Study on Generation, Causes and Prevention of Cracks in Structural and Non Structural Members in Buildings

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Abstract - Building cracks are one kind of universal problem that occur in any type of concrete structure. It is most important to understand the causes and preventive measures to be taken. A Crack is to be affects the building artistic and destroys the wall integrity, affects the structure safety and reduce the durability of concrete. Some wrong steps are during construction and some unavoidable reasons are to be form different types of cracks are appeared on structure; they are to be classified into structural and non-structural cracks. Structural cracks are due to incorrect design, faulty construction, poor quality& material, over loading which of these may endanger the safety of structures. Non-structural cracks are due to elastic deformation, thermal movement, creep, vegetation, chemical reaction etc. In concrete, cracks can't be prevented entirely but they can be control uses adequate material and repair techniques to use of construction. Some types of cracks causes serious problem and they are to be structurally hazardous. This paper gives information to causes and preventive measures should be taken to control the cracks before construction of the structure.

Keywords-Building Cracks, causes of cracking, structural failure, preventive measures.

I. INTRODUCTION

Concrete slabs exposed to direct sunlight experience temperature related horizontal movements. In addition, temperatures on the top surface will be higher than those on the underside of the slab, causing an upward deflection of the slab during heating. In a typical building, masonry and concrete elements are connected to each other at their respective interfaces. Therefore, significant movements may be generated on the masonry walls due to the movement of the roof slab. These movements can result in overstressing and cracking in masonry. These cracks may not be structurally serious but may lead to ingress of moisture and in any case are not acceptable especially where good finish is desired.

Cracking is the most common and visible defect found in masonry. Most buildings crack at some time during their service life. The appearance of a crack is a symptom of distress within the fabric of a building. Cracking in brittle materials such as masonry are caused by internal stresses building up until they exceed the rupture strength of the material. Once the rupture strength is exceeded the crack develops and internal stresses are dissipated. These stresses are generally caused by the movements of the building due to uneven foundation settlements, temperature changes, shrinkage due to moisture changes, chemical processes or creep deformations of materials.

Concrete structures are full of cracks. Failure of concrete structures typically involves stable growth of large cracking zones and the formation of large fractures before the maximum load is reached. When a crack length reaches a certain critical length, it can propagate, even though the average stress is much less than the tensile strength of the test specimen. Fracture mechanics tries to find the quantitative relations between crack length, material's resistance to crack growth, and the stress at which cracks start to propagate.

Formations of cracks require a certain amount of energy, which agrees with the fracture mechanics concept. Finite element analysis based on the strength criteria is un-objective around sharp crack, that is, the analysis depends on the choice of mesh size. Limit analysis approach based on plasticity theory cannot be justified in brittle types of failures, e.g., punching shear, shear failure without shear reinforcement, etc. Size effect can be addressed by fracture mechanics.

1.1 OBJECTIVE OF WORK

The objective of this paper is to provide an overview of the design principles and the behaviour of reinforced concrete

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members and masonry subjected to cracks. Factors affecting the formation of cracks due to externally applied loads or due to restraints against drying shrinkage are discussed. The report is directed primarily to the general reader in need of working information on the structural behaviour and the cracking of reinforced concrete.

II. LITERATURE REVIEW

Baweja et al examined the long term performance of plain and blended cement concretes for ten individual structures. They observed that the major factor influencing concrete performance adversely was the low initial specified strengths. They found that chloride ion concentration profiled with in the first 50mm of the surfaces of the wharf structures and the slab on grade structures considered showed these to peak at around 20mm below the concrete surface. This could have implications on reinforcement corrosion if bars were located in these regions.

Beeby reviewed the evidence arising from exposure tests on reinforced concrete members relating to the influence of cracking on corrosion. This evidence gives no reason to conclude that any relationship exists between crack width and corrosion. This result was confirmed by considerations of the chemistry of corrosion of steel in concrete and the physical nature of cracks. This study was limited to the consideration of the corrosion of reinforcing bars in structures exposed to the atmosphere. Pre-stressed concrete and submerged structures are not considered. A structure, however well it is designed and constructed requires periodic maintenance. The maintenance and repair of concrete surface may be necessitated due to any one of several causes, such as the effects of normal wear and tear, stresses induced by abnormal differential temperatures, inadvertent errors in 16 design, detailing and construction, exposure to aggressive environments like fire and earthquake, etc.

