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Causes and Preventive Measures of Cracks in Residential Building

Vinayak Pavate[1], Akanksha Anuse[2], Sneha Dongale[3], Srushti Katakr[4], Anurag Pednekar[5]
[1] Lecturer, [2, 3, 4, 5]Student, Department of Civil Engineering, Sanjay Ghodawat Polytechnic, Atigre, 416118, India

***Abstract:** Building cracks are one kind of universal problem that occurs in any type of concrete structure. It is most important to understand the causes and preventive measures to be taken. A crack affects the buildings artistic and destroys the walls integrity, affects the structures safety, and reduces the durability of concrete. Some wrong steps are during construction and some unavoidable reasons are to be form different types of cracks appear on structures; they are to be classified into structural and non-structural cracks. In concrete, cracks can't be prevented entirely but they can be controlled by using adequate material and repair techniques to use of construction. Some types of cracks causes serious problem and they are to be structurally hazardous.*
***Keywords:** building cracks, structural failure, repair techniques for masonry walls, self -healing of concrete and reinforcing steel.*

I. INTRODUCTION

Occurrence of various crack patterns in the building during construction, after completion when it is subjected to super imposed load or during the service life, is a common phenomenon. A building component develops cracks whenever the stress in the components exceeds its strength. Stress in the building component could be caused by externally applied forces, such as dead, live, wind or seismic loads, foundation settlement etc. or it could be induced internally due to thermal movements, moisture changes, elastic deformation, chemical action etc.

A. Cracks In Buildings Could Be Broadly Classified As Structural And Non-Structural Cracks

1) Structural Cracks: These occur due to incorrect design, faulty construction or overloading and these may endanger the safety of a building. e.g. Extensive cracking of an RCC beam.
2) Non structural Cracks: These are mostly due to internally induced stresses in buildings materials and do not endanger 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. e.g. Vertical crack in a long compound wall due to shrinkage or thermal movement.

Cracks may appreciably vary in width from very thin hair crack barely visible to naked eye to gaping crack. Depending upon the crack width cracks are classified as:

a) Thin Crack - less than 1 mm in width,
b) Medium Crack - 1 to 2 mm in width,
c) Wide Crack - more than 2 mm in width.
d) Crazing - Occurrence of closely spaced fine cracks at the surface of a material is called crazing.

Cracks may of uniform width throughout or may be narrow at one end gradually widening at the other. Crack may be straight, toothed, stepped, map pattern or of random type and may be vertical, horizontal or diagonal. Cracks may be only at surface or may extend to more than one layer of material. 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.

The commonly used building material namely masonry, concrete, mortar etc. are weak in tension and shear. Therefore the stresses of even small magnitude causing tension and shear stresses can lead to cracking. Internal stresses are induced in the building components on account of thermal movements, moisture change, elastic deformation, chemical reactions etc..

All these phenomenon causes dimensional changes in the building components, and whenever this movement is restraint due to interconnectivity of various member, resistance between the different layers of the components etc., stresses are induced and whenever these stresses (tensile or shear) exceed the strength of material cracking occurs.

Depending upon the cause and certain physical properties of building material these cracks may be wide but further apart or may be thin but more closely space. As a general rule, thin cracks even though closely spaced and greater in number, are less damaging to the structures and are not so objectionable from aesthetic and other considerations as fewer number of wider cracks.

B. Scope

This project focuses on the assessment of the causes, prevention, and repairs of cracks in buildings. Specifically, this study focuses on determining whether cracks in buildings can be prevented, whether cracks in buildings can be repaired, and examining the causes of cracks in buildings.

C. Objectives

1) To study the causes of cracks in buildings.
2) To study factors affecting the formation of cracks due to externally applied loads or due to restraints against drying shrinkage.
3) To study preventive measures for cracks and more alternatives for preventive measures.

D. Methodology

1) Comprehensive literature review to study the causes and preventive measures of cracks in buildings.
2) Analyze crack formation.
3) Study factors affecting on crack formation.
4) Assembling preventive measures.
5) Investigation of repairs and alternatives.
6) Preparation of a model of cracks in buildings.

II. STUDY THE CAUSES OF CRACKS IN BUILDING

A. Thermal Movement

All materials more or less expand on heating and contract on cooling. When this movement is restrained, internal stresses are created in the component and may cause cracks due to tensile or shear stress. Thermal movement is one of the most potent causes of cracking in buildings and calls for careful consideration.

