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Causes and Effects of Structural Cracks

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ABSTRACT

Failure generally occurs due to complete fracture (brittle failure or excessive deformation), which may or may not result in rupture. In most cases, cracks are responsible for concrete failure. Cracks in reinforced concrete structures are early signs of distress that must be diagnosed accurately to prevent the same cracks from reappearing over time. This paper presents the causes of structural cracks and some remedies.

Keywords - Failure, deformation, structural cracks, reinforced concrete.

1. INTRODUCTION

Concrete is a worldwide used construction material. Concrete properties have been boosted as a consequence of deep research. In fact, the improvements have been focused on its applications, mechanical strength and chemical resistance enhanced and development of latest materials such as pre-stressed concrete. We observe that all these improvements and technical advances have not brought concrete to perfection with time. When we look attentivelyat the reinforced concrete structures of the latest buildings in the world, we notice that none of these structures is fullyintact. This reveals the inevitable concrete weakness that is its possibilityto crack. We know that cracks are different therefore can be developed as a result of many hidden circumstances.

The main objective of this paper is to identify the types of structural cracks, their causes and some remedies.

2. LITERATURE REVIEW

2.1General

The strength of a material and its capacity to withstand load decrease gradually due to internal issues (cracks).Cracks origin is always found near the spot where the highest tensile stress concentration is built up under load. They appear in either hardened or plasticconcrete. Cracks may be a representation of damage, they may direct to serious structural problems. We have two types of cracks that are structural and non-structural cracks.

Non-structural cracks are those that do not affect the stability of the structures automatically at the beginning. They are superficial in nature and less severe, while the structural cracks are deep-seated and potentially dangerous because touching the structural integrity.

In fact, crack is considered as a dangerous disease similar to cancer that should be treated in its primary stage but become destructive in later stages. In order to avoid this cancer (crack) in the structures, Engineers must understand its sources that means its causes.

2.2Classifications of Cracks

Thin – narrower than 1 mm.
Medium – 1mm to 2 mm wide
Wide – Cracks larger than 2 mm
Cracks have straight, toothed, stepped, map patterns or random and are diagonal, vertical or, horizontal.

3. TYPES OF STRUCTURAL CRACKS IN SLAB

3.1 Plastic shrinkage cracking

3.1.2 Causes

This crack occurs while in the concrete in the curing stage and can be reduced or prevented with proper joint placement.

This crack appears on the horizontal surface of fresh concrete after placement as shown in Figure 1. This is due to the rapid drying of the concrete before its setting time caused. This happens when the evaporation rate exceeds the rate of bleeding; the concrete dries and shrinks at the surface while the interior of the concrete does not dry and shrink and result in a high amount of paste due to segregation, which causes a tensile force at the concrete surface. The rate of evaporation depends on the weather: higher air temperature, lower relative humidity and high wind speed in sun exposure.

Figure 1: Plastic shrinkage

3.1.3 Remedies

In adverse conditions, building windbreaks help in reducing the wind velocity and provide a sunshade to control the surface temperature of the concrete. Constructors can schedule concrete placement at night or early in the morning. Fog nozzles are used to saturate the air above the surface.

3.2 Spalling

3.2.1 Causes

This crack is due toreinforcement corrosionor reaction between implanted steel bars in the concrete mixture. When the steel bars corrode, the expansion of the rust is 10 times the original volume that provokesthe formation of tension forces inside the concrete. The problem is, concrete becomes impuissant to hold the tension forces, therefore the pieces between the corroded steel and the surface near to it start breakingoff. Another cause may be:

Poor surface finishing or improper curing of the slab reaction between implanted steel bars in the concrete mixture or bad concrete mixing

- Steel exposed by minor spall leaves it unsafe and gets more corroded shown in Figure 2. The more rate of corrosion in steel more will be the spalling, shown inFigure 3.
- Spall in an area can be the firstslice of a big problem hidden inside which may present complete destruction of the steel by corrosion.

A wide spall area in a slab is a sign of structural danger. When more concrete has broken down at the bottom of the slab, leaving the reinforcing uncovered, the tension and compressive forces cannot be helddue to the absence of concrete that resultsin the steel acting as a cage only shown byFigure 3.

Figure 2: Minor spall area due toreinforcement corrosion.

Figure 3: Large spall area on all balconies

3.3 Expansion cracks

In hot weather,the reinforced concrete slab expands, as it gets hotter. During its expansion, the stress developed in the concrete slab pushes away any object on its way such as walls or a slab next to it. If the concrete does not have a space to expand, the force will cause a crack in the slab and in the structural element near to it as shown in Figure 4.

Figure 4: Expansion crack

3.3.1 Remedies

An expansion joint made of a compressible materialis used as a separation or isolation joint, between two static surfaces. The compressible material acts as a shock absorber that relieves stress on the concrete and can stopcrack.

