



Fig -10: Map Pattern or Random type

#### 1.4.5 Vertical, Horizontal or Diagonal

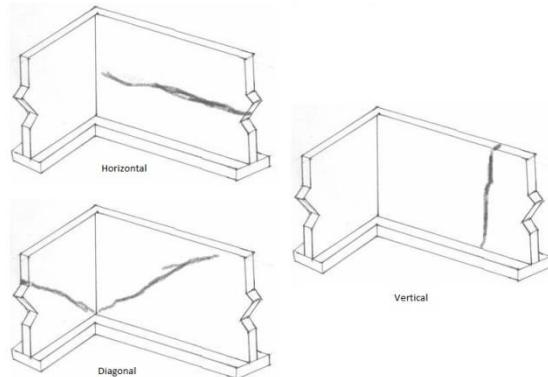


Fig -11: Vertical, Horizontal or Diagonal

#### 1.5 Types and Summary of Cracks in Reinforced Concrete Beams:

##### 1.5.1 Flexure Cracks in Reinforced Concrete Beam:

Flexure word also means "Bending". Cracking in reinforced concrete beams subjected to bending usually starts in the tensile zone i.e. soffit of the beam. The width of flexural cracks in reinforced concrete beams for short-term may stay narrow from the surface to the steel. However, in long-term under continuous loading, the width of crack may get increased and become more uniform across the member.

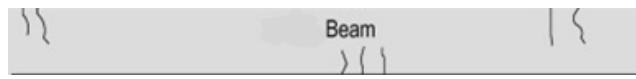


Fig -12: Flexure Cracks in RC Beam

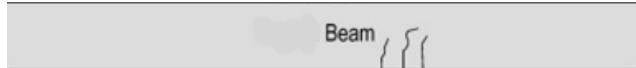


Fig -13: Flexure Cracks in RC Beam

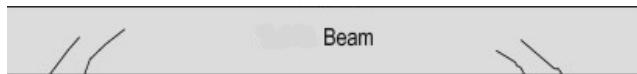
Table -1: Flexure Cracks

Member	Crack Type	Important Characteristics	Possible Reasons
RC Beam	Flexure Cracks in Reinforced Concrete Beams	Originates in maximum moment region	Flexural capacity of the beam is inadequate.
		May be in single or groups	When cross section or main reinforcement in beam is insufficient
		Maximum width at bottom/top of beam	i.e. it is loaded more than defined loads.

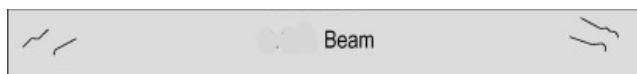
##### 1.5.2 Shear Cracks in Reinforced Concrete Beam:

Shear cracks in reinforced concrete beams occur in hardened stage and it is usually caused by structural (self-weight) loading or movement. These types of cracks are better illustrates as diagonal

tension cracks due to combined effects of flexural (bending) & shearing action.



**Fig -14:** Shear Cracks in RC Beam



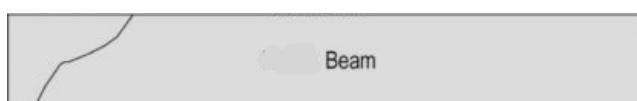
**Fig -15:** Shear Cracks in RC Beam

**Table -2:** Shear Cracks

Memb er	Crack Type	Important Characteristics	Possible Reasons
RC Beam	Shear Cracks in Reinforced Concrete Beams	Originates nearer to supports	Shear capacity of the beam is inadequate.
		May be in single or groups	When cross section or torsional reinforcement in beam is insufficient
		Maximum width at neutral axis region or at bottom of beam.	Both here happen due to loading more than defined loads.

### 1.5.3 Torsion Cracks in Reinforced Concrete Beam:

Usually, beams are subjected to torsion along with bending moment and shear force. Bending moment & shear force occurs as loads acts normal to the plane of bending. However, loads away from the bending plane will cause torsional movement.