The extent of thermal movement depends upon:

Ambient temperature variation Coefficient of thermal expansion The expansion of cement mortar and concrete is almost twice that of bricks and brick work. Movement in brickwork in the vertical direction is 50% greater than in the horizontal direction. Dimensions of components The cracks due to thermal movement are caused either by external heat, due to variation in ambient temperature, or by internally generated heat, i.e., heat of hydration in mass concrete during construction. Cracks in the building component due to thermal movement open and close alternately with changes in the ambient temperature. Concreting done in the summer is more susceptible to cracking due to the drop in temperature. in winter since thermal contraction and drying shrinkage act in unison. Whereas the concrete job done in the winter is less liable to cracking, though it may require wider expansion joints.

Generally speaking, thermal variation in the internal walls and intermediate floors is not great and thus does not cause cracking. It is mainly the external walls exposed to direct solar radiation, and the roof, which is subjected to substantial thermal variation, is more liable to cracking.

B. Chemical Reactions

Due to chemical reactions, materials used in construction result in an appreciable increase in the volume of materials. The internal stresses are set up in construction materials, which may result in outward thrust and hence form the wall cracks. The materials involved in chemical reactions also lose strength.

The soluble sulphates present in the soil, groundwater, or clay bricks react with the tricalcium aluminate content of cement and hydraulic lime in the presence of moisture. It forms products that occupy a much bigger volume than those of the original constituents. This expansive nature of materials results in the weakening of masonry, concrete, and plaster. Hence, the wall cracks due to a chemical reaction.

The alkali-reaction, or alkali-granulate reaction (AGR), is a chemical reaction between reactive aggregates and the alkalis contained in the cement. This reaction produces an expansion inside the concrete, which will create tension, swelling, and cracks.

There are three types of reactions:

1) Alkali-carbonate reactions: This reaction is created with aggregates composed of clay dolomite and fine-grained limestone, with the inclusion of clay minerals. The mechanism of swelling is related to the water absorption of clays.
2) The alkali-silicate reaction is similar to the alkali-silica reaction but has slower kinetics, is very rare, and will generally occur a few decades after the concrete element has been manufactured.
3) Alkali-silica reaction: This is the most common type of reaction and usually occurs within a few years after the concrete element is manufactured.

C. Shrinkage Crackin

When concrete is mixed, more water than is needed for hydration is mixed with the dry components, such as sand, cement, and aggregate. Most of the water will eventually evaporate, causing shrinkage in the concrete slab.

Since water evaporates from the surface, which is exposed to air, at a rate different from the underlying concrete, this differential shrinkage rate produces tensile stresses, which are relieved by cracking of the concrete near the surface.

Types of shrinkage in concrete

There are two types of shrinkage in concrete:

1) Initial Shrinkage
2) Plastic Shrinkage

Initial shrinkage cracks in concrete

Initial shrinkage cracks in concrete normally occur in all building materials or components that are cement or lime - based, such as concrete, mortar, masonry units, plaster, etc., and are one of the main causes of cracking in structures. Initial shrinkage in concrete and mortar occurs during the construction of structural members due to the drying out of moisture. The initial shrinkage of concrete is partly reversible if moisture is maintained in the concrete, but it becomes irreversible when the concrete becomes dry. During curing, due to subsequent wetting and drying, this shrinkage exceeds and a crack is developed in the concrete.

Extent of Initial Shrinkage in Concrete

The extent of initial shrinkage in cement concrete and cement mortar depends on a number of factors, including:

a) *Cement Content:* It increases with the richness of the mix.
b) *Water Content:* The greater the water quantity used in the mix, the greater the shrinkage.
c) *Maximum size, Grading, and Quality of Aggregate:* With the use of the largest possible maximum size of aggregate in concrete and with good grading, the requirement of water for desired workability is reduced, with consequently less shrinkage on drying due to a reduction in porosity. E.g., for the same cement aggregate ratio, the shrinkage of sand mortar is 2 to 3 times that of concrete using 20 mm maximum size aggregate and 3 to 4 times that of concrete using 40 mm maximum size aggregate.
d) *Curing:* If the proper curing is carried out as soon as the initial set has taken place and is continued for at least 7 to 10 days, then the initial shrinkage is comparatively less. When the hardening of concrete takes place in a moist environment, there is initially some expansion, which offsets some subsequent shrinkage.
e) *Presence of Excessive Fines in Aggregates:* The presence of fines increases the specific surface area of aggregate and consequently the water requirement for the desired workability, with an increase in initial shrinkage.

D. Design Mistake

Common design and detailing errors in construction arise due to either inadequate structural design or a lack of attention to relatively minor design details.

Contents

Types of Design and Detailing Errors in Construction and Their Prevention

- Inadequate structural design
- Poor design details
- Neglect of the creep effect:

1) Inadequate Structural Design

Due to inadequate structural design, the concrete is exposed to greater stress than it can handle, or the strain in the concrete increases more than its strain capacity and fails.