3.4 Heaving cracks

Expansion of clay soils causes slab heaving due to the absorption of moisture. Garden irrigation, broken sewer pipes, groundwater, rainwater, poor surface drainage are some sources of moisture.

Roots of trees near reinforced concreteslabs may enter inside the concrete and destroy it by lifting and cracking the concrete.

4. TYPES OF STRUCTURAL CRACKSIN BEAMS

4.1 Overloading cracks

Concrete may get damaged or even fail when a structure is overloaded beyond its safety factors. Several types of cracks may be developed due to the Overloading of a structural member. The identification of the type of loading depends on the direction and location of cracks.

4.1.1Causes

4.1.2 Shear crack

The shear crack occurs due to the reason of shear failure and it occurs near the supports of the beam. It appears at an angle of 45 degrees and it is a very serious structural active cracks. It can appear as diagonal cracks at quarter points along the beam and designate serious structural problems.This happens due to a lack of shear reinforcement.This happens when the shear capacity of the beam is inadequate or due to insufficient stirrups cross-section in the beam.

4.1.3 Flexural crack

There are two types of flexural cracks, one is developed at the top of the support, which is negative, and the one developed at the bottom that is a positive one. This crack develops at the bottom near the mid-span and spread upwards. It may be single or multiple cracks and occur when the tension of the beam occurs at the bottom due to heavy load flexural cracks forming. This is due to maximum bending moment inside the beam,poor design, insufficient reinforcements or insufficient concrete cover.

4.1.4 Torsion crack

Pure torsion in a beam is a crack running throughout the length of the member. Insufficient torsion and shear reinforcement of beam.

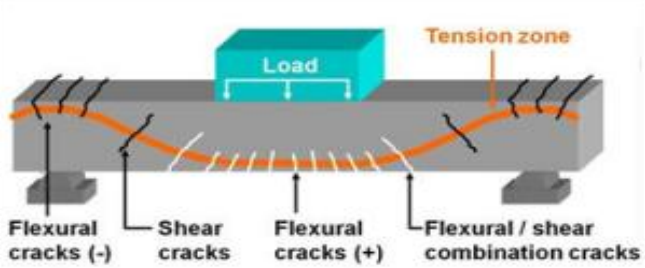

Figure 5:locations and directions of overloading cracks

4.1.5Remedies

- Provide adequate and sufficient cross-section of stirrups and main reinforcement bar in the beam.

- Good design and construction practicesshould be followed.

5.TYPES OF STRUCTURAL FOUNDATION CRACKS

5.1 Settling cracks

5.1.1Cause

The presence of voids in the ground underneath creates settlement, which is due to insufficient compaction of the soil below the foundation. These are the very dangerous cracks.

Figure 6: Settling cracks

5.2 Stair-Step or Diagonal Cracks

5.2.1CAUSES

stair-step or diagonal cracks frequently appear in masonry along the mortar joints between bricks as stairs. This crack has the same causes as heaving. In fact,the presence of water in the soil is onecause. The soil is expended and pooled in contact with water and develop pressure in the foundation. This pressure is exerted on the wall that starts cracking in a zigzag manner. It may also appear at the corner of the house.

5.3 Vertical and Horizontal Cracks

5.3.1CAUSE

This is a sign of a big problem in the foundation. This happens as a result of shifting or moving of the soil under the house. When the soil expands wall moves inward. We observe many kinds of vertical cracks, which have different meaningsdepending on the type of foundation material. The new building can experiment with hairline vertical, smallercracks because of initial settlement. These types of cracks are normally minor but when they become wider, they represent a serious danger to be treated urgently.

Figure 7: Foundation crack

5.3.2Remedies

- Provide horizontal movement of joint between the top of the walls and thebottom beam. If the movement of the joint is not provided it willcause the separation cracks in between RC beam and masonry Joints.
- Provide lateral support to the brick panel's walls at the top by using restraints like telescopic anchorage. It allows the movement in the vertical direction as well as take horizontal shear due to the wind, etc.
- Provide a proper drainage system.
- Foundation soil should be well compacted.
- Vegetation should be far away from the houses.
- Avoid construction on clay soil.

6. TYPES OF STRUCTURAL CRACKS in Reinforced Concrete Column

1) When the stress in the structure is greater than its strength, cracks start developing automatically in the structure. In fact, stress is caused by externally applied loads that lead to cracks inthe column.

2)

6.1 Splitting Cracks in column

The cracks widths vary; they are vertical cracks, short and parallel.

6.1.1 Causes

3) Insufficient steel reinforcement, deficient cross-section, and/or inferior concrete quality, and corrosion in reinforcement are the main causes of the occurrence of splitting cracks into columns.

This crack occurs at the maximum load-carrying capacity of the column and due to insufficiency of the main reinforcement.