Datta and **Aggrwal** in their paper outlines the agencies and processes which cause the deterioration of concrete surfaces and describes methods of maintenance and repairs including removal of stains. Development of cracks in buildings results in loss of strength and stability, causes rain penetration, decreases sound insulation and affects aesthetics and overall efficiency.

Suresh Chand in his paper mentioned the task of selecting causes of cracks and suggested remedial measures to combat the situation. Methods of repair and precautions to be taken while repairing the cracks have also been described.

Sirivivatnanon in his paper presented a review of durability problems in reinforced concrete structures caused by lack of sufficient concrete cover and a statistical concept to analyses and to quantify in situ concrete cover in buildings. Cover data of large number of buildings in Australia and Japan were analysed. It was found that the level of confidence (LOC) for achieving minimum concrete cover for durability were poor, with less than 50 percent of the structures achieving a 90% LOC. It was suggested that an LOC of 90% could be achieved with improvements in design detailing, selection of suitable spaces and good installation practice. The correct choice of the concrete type, cover thickness and good concreting practice, could prove to be the most economical way of achieving the design service life of concrete structures.

III. TYPES OF CRACKS

3.1 TYPES OF CRACK PATTERNS

A crack is a complete or incomplete separation of concrete into two or more parts produced by breaking or fracturing. Cracks are one kind of universal problem of concrete of construction as it affects the building artistic and it also destroy the wall's integrity, affects the structure safety even reduce the durability of structure. Cracks develop due to deterioration of concrete or corrosion or inappropriate selection of constituent material and by temperature and shrinkage effects.

Cracking is a failure that occurs most often in structures. In order to treat the crack, one must know the causes of stresses that have resulted in the formation of cracks. An estimation of these stresses before the construction will help in bringing designs that will have the provision to anticipate for movements that are the reason for cracks. The occurrence of cracks may be in different ways but certain typical modes and characteristics exist for these. The cause of cracks can be clearly understood from the type and the magnitude of the cracking.

3.1.1 MASONRY

The main reason behind the formation of cracks in the walls is the deformation. These deformations occurred may be at the macroscopic level or at the macroscopic level. Here different deformations as different causes of crack formation are explained below:

1. Deflections in Slab or Roof Elements
2. Differential changes due to temperature changes and stresses
3. Roof Expansion and Construction
4. Cracking due to Creep and Shrinkage
5. Poor Detailing and Improper Construction
6. Load Bearing Parameters
7. Foundation Factors
8. Settlement

3.2 STRUCTURAL CRACKS

Structural cracks occur due to incorrect design, faulty construction or overloading and these may endanger the safety of a building. Structural cracks are formed in beams, columns and slabs.

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3.2.1 BEAM

A beam is a structural element that is capable of withstanding load primarily by resisting against bending. The bending force induced into the material of the beam as a result of the external loads, own weight, span and external reactions to these loads is called a bending moment. Beams are characterized by their profile (shape of cross-section), their length, and their material.

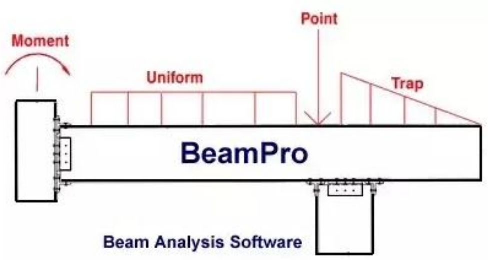

Fig No. 1 Types of cracks in Beams

3.2.2 SLABS

A concrete slab is a common structural element of modern buildings. Horizontal slabs of steel reinforced concrete, typically between 4 and 20 inches (100 and 500 millimetres) thick, are most often used to construct floors and ceilings, while thinner slabs are also used for exterior paving. Sometimes these thinner slabs, ranging from 2 inches (51 mm) to 6 inches (150 mm) thick, are called mud slabs, particularly when used under the main floor slabs or in crawl spaces.

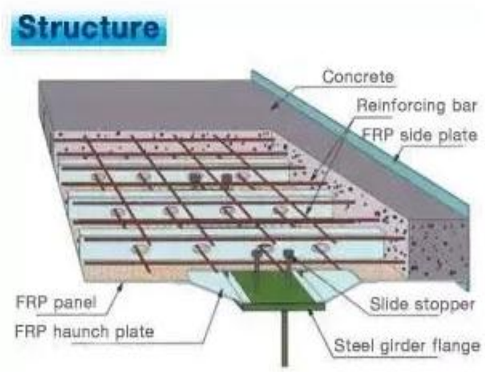

Fig No. 2 Types of cracks in Slabs

3.2.3 COLUMNS

A column or pillar in Architecture and Structural engineering is a structural element that transmits, through compression, the weight of the structure above to other structural elements below. In other words, a column is a compression member. The term column applies especially to a large round support (the shaft of the column) with a capital and a base or pedestal [1] and made of stone or appearing to be so. A small wooden or metal support is typically called a post, and supports with a rectangular or other non-round section are usually called piers.