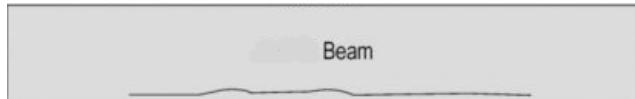
**Fig -16:** Torsion Cracks in RC Beam

**Table -3:** Flexure Cracks

Memb er	Crack Type	Important Characteristics	Possible Reasons
RC Beam	Torsion Cracks in Reinforced Concrete Beams	Originates nearer to maximum torsion region	Torsional strength of the beam is inadequate.
		Single generally uniform width. Appears over the whole periphery in helical form.	When cross section or torsional reinforcement in beam is insufficient

### 1.5.4 Corrosion Cracks in Reinforced Concrete Beam:

Corrosion cracks in reinforced concrete beams run along the line of reinforcement. It usually separates the concrete from reinforcing bars. It is mostly manifested by discoloration of paint or stains of rust.



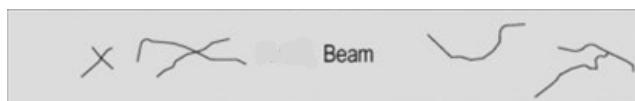
**Fig -17:** Torsion Cracks in RC Beam

**Table -4:** Corrosion Cracks

Memb er	Crack Type	Important Characteristics	Possible Reasons
RC Beam	Corrosion Cracks in Reinforced Concrete Beams	Runs along the line of reinforcement.	Bond between reinforcing bars and concrete not satisfactory.
		Uniform width in general	May be due to corrosion bars/fire damage

### 1.5.5 Shrinkage Cracks in Reinforced Concrete Beam:

Shrinkage cracks in reinforced concrete beams occur during two stages, which are a pre-hardening stage and hardened stage. In pre-hardening stage, these types of cracks are called as plastic shrinkage cracks & in the hardened stage they are known as drying shrinkage cracks. Shrinkage cracks occur when fresh concrete is subjected to a very rapid loss of moisture.



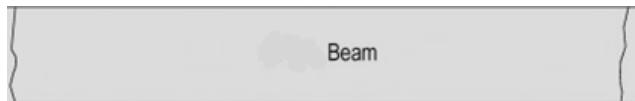
**Fig -18:** Shrinkage Cracks in RC Beam

**Table -5:** Shrinkage Cracks

Memb er	Crack Type	Important Characteristics	Possible Reasons
RC Beam	Shrinkage Cracks in Reinforced Concrete Beams	No regular pattern or thickness and in general superficial	Curing is inadequate or no control over water-cement ratio.
			Usage of excessively rich mix.
			Shrinkage reinforcement, if any, insufficient.

### 1.5.6 Sliding Cracks in Reinforced Concrete Beam:

The diagonal mode of failure by sliding along the critical cracks is known as a failure by sliding and usually appears at the edge of the supports of the beam. These types of concrete cracks appear if concrete gets disturbed in a fresh state.



**Fig -19:** Sliding Cracks in RC Beam

**Table -6:** Sliding Cracks

Memb er	Crack Type	Important Characteristics	Possible Reasons
RC Beam	Sliding Cracks in Reinforced Concrete Beams	Runs vertically at edge of support	Concrete in the beam is disturbed at early age when adequate strength is not attained.
		Maximum width at bottom of beam	May be due to disturbance of formwork at green stage or early de-shuttering.

**1.5.7 Tension Cracks in Reinforced Concrete Beam:**

Tension cracks in reinforced concrete beams occur usually due to shrinkage or temperature variations. Tension cracks usually appear in those members where restraint is provided in the longitudinal movements. Usually, tension cracks tend to propagate over the full depth of the cross-section of beam.

**Fig -20:** Tension Cracks in RC Beam**Table -7:** Tension Cracks

Memb er	Crack Type	Important Characteristics	Possible Reasons
RC Beam	Tension Cracks in Reinforced Concrete Beams	Appear over the whole periphery. Generally over the whole length of member.	Capacity of member in Tension is inadequate
		Parallel to each other & Uniformly observed.	Tensile Reinforcement is insufficient.