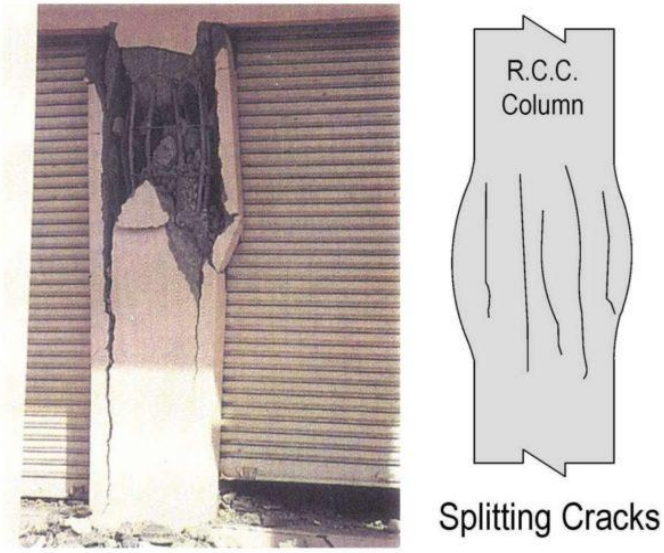

Figure 8: splitting crack

6.2 Diagonal cracks in the column

These cracks run inthe diagonal direction, they appear anywhere in the height and have a constant thickness.

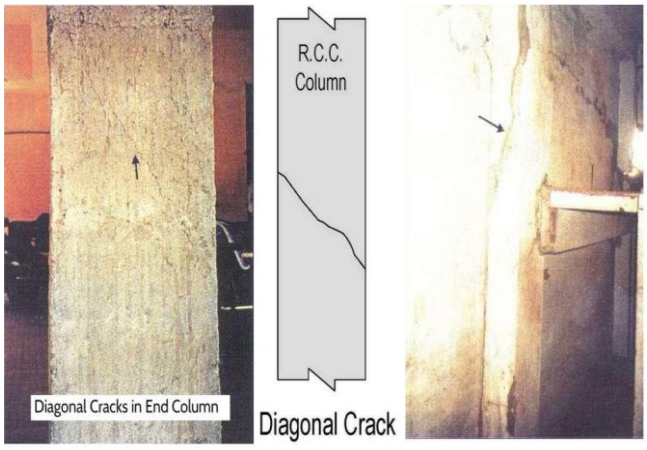

Figure 9: Diagonal crack

6.2.2 Causes

Load carrying capacity and cross-section are insufficient.

Inadequate steel reinforcement

7.HORIZONTALCRACKS IN REINFORCED CONCRETE COLUMN

7.1 Causes

This initiates at the beam-column junctions as indicated by the Figure below. This crack might be because of incorrect design, faulty construction, overloading, corrosion of reinforcement, isolated settlement of the foundation, creep and shrinkage. Columns with adequate moment resistance capacity, insufficient reinforcements, or improper disposition of installed reinforcement are prone to horizontal cracking; due to the effect of shear force and direct load and uniaxial bending. Horizontal crack reduces the column's shear strength and gives rise to failure.

This crack is developed horizontally at the beam-column junction due to the shear force shown in the figure below.

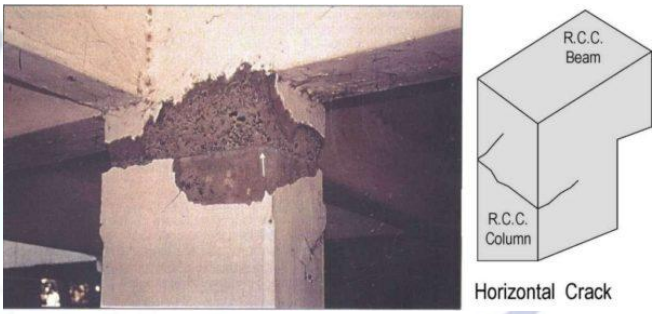

Figure 10. Crack at beam-column junction due to shear force.

8.Corrosion Cracks in Reinforced Concrete Column:

This type of crack expands with time, run along the line of reinforcement as shown in the figure.

8.1 Causes

This crack is provoked by a chemical reaction between the construction elements. It can be developed when the bond between reinforcing bars and concrete is adequate or because of moisture, air and water penetrate through an existing crack.

A crack may occur in the column due to wrong design, faulty construction or overloading, reinforcement's corrosion due to settlement of foundation or creep and shrinkage.

8.2 Remedies

Use corrosion resistance bars, select a good grade of concrete and good mixing and placement.

Materials of good quality should be used. Follow the standard construction practices and guidelines to minimize the drying shrinkage.

9. CONCLUSIONS

This paper has gone through the main sources of structural cracks and their remedies and tried to explainhow cracks occur. It is suggested that care should be taken in the design of the structures in all the steps of the construction from the analysis to the design until the end of the service life to avoid failure.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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