The symptoms of such failures due to inadequate structural design show either spalling of concrete or cracking of concrete. Excessively high compressive stress due to inadequate structural design results in spalling of concrete. Also, high torsion or shear stresses result in the spalling or cracking of concrete. High tensile stresses also result in the cracking of concrete.
To identify the inadequate design as the cause of the structural damage, the structure shall be inspected, and the locations of the damage should be compared to the types of stresses that should be present in the concrete. For rehabilitation projects, thorough petrographic analysis and strength testing of concrete from elements to be reused will be necessary.

2) Poor design details

Poor design details can cause localised concentrations of high stresses in structural members even if the design is adequate to meet the requirements. These high stresses may lead to cracking of the concrete that allows water or chemicals to pass through the concrete. Thus, poor design details may lead to seepage through the structural members.
Poor design detail may not lead to structural failure, but it can become the cause of the deterioration of concrete. These problems can be prevented by a thorough and careful review of the plans and specifications for the construction work.

Types of poor design detailing and their possible effects on structures are discussed below:

a) *Abrupt Changes in Section:* Abrupt changes in the section may cause stress concentrations that may result in cracking. Typical examples would include the use of relatively thin sections rigidly tied into massive sections or patches and replacement concrete that is not uniform in plan dimensions.
b) *Insufficient Reinforcement at Corners and Openings:* Corners and openings also tend to cause stress concentrations that may cause cracking. In this case, the best prevention is to provide additional reinforcement in areas where stress concentrations are expected to occur.

E. Corrosion of Reinforcement

Normally, concrete provides good protection for steel reinforcement embedded in it. The protective quality of concrete depends on its high alkalinity and relatively high electrical resistivity. of protection depends upon the quality of concrete, depth of concrete cover, and workmanship.
However, when the reinforcement steel gets corroded, it increases in volume with the setting up of internal stress in concrete. In the course of time, it first causes cracks in the line with the direction of reinforcement, later causing spalling of the concrete and the covering of reinforcement from the body of the concrete. thus seriously damaging the structure.
Factors that contribute to the corrosion of reinforcement in concrete are:

1) The presence of cracks in concrete
2) Permeability of concrete
3) Carbonation
4) Formation of corrosion (galvanic) cells,
5) Electrolysis,
6) Alkali-aggregate reaction, use of calcium chloride as an accelerator,
7) presence of moisture
8) Ingress of sea water into porous concrete
9) Presence of soluble sulphates
10) Inadequacy of cover to reinforce
11) Impurities in mixing or curing water: Excessive sulphates and chlorides

F. Vegetation

Concrete contains microscopic cracks that are invisible to the naked eye. Plants have new cell growth at the tips of their roots. As the plant grows, so does the root system. The sensitive tips of the roots have the power to seek the path of least resistance for growth. Microscopic concrete cracks present this path for plants growing beneath the sidewalk.
Once a plant’s roots discover a microscopic crack in the concrete, they force their way into the slab. Even small weeds and seedlings have the power to displace concrete using the potential energy from root growth. Over time, the plant’s continued growth can crack, break, or buckle the surrounding concrete, at which point you may see the plant break through the surface.

1) Tree Roots and Concrete

Tree roots present an even bigger potential problem for concrete surfaces. They move through cement in the same way as smaller plants, but with much greater potential energy. Trees near your concrete areas could push roots beneath and through the surface, causing expensive damage and dangerous cracks in the slab. You may have to cut the roots or even remove the tree to permanently resolve this problem.

G. Earthquake

Cracks and movement are to be expected even in moderate seismic events. Many factors will need to be considered to determine the ability of the structure to continue to provide safe shelter; however, a few quick checks can help put worried minds at ease. Let's discuss a little bit about how buildings are intended to function during a seismic event so we can see why those cracks might show up. Most structures transfer lateral loads, such as wind or seismic, to the foundation through shear walls, braces, or moment frames. The stiffness of the individual elements will control how much the structure moves under load. Flexible structures, such as moment frames that resist lateral forces through bending of the beams and columns, allow for large movements. Typical home construction utilises shear walls, which transfer loads primarily through shear in the plywood.

Interior wall finishes are typically more stiff and brittle than the structure itself. It is expected that these brittle finishes that have a very low tolerance for movement will crack as the larger and more flexible parts of the structure begin to move.

Shear walls can be very strong, but unavoidable features will create weak points in the walls. Doors and windows perforate shear walls and create areas that are prone to additional flex and rotation where headers frame full-height walls. It is common to find cracks that propagate from the corners of doors and windows since these areas act as hinges and rotate as the building moves back and forth. These cracks that run diagonally from perforations are generally of little concern to the integrity of the building.