**2. CASTING & EXPERIMENTAL SETUP**

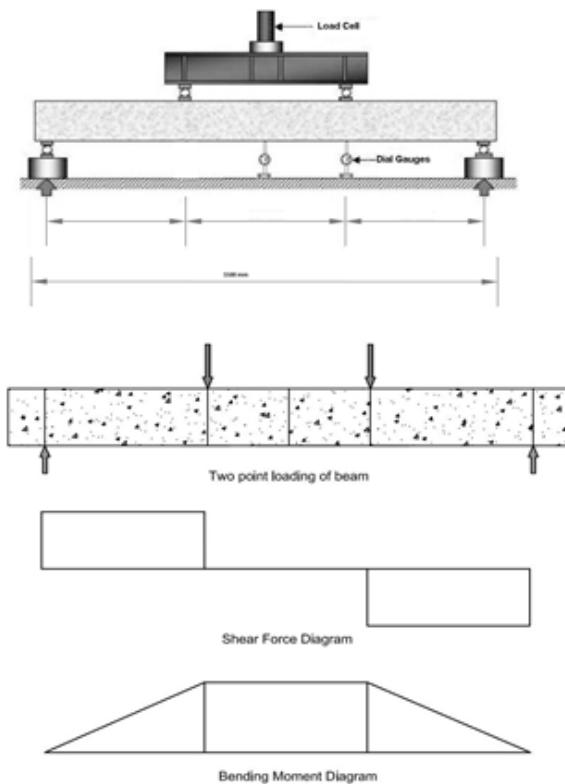
**Reinforcing steel:** HYSD bars of 8mm diameter were used as main reinforcement. 6mm diameter mild steel bars were used for shear reinforcement. 8mm Rings were provided at 6 inch intervals along the length of the specimen.

**Concrete Mixing:** Mixing of concrete should be done thoroughly to ensure that concrete of uniform quantity is obtained. Hand mixing is done in small works, while machine mixing is done for all big and important works.

**Compaction:** Specimens were compacted by using needle vibrator for good compaction of concrete. Finally the surface of the concrete will be leveled, finished and smoothened by metal trowel and wooden float.

**Curing of concrete:** The concrete is cured to prevent or replenish the loss of water which is essential for the process of hydration and hence for hardening also curing prevents the exposure of concrete to a hot atmosphere and to drying winds which may lead to quick drying out of moisture in the concrete and thereby subject it to contraction stresses at a stage when the concrete stronger more durable more resistant to abrasion and to frost. Curing period is 28 days.

Beam specimens were tested in the loading frame. The testing procedure for the entire specimen was same. The most commonly used load arrangement for testing of beams will consist of 2 point loading. This has the advantages of substantial region of nearly uniform moment coupled with very small shears. The load will normally be concentrated at a suitable shorter distance from a support. Two point loading arrangement was done as shown in the figure. 21 & 22. The load is transmitted through a load cell and spherical seating on a beam. This beam bears on rollers scattered on steel plates bedded on the test member with mortar, high strength plaster or some similar material. The loading frame must be capable of carrying the expected test loads without significant distortion. Ease of access to the middle third for crack observations, deflection readings and possibly strain measurements as important consideration as is safety when failure occurs. The specimen was placed over the two steel rollers bearing leaving ends of the beam. Two number of dial gauges were used for recording the deflection of the beams. One dial gauge was placed just below the center of the beam and the remaining dial gauges were placed just below the point loads to measure deflections.

**Fig -21:** Experimental Set-up of RC Beam



**Fig -22:** Experimental Set-up of RC Beam in Laboratory



**Fig -23:** Data logger

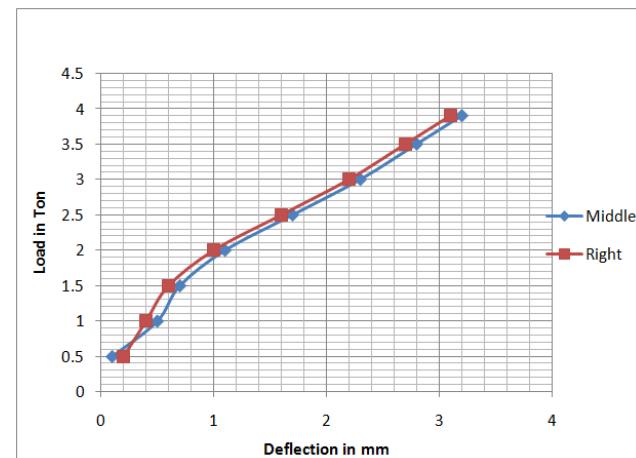
### 3. EXPERIMENTAL INVESTIGATION & STUDY