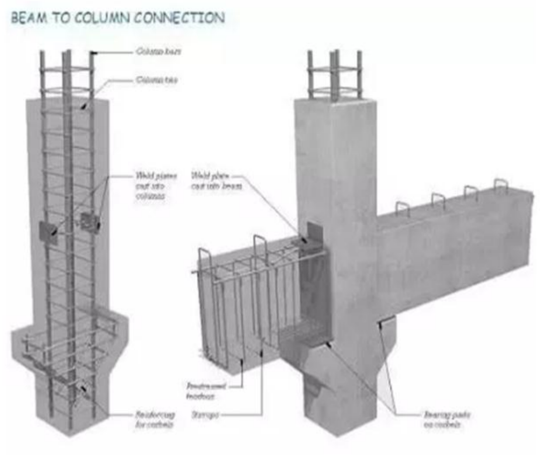

Fig No. 3 Types of cracks in Columns

3.3 NON-STRUCTURAL CRACKS

They may due to internal forces developed in materials due to moisture variations, temperature variation, crazing, and effects of gases, liquids etc. Non-structural cracks are formed due to alkali-aggregate reaction, due to corrosion of steels.

IV. CAUSES AND PREVENTION OF CRACKS IN CONCRETE STRUCTURES

Concrete can crack due to a number of causes. Some of the most significant causes are discussed in detail.

4.1 TENSILE STRENGTH OF CONCRETE

The tensile strength of concrete is a widely scattering quantity. Cracking occurs when tensile stresses exceed the tensile strength of concrete. To control cracks in concrete, the tensile strength of concrete is primarily importance. The concrete cracks may occur due to restraint forces.

4.1.1 CAUSES OF CRACKING DURING CONCRETE HARDENING

Concrete cracking can develop during the first days of placing and before any loads applied to the structure. Stresses develop due to different temperatures within the concrete. These stresses exceed the developing tensile strength, cracks to be occurred. If concrete members are allowed to cool, tensile stresses reach the higher values than developing tensile strength.

PREVENTIVE MEASURE

Keep the temperature within the concrete a slow as possible to minimize the cracks. Cement with low heat of hydration should be selected. Heat development can also be reduced by adding fly ash or slag furnace cement.

4.1.2 CAUSES OF CRACKING AFTER CONCRETE HARDENING

Tensile stresses due to dead and live loads causes cracking. Normal reinforcement should be designed to provide required strength. Cracks can also be initiated by tensile stresses due to restrained deformations from

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temperature variations or from shrinkage and creep of concrete.

4.1.2.1 ELASTIC DEFORMATION

It is to be occurred, when a material goes strains under a stress. Two materials are having different elastic properties meet together under the effect of weight then different stresses are came in these materials produced cracks at junctions. Dead and Live loads are he main reason of elastic deformation inn any structural building.

PREVENTIVE MEASURES

To create the slip (continues) joints under the support of concrete slab on walls. To provide the horizontal joints between reinforced cement concrete slab or beam and brick panel top most.

4.1.2.2 THERMAL MOVEMENT

Thermal movement is one of the most important causes of crack in buildings. Most of the materials are expanding when they are to be heated and contract when they are to be cooled. The expansion and contraction can changes with the temperature occur on the building's cross sectional area.

Table: 1 Coefficient of thermal expansion of some common building materials (within the range from 0^0C to 100^0 C)

S NO	Material	Coefficient of thermal expansion
1	bricks and brick work	5 to 7
2	cement mortar and concrete	10 to 14
3	sand lime bricks	11 to 14
4	stones	
	a) igneous rocks	8 to 10
	b) lime tones	2.4 to 9
	c) marble	1.4 to11
5	metals	
	a) bronze	17.6
	b) copper	17.3
	c) steel and iron	11 to 13

PREVENTIVE MEASURE

Thermal joints can be neglected and to be introduced by slip joints, expansion and construction joints. The joints should be designed at the time of planning and should be constructed carefully.