Not all walls in a typical home are going to be designated as shear walls. Many interior walls are considered partition walls and are just along for the ride. It is common to find vertical cracks where partition walls intersect other walls or horizontal cracks where these walls intersect roof or floor structures above. These cracks form because the finish is unable to hold together the difference in movement between walls and do not indicate a failure.

Significant cracks in buildings will typically occur somewhere in the middle of the wall and run roughly horizontally. These cracks indicate that slippage or rupture of the plywood may have occurred, which will reduce the capacity of the wall. Of course, any floors or roofs that begin to sag or become uneven could indicate a problem. Walls that become noticeably out of plumb, especially if they are exterior walls, may also indicate hidden damage. Any of the aforementioned conditions should be evaluated by a professional.

It is also worth noting that existing cracks may go unnoticed until after a seismic event, when people are typically looking for damage. See if you can figure out if the crack has been there for a while. Maybe there is dust inside the crack or the colours have faded.

H. Elastic Deformation

Structural components of a building undergo elastic deformation due to dead and superimposed live loads, in accordance with Hook's law. The amount of deformation depends on the elastic modulus, the magnitude of loading, and the dimension of the component. This elastic deformation, under certain circumstances, causes cracking in the building as follows:

1) When walls are unevenly loaded with wide variations in stress in different parts, excessive shear stress is developed, which causes cracking in walls.
2) When a beam or slab of large span undergoes excessive deflection and there is not much vertical load above the supports (as in the case of a roof slab), the ends of the beam or slab curl up, causing cracks in the supporting masonry.
3) When two materials with widely different elastic properties are built side by side under load, shear stresses are set up at the interface of the two materials, resulting in cracks at the junction. Such a situation is commonly encountered in the construction of RCC-framed structures and brick masonry panel (external) and partition (internal) walls. Elastic deformation is the temporary deformation of a material in response to an applied force or stress, where the material returns to its original shape and size once the force or stress is removed. This type of deformation occurs in materials that exhibit elastic behaviour, which means they have the ability to store and release energy when subjected to stress.
4) The amount of elastic deformation that a material can undergo before it becomes permanently deformed is determined by its elastic modulus, or Young's modulus, which is a measure of its stiffness or resistance to deformation. The elastic modulus is defined as the ratio of the stress applied to a material to the resulting strain or deformation it undergoes.

5) Materials with high elastic moduli, such as steel or diamond, exhibit little elastic deformation and are therefore considered to be very stiff. Materials with low elastic modules, such as rubber or plastics, can undergo significant elastic deformation and are therefore considered to be more flexible.
6) Elastic deformation is important in many engineering applications, such as designing structures and machines that can withstand varying loads and stresses without deforming or breaking. It is also important in materials testing and research, where it can be used to measure the mechanical properties of a material and its response to stress.

I. Poor Restore And Renovation

After a certain time period, every structure wishes to be repaired and maintained. Some structures no longer want a completely early appearance, while others may additionally need a very close look at their deterioration troubles. It is usually better and wiser to become aware of troubles before they cause any harm. Poor restoration and renovation of cracks in structures can have serious consequences, leading to further damage and potentially compromising the safety and stability of the structure.

Here are some issues that can arise from poor restoration and renovation of cracks:

1) *Incomplete Repair:* If the crack is not properly repaired, it can continue to grow and cause further damage to the structure. For example, if a crack in a concrete wall is not properly filled and sealed, water can seep into the crack and freeze, causing the crack to widen and the concrete to weaken.
2) *Cosmetic Issues:* Poorly filled or patched cracks can be unsightly and detract from the appearance of a building or structure. This can be especially problematic for buildings that are intended to be visually appealing, such as historical buildings or architectural landmarks.
3) *Structural Integrity:* Cracks can be a sign of underlying structural issues, such as settling or shifting of the foundation. If the underlying issue is not addressed and the crack is simply patched over, the structural integrity of the building can be compromised.
4) *Safety Concerns:* Cracks in structures can pose safety concerns if they are not properly repaired. For example, a crack in a bridge can weaken the structure and potentially lead to a collapse, causing injury or loss of life.

To avoid these issues, it is important to ensure that cracks in structures are properly assessed and that appropriate restoration and renovation methods are applied. This may involve the use of specialised materials, techniques, and equipment and should be carried out by qualified professionals with experience in structural restoration and renovation.