This chapter gives us the clear idea of investigation & study of crack patterns in RC Beam specimens. The load deflection history & mid-span deflection of all beams were recorded. After setting and reading all gauges the load was increased incrementally up to the calculated working load, with loads and deflections recorded at each stage, loads will then normally be increased again in similar increments upto failure, with deflection at this stage will usually be large and easily measured from a distance. Similarly cracking and manual strain observations must be suspended as failure approaches unless special safety are taken. If it is essential that precise deflection readings are taken upto collapse. Cracking and failure mode was checked visually and a load was prepared.

**Table -8:** Load Vs Deflection set-1

(Average value of 3 beams)

Load	DEFLECTION IN MM	DEFLECTION IN MM
	LVDT 1(Middle)	LVDT2(Right)
0.5	0.1	0.2
1	0.5	0.4
1.5	0.7	0.6
2	1.1	1
2.5	1.7	1.6
3	2.3	2.2
3.5	2.8	2.7
3.9	3.2	3.1



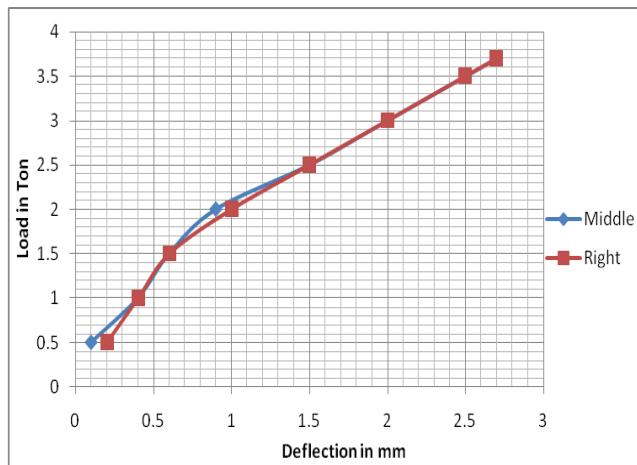
**Chart -1:** Load Vs Deflection graph set-1

(Average value of 3 beams)

**Table -9:** Load Vs Deflection set-2

(Average value of 3 beams)

Load	DEFLECTION IN MM	DEFLECTION IN MM
	LVDT 1(Middle)	LVDT 2(Right)
0.5	0.1	0.2
1	0.4	0.4
1.5	0.6	0.6
2	0.9	1
2.5	1.5	1.5
3	2	2
3.5	2.5	2.5
3.7	2.7	2.7



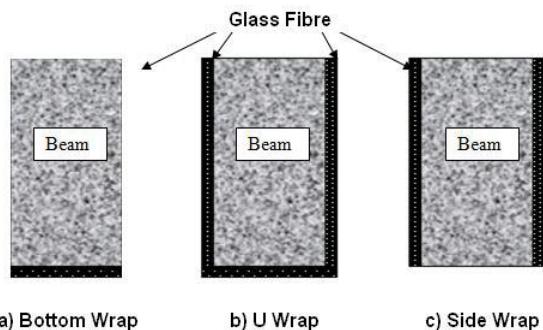
**Chart -2:** Load Vs Deflection graph set-2

(Average value of 3 beams)

#### 4. CONCLUSION

The ultimate load carrying capacity & crack patterns of RC Beams have been studied in this experimental investigation.

In order to increase the load carrying capacity of beam we can also use wraps of like GFRP, FRP etc., some of the wrapping techniques are:



**Fig -24:** Wrapping Techniques

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