4.1.2.3 CREEP

In concrete, creep depends on water and cement content, water cement ratio, temperature, humidity, use of admixtures and pozzolans, age of concrete at the time of loading and size and shape of the component. Creep increases with increase in water and cement content, water cement ratio, and temperature. It decreases with increase in humidity of the surrounding atmosphere and age of material at the time of loading. In case of brick work, creep depends on stress/strength ratio. Creep in brick work with weak mortar, which is generally high stress/strength ratio, is to be more.

PREVENTIVE MEASURE:

Use the admixtures and pozzolans in concrete to increase the creep. In steel the amount of creep increase with the rise of temperature.

4.2 CHEMICAL REACTION

Certain chemical reactions in building material results in appreciable increase in volume of materials, due to which internal stresses may lead to formation of cracks. The common chemical reactions are:

- Carbonation
- Chlorides
- Sulfate attack
- Alkali aggregate reaction

4.2.1 CARBONATION

In some areas, the concentration of carbon dioxide is to be high with a relative humidity of 50 % – 60 % associated with high water cement ratio and low cement content a reaction takes place known as carbonation due to the alkalinity of concrete comes down and causes to corrosion of rebars. Carbon dioxide penetrates into concrete and a chemical reaction that leads reduction of alkalinity of concrete is explained below:

$$CO_2 + H_2O \rightarrow H_2CO_3 \text{ (Carbonic acid)}$$

$$Ca(OH)_2 + H_2CO_3 \rightarrow CaCO_3 + 2H_2O$$

4.2.2 CHLORIDES

A chloride enters into the concrete when it comes into contact with the environment containing chlorides such as sea water or de-icing salts. Generally the chloride action starts the surface and creeps inwards. This process is time taken and essentially depends on:

1. The amount of chlorides comes into contact with the concrete surface
2. Permeability of concrete
3. Amount of moisture present

Chloride induced corrosion is very effective in the presence of moisture and contacted with carbonation.

Table 2 presents the tolerable crack width in reinforced concrete as suggested by ACI 224R-90.

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Table.2: Tolerable Crack Width for Different Exposure Condition

Exposure Condition	Tolerable Crack Width (mm)
Dry air, protective membrane	0.41
Humidity, moist air, soil	0.30
De-icing chemicals	0.18
Seawater and seawater spray, wetting and drying	0.15
Water-remaining structures	0.10

4.2.3 SUFPHATE ATTACK

The presences of soluble sulfates such as sodium, calcium or magnesium sulphates are the most common in soil and water. All sulphates are comes in contact with concrete, they react with cement paste and can form gypsum and ettringite. This compound expands, pressurizes and disrupts the paste. As a result surface scaling and disintegration and followed by mass deterioration takes place in concrete.

4.2.4 ALKALI AGGREGATE REACTION

Alkali aggregate reaction (AAR) may create the expansions and severe cracks on concrete structures and concrete pavements. The mechanism that causes alkali aggregate reaction are not fully understood. What known about this type of reaction is that certain aggregates, such as reactive form of silica, reacts with potassium, sodium and calcium hydroxide from the cement and form a gel around the reacts with aggregates. The aggregate surrounding the gel exposed to moisture, it will be expands, creating forces that causes tension cracks to formed aggregate surroundings.

Alkalies + reactive silica → Gel reaction product

Gel reaction product + moisture → Expansion

PREVENTIVE MEASURE

To control this type of cracks from the effect of alkali-silica reactions should be used for proper size of aggregates, Pozzolana cement and low Alkali cement.

4.3 POOR STRUCTURAL DESIGN AND SPECIFICATIONS

The buildings lose from its durability on the blue print itself or at the time of preparation for the specifications of concrete materials, concrete and various other parameters. It is also important to the geotechnical (soil) investigation to determine the type of foundation, the type of concrete material to be used in concrete and the grade of concrete depends on chemicals present in ground water and subsoil. In addition, inadequate skills and poor experience of the contractor, ultimately causes deterioration (the process of impaired quality) of the building and closely spacing of the reinforcement steel due to inadequate detailing and slender concrete causes segregation. The structural consultant to provide adequate reinforcement steel to prevent structural members for developed the large cracks from applying load.

PREVENTIVE MEASURE (PRECAUTIONS)

- Proper specifications should be maintained for concrete and materials.
- Should be maintained for quality of concrete and thickness of cover from the concrete surrounding the reinforcement steel.
- Select the proper construction companies for their designs. Special care should be taken from the design and the structure must be inspection for all phases of the construction project.
- Constructible and adequate steel design.
- Proper designations to take care for environmental conditions (sub- soil conditions).