III. FACTORS AFFECTING THE FORMATION OF CRACKS

A. High-cycle Fatigue Cracking

Repetitive loading at moderate stresses can result in the formation of fatigue cracks and possibly failure. These cracks are generally attributed to vibrations, rubs, or resonant frequency events. The stages of fatigue cracking include the accumulation of material damage, crack initiation, crack propagation, and ultimately final failure. At the common frequencies experienced by gas turbines, cycles accumulate rapidly. Endurance limit cycles in the order of 107 can occur within hours or days. Therefore, parts are designed to avoid experiencing cyclic stress intensities or events that would result in fatigue crack formation.
While NDT methods can detect cracking, metallurgical analysis is used to determine the nature of crack initiation and the reparability of the remainder of the blade set. Efforts are made to determine if crack initiation was due to an isolated cause (i.e., impact, material defect, etc.) or if the entire set was susceptible (i.e., resonant frequency). Once identified as fatigue cracking, further investigation as to the engine condition responsible for the elevated loading may be warranted.

B. Drying Shrinkage

When concrete dries, it contracts or shrinks. When it is wet, it expands. The expansion does not occur to the same extent as the shrinkage. These volume changes, along with changes in moisture content, are an inherent characteristic of hydraulic-cement concrete. The change in moisture content of cement paste causes concrete to shrink or swell. Aggregate reduces the unit volume of cement paste and provides an internal restraint that significantly reduces the magnitude of these volume changes in concrete. In addition to drying shrinkage, the cement paste is also subject to carbonation shrinkage. Shrinkage results from the cracking of concrete due to drying shrinkage. 224R-12 ACI COMMITTEE REPORT: effects of carbon dioxide on the chemical changes of calcium silicate hydrate and crystalline-hydration products and the drying of the pores by removing absorbed water Calcium hydroxide will form calcium carbonate by reacting with atmospheric carbon dioxide.

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Because carbon dioxide does not penetrate more than about 12 mm (0.5 in.) into the surface of high-quality concrete with low porosity, carbonation shrinkage is of minor importance in the overall shrinkage of most concrete structures. Carbonation does, however, play an important role in the shrinkage of small laboratory test specimens and structures constructed with low-quality, porous concrete, particularly when subjected to long-term exposure to drying. The amount of carbonation shrinkage observed on a small laboratory specimen can be greater than the shrinkage of the concrete in the structure. This effect results from the greater surface area-to-volume ratio in smaller specimens.

There are so many factors that may cause drying shrinkage; some of them are listed below:

1) Due to use of excessive water than its design requirements.
- By adding extra water at the site for convenience and workability purposes.

2) Due to the relative humidity of the surroundings
- Relative humidity plays a major role in evaporating the water.

3) Due to a lack of curing
- Lack of curing results in shrinkage due to water loss from the hydrated cement paste.

4) Due to the use of excessive cement content compared to its design requirements
- Excessive cement content undergoes rapid hydration and produces a large volume of hydrated cement paste. This results in a greater amount of drying shrinkage.

5) Due to improper compaction and moisture content
6) Due to the size of the aggregate used and the mix proportion,
- The most important property of aggregate that affects drying shrinkage is its modulus of elasticity. Aggregates with a high elasticity modulus show low drying shrinkage.

7) Due to the geometry of the concrete member,
- The geometry of the concrete member also affects the drying shrinkage.

8) Due to improper use of minerals and chemical additives
- Generally, low dosages of chemical additives do not affect drying shrinkage, but high dosages do considerably affect drying shrinkage.

9) Due to a lack of control joints
- Contraction joins are required to minimize the drying and shrinkage effects.

IV. PREVENTIVE MEASURES

A. *To prevent Cracks Due to Thermal Movement*

1) Dark-coloured and rough-textured materials on exteriors have lower reflectivity and react more to thermal expansions.
2) Plan for a layer of adequate thickness with a good reflective surface over concrete roof slabs to minimize these cracks.
3) A slip joint should be introduced between the slab and its supporting wall, or some length from the supporting wall, or the slab should bear only on part of the width of the wall.
4) Mortar for parapet masonry should be 1 cement: 1 lime: 6 sand
5) The construction of masonry over the slab should be delayed as much as possible (at least one month) so that the concrete undergoes some drying shrinkage prior to the construction of the parapet.
6) A good bond should be ensured between parapet masonry and the concrete slab.
7) The bearing portion of the wall is rendered smooth with plaster, allowed to set and partly dry, and then given a thick coat of whitewash before casting the slab so that there is a minimum bond between the slab and the support. To ensure more efficient functioning of this joint, in place of whitewashing, 2 or 3 layers of tarred paper are placed over the plastered surface to allow for easy sliding between the RCC slab and the supporting masonry.
8) To avoid cracks near door frames, provide a groove.

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B. To prevent Cracks Due to Chemical Reaction

1) For structural concrete in foundations, if sulphate content in soil exceeds 0.2 percent or in groundwater exceeds 300 ppm, use very dense concrete and either increase the richness of the mix to 1:1.5:3 or use sulfate-resistant Portland cement or super-sulfated cement, or adopt a combination of the two methods depending upon the sulphate content of the soil.
2) Cracking caused in concrete due to carbonation can be avoided or minimised by the ensuing use of Exposed concrete items in thin sections, such as sunshades, fins, and louvres of buildings, are made with a richer mix (1:1.5:3).

C. To Prevent Cracks Due to Shrinkage Cracking

Concrete tends to shrink due to drying whenever its surfaces are exposed to air with low relative humidity or high winds. Because various kinds of restraint prevent the concrete from contracting freely, cracking should be expected unless the ambient relative humidity is kept near 100%. The control of cracking consists of reducing the cracking tendency to a minimum, using adequate and properly positioned reinforcement, and using contraction joints.

1) *Reduction of Cracking Tendency:* Most measures that can be taken to reduce concrete shrinkage will also reduce the cracking tendency. Drying shrinkage can be reduced by using less water in the mixture and the largest practical maximum-size aggregate. A lower water content can be achieved by using well-graded aggregate, a stiffer consistency, and a lower initial temperature of the concrete. Concrete can withstand higher tensile strains if the stress is slowly applied; therefore, it is desirable to prevent the rapid drying of concrete. Prevention of rapid drying can be attained by using curing compounds, even after water curing.
2) *Reinforcement:* Properly placed reinforcement, used in adequate amounts, will reduce the number and width of cracks, reducing unsightly cracking. By distributing the shrinkage strains along the reinforcement through bond stresses, the cracks are distributed so that a larger number of narrow cracks occur instead of a few wide cracks. Although the use of reinforcement to control cracking in a relatively thin concrete section is practical, it is not needed in massive structures, such as dams, due to the low drying shrinkage of these mass concrete structures. The minimum amount and spacing of reinforcement to be used in structural floors, roof slabs, and walls for control of temperature and shrinkage cracking The minimum reinforcement percentage, which is between 0.18 and 0.20%, does not normally control cracks within generally acceptable design limits. To control cracks to a more acceptable level, the percentage requirement needs to exceed about 0.60%.
3) *Joints:* The use of joints is an effective method of preventing the formation of unsightly cracking. If a sizeable length or expanse of concrete, such as walls, slabs, or pavements, is not provided with adequate joints to accommodate shrinkage, the concrete will make its own joints by cracking. Contraction joints in walls are made, for example, by fastening wood or rubber strips to the form, which leave narrow vertical grooves in the concrete on both faces of the wall. Cracking of the wall due to shrinkage should occur at the grooves, relieving the stress in the wall and preventing the formation of unsightly cracks between the joints. These grooves should be sealed to prevent moisture penetration. Sawed joints are commonly used in pavements and slabs-on-grade. Joint location depends on the particulars of placement. Each element should be studied individually to determine where the joints should be placed.

D. To Prevent Cracks Due to Design Mistake

1) For inadequate structural design: through review of all design calculations and careful review of the revaluation method.
2) For poor design details: through a careful review of all design calculations.

E. To Prevent Cracks due to Corrosion of Reinforcement

Corrosion of reinforcement bars may be prevented or at least delayed by practicing good measures. Also, damaged steel bars can be repaired, and the concrete structure can be restored properly. Some measures are given below:

1) *Adequate Concrete Cover:* A good amount of concrete cover should be provided over the steel reinforcement bars. This ensures proper maintenance of the alkaline nature of the concrete and the passivity of the steel bars. The steel bars should be precisely placed in position.
2) *Employing good-quality Concrete:* high-quality concrete must be used. It helps maintain a proper alkaline nature. For the concrete, a water/cement ratio of 0.4 or less is to be maintained, as excessive water may damage the steel bars.
3) *Proper Compaction:* Concrete must be sufficiently compacted such that no air voids or air pockets are present in it.

4) *Using FBEC Bars:* Fusion Bonded Epoxy Coating (FBEC) is applied to the steel bars to prevent corrosion. Epoxy powder is spread electrostatically on the steel bars. The powder melts and flows over the bars upon heating, which forms a protective coating. They are thermoset polymer coatings because heat will not melt them. Apart from rebar, it also has wide applications in pipeline construction.
5) Use of Cement-Based Polymers: Cement-based polymers can be used in the concrete to enhance its protection against corrosion. The cement-based polymers act as a binder in the concrete. They also increase the durability, tensile strength, and vibration damping of the concrete.
6) The Rapid Chloride Permeability Test (RCPT): This test is performed to assess the degree of corrosion. The quantity of electrical current that passes through a sample 50 mm thick and 100 mm in diameter in 6 hours is measured. Based on this, a qualitative rating is given to the permeability of the concrete.
7) Use of Migratory Corrosion Inhibitors: These are to be used in the concrete mix or applied to the hardened surface of the concrete. These inhibitors diffuse through the concrete cover and reach the steel bars to protect them against corrosion. Calcium-nitrite-based inhibitors are quite common.