4.4 POOR CONSTRUCTION PRACTICES

The construction companies had in general follow to no-technical persons most of them had a little or no knowledge of correct construction industry. There is a general lack of good construction practices either due to negligence, carelessness, ignorance. Or still, a combination of all of these. For a healthy building it is absolutely necessary for the construction company and the owner to select good quality materials and good construction practices. All the way to building completion every step must be properly supervised and controlled.

MAIN CAUSES

- Improper (irregular) selection of materials.
- To select the cheap quality materials for plumbing and sanitation.
- Do not maintain the proportion mixing of the constituents like concrete, mortar etc.
- Inadequate controlling on various steps for concrete production like batching, mixing, Transportation, placing, finishing and curing.
- Improper construction joints between subsequent concrete pours or frame work and masonry.

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4.5 MOISTURE MOVEMENT

All most of the building materials (concrete, mortar, brick, timber etc.) expands on absorbing moisture from atmosphere and shrink on drying. It is to be a cyclic nature and causes due to increase or decreases by the inter pore pressure from the moisture changes. Shrinkage may cause by the following factors:

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Excessive water: The quantity of water used in the concrete mix or mortar mix causes shrinkage. Compacted concrete contains high shrinkage and high quantity of water than vibrated concrete. Based on researchers moisture movement for dome of the building materials

Table: 3 Moisture movement for some of the common building materials

S No	Material	Moisture movement
1	Burnt clay bricks, limestone	0.002 to 0.01
2	Hollow clay bricks, terracotta	0.006 to 0.016
3	Sand stone, sand lime bricks	0.01 to 0.05
4	cement lime mortar, dense concrete	0.02 to 0.05
5	autoclaved concrete, clinker concrete	0.03 to 0.08
6	marble	negligible

PREVENTIVE MEASURE

Use the minimum quantity of water for mixing the cement concrete or cement mortar based on water -cement ratio. Don't use excessive cement in mortar mixing. Shrinkage cracks in masonry could be controlled by the use of rich cement mortar and by delay the plastering work it will be dried after curing and most of the initial shrinkage undergoes. In case of concrete structures, shrinkage cracks can be controlled by using temperature reinforcement. Plaster with the well graded sand from less shrinkage and is applied for the external faces of the walls..

4.6 CORROSION OF REINFORCEMENT

The products of cement hydration are highly alkaline in nature and the p^H value of hardened concrete ranging from 12.6 to 13.5. Therefore the steel in RCC structure is safely protecting by the layer of concrete around. The two main causes that lead to the loss of resistance of steel in concrete are:

1. Reduce the alkalinity of concrete surrounding the steel with p^H value of lower than 11 to 11.5 maintain.
2. Chemicals are presence, which destroys the passivity even while the alkalinity of surrounding concrete remains high.

Fig: 4 corrosion of reinforcement

The essentials for triggering corrosion of reinforcing steel bars in concrete are:

1. De-passivation of steel
2. Oxygen
3. Occurring irregular intervals presence of water i.e. alternate wetting and drying.

4.7. PERMEABILITY OF CONCRETE

As deterioration processes in concrete begin with penetration of various aggressive agents, low permeability is the key to its durability. Concrete permeability is controlled by the factor like water-cement ratio, degree of hydration/curing, air voids due to the deficient compaction, micro-cracks due to load and cyclic exposure to thermal variation. The first three are important to the concrete strength. The permeability of cement paste is a function of water-cement ratio given good quality materials, satisfactory proportion and good construction practice. The permeability of the concrete is a direct function of the porosity and interconnection between the pores of the cement paste

4.8 VEGETATION

Fast growing trees in the construction area surrounding the compound walls sometimes causes in walls. Due to the expansive action of roots are come into the foundation below. Tree roots are spread horizontally from all sides. The cracks occur on clay soil because moisture contains roots.

PREVENTIVE MEASURE

Don't grow any type trees nearer to the structures. Tree saplings can be removed as soon as possible near of compound walls.

V. CONCLUSION

This paper can be divided into four parts. First part considers introduction of cracks and about the researchers has to be tells that previous attempts in second part. Third part contains types of cracks in masonry and concrete structures. The last part contains causes of cracks and its preventive measures to be followed to cure cracks before construction from any type of structures. If proper design is considered for construction materials and proper measures to be taken to control cracks. We focus on main causes of cracks and preventive measures should be taken initially, our structure is to be safe.

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