F. To prevent Cracks Due to Vegetation

1) Do not let trees grow too close to buildings, compound walls, garden walls, etc., taking extra care if the soil under the foundation happens to be shrinkable soil or clay. If any saplings of trees start growing in fissures in walls, etc., remove them at the earliest opportunity.
2) If some large trees exist close to a building and these are not causing any problems, as far as possible, do not disturb these trees if the soil under the foundation happens to be shrinkable clay.
3) If, on any site intended for new construction, vegetation, including trees, is removed and the soil is shrinkable clay, do not commence construction activity on that soil until it has undergone expansion after absorbing moisture and has stabilised.

G. To Prevent Cracks Due To Foundation Movement And Settlement Of Soil

1) Plan for under-reamed piles in the foundation for construction on shrinkable soils.
2) Plan for plinth protection around the building.
3) Slip or expansion joints to ensure that the new construction is not bonded with the old construction and the two parts (old and new) are separated right from bottom to top. When plastering the new work, a deep groove should be formed, separating the new work from the old.
4) For filling deep, say exceeding 1.0m, the soil used for filling should be free from organic matter. Brickbats and debris filling should be done in layers not exceeding 25 cm in thickness, and each layer should be watered and well rammed.
5) If filling is more than 1 metre in depth, the processes of flooding and compaction should be carried out after every metre of fill.

H. To Prevent Cracks Due To Elastic Deformations

1) When large spans cannot be avoided, deflection of slabs or beams could be reduced by increasing the depth of slabs and beams so as to increase their stiffness.
2) Adoption of a bearing arrangement and provision of a groove in plaster at the junction of wall and ceiling will be of some help in mitigating the cracks.
3) Allow an adequate time lag between the work of wall masonry and the fixing of tiles.
4) Panel walls in RCC-framed structures: -

As far as possible, all framework should be completed before taking up the masonry work of cladding and partitions, which should be started from the top storey downward.

V. CASE STUDY

For better understanding and gaining knowledge about the project, our team visited a site which had cracks in the building.

1) *Address:* Panchsheel Nagar, Shinde Mala, Sangli
2) *Name of Owner:* Mahesh Baban Shinde
3) *Type of building:*
a) Residential
b) Load bearing structure

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4) Salient Features of Building
a) Wall Type: Brick wall
b) Grade of concrete for column and beam: M20
c) Type of Soil: Black cotton soil

5) Types of Cracks

Non-structural cracks

a) On a Concrete Background

Shrinkage cracks occur due to the following causes:

- Mortar used to be too rich or wet.
- Curing has been inadequate.
- The sand used is too fine, and
- Rendering and plastering are done too long after the casting of concrete.

b) For Prevention of Such Cracks

Plastering should be done as soon as feasible after the removal of shuttering by hacking and roughening the surface and applying cement slurry to the concrete surface to improve bond.

c) In Masonry Structures

- Commonly observed cracks in masonry structures are:
- Cracks at ceiling level in cross walls: In load-bearing structures where a roof slab undergoes alternate expansion and contraction due to temperature variation, horizontal cracks (shear cracks) may occur in cross walls due to inadequate thermal insulation or protective cover on the roof slab.

6) To Prevent Such Cracks, The Following Measures May Be Adopted

Over flat roof slabs, a layer of some insulating material having good heat insulation capacity, preferably along with a high reflectivity finish, should be provided so as to reduce the heat load on the roof slab. In Western India, it has been a common practise to lay a layer of broken china in lime mortar over lime concrete terracing, which, because of its high reflectivity coefficient, reduces heat load on the roof and at the same time gives a good wearing and draining surface on the terrace.

Slip joint should be introduced between the slab and its supporting wall, as well as between the slab and the cross walls.

The slab should either project some length from the supporting wall or bear only part of the width of the wall. On the inside, wall plaster and ceiling plaster should be made discontinuous by a groove about 10 mm in width.

7) General Measures For Prevention Of Cracks

a) Non-structural cracks in buildings usually occur due to more than one cause, as already mentioned in the previous chapter; therefore, measures for prevention of cracks in many cases are common to more than one cause. Measures for the prevention of cracks could be broadly grouped under the following sub-heads:
b) Choice of materials
c) Specifications for mortar and concrete
d) Design of buildings (architectural, structural, and foundation)
e) Construction techniques and practises, and
f) Environment

VI. CHOICE OF MATERIALS

For selecting materials for building construction, the following precautions shall be taken:

A. Masonry Units

Only well-burned bricks should be used for masonry.Burnt clay bricks and other burnt clay products should not be used in masonry for a period of at least 2 weeks in the summer and 3 weeks in the winter after unloading from kilns. They should be kept exposed to the atmosphere during this period.

If the use of burnt clay bricks containing excessive quantities of soluble sulphates cannot be avoided, rich cement mortar shall be used for masonry, as well as plaster or super-sulphate cement. All possible steps shall be taken to prevent dampness in masonry.

1) The use of porous stone with high drying shrinkage, e.g., sand stone, should be avoided for masonry and concrete work.
2) While using manufactured masonry units having a high value of drying shrinkage, e.g., concrete blocks and sand lime bricks, suitable precautions should be taken, i.e.,
3) They should be protected from wetting at the site due to rain and should be lightly wetted before use.
4) The use of strong and rich mortar for laying should be avoided. The mortar used should have high water retensivity; hence, composite cement lime mortar is more preferred.
5) Curing of masonry should be done sparingly to avoid the bodies of blocks getting wet.
6) Before plastering, masonry shall be allowed to dry and undergo initial shrinkage. Excessive wetting of masonry at the time of plastering and curing should be avoided.

B. Fine Aggregate

The use of fine aggregate for mortar and concrete that is too fine or contains too much clay or silt and is not well graded should be avoided. The percentage of clay and silt in fine aggregate (uncrushed) should not exceed 3 percent.

C. Coarse Aggregate

Coarse aggregate for concrete work should be well graded so as to obtain concrete of high density.

1) The maximum size of coarse aggregate should be the largest possible, consistent with the job requirements.
2) Coarse aggregates of stones that are porous and have high shrinkage properties, e.g., sandstone, clinker, foamed slag, expanded clay, etc., should be avoided. Aggregate made from lime stone, quartzite, granite, dolomite, and basalt is more desirable.
3) The use of brick aggregate containing excessive amounts of soluble sulphates for concrete in the base course should be avoided.
4) The course aggregate should not contain fines of more than 3%.

D. Cement

When the use of bricks containing excessive quantities of soluble sulphates is unavoidable, the content of cement in mortar should be increased or super-sulfated cement should be used.

If use of alkali-reactive aggregate is unavoidable, the alkali content of cement should not exceed 0.6 percent. If low-alkali cement is not economically available, use of pozzolanas should be made to check the alkali-aggregate reaction.

In massive structures, in order to limit the heat of hydration, low-heat cement should be used.

E. Calcium Chloride

Its use in concrete as an accelerator should be avoided as far as possible. If unavoidable, its quantity should be limited to 2 percent of the cement content.

F. Gypsum (Plaster of Paris)

Gypsum plaster ($CaSO_4$) should not be used for external or internal work in locations that are likely to get or remain wet. It should be remembered that gypsum and cement are incompatible since, in the presence of moisture, a harmful chemical reaction takes place.

G. Mortar for Plaster

Mortar for plaster should not be richer than what is necessary in consideration of resistance to abrasion and durability. Plaster should not be stronger than the background; otherwise, due to shrinkage, it will exert sufficient force to tear off the surface layer of weak bricks.

Composite cement-lime mortar of a 1:1:6 mix or weaker for plaster work is less liable to develop shrinkage cracks as compared to plain cement mortar and should thus be preferred.

Plaster with coarse, well-graded sand or stone chips (roughcast plaster) is liable to suffer from fewer shrinkage cracks; hence, the use of such plaster on the external surface of walls, from considerations of cracking and resistance against penetration of moisture through walls, shall be preferred.

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H. Mortar for Masonry Work

Rich cement mortar, which has high shrinkage, should be avoided. Composite cement-lime mortar should be preferred. Mortar for masonry should not contain excessive water.

While using concrete blocks or sand lime bricks as masonry units in non-load-bearing walls, the use of rich cement mortar should be avoided. 1:2:9 in summer and 1:1:6 cement lime mortar for the work done in winter will be adequate.

I. Cement Concrete

The mix should not be richer than what is required for strength considerations. The aim should be to obtain strong and durable concrete through careful mix design, grading of aggregates, control of the water-cement ratio, thorough mixing, proper compaction, adequate curing, etc. An oversanded mix should be avoided. The quantity of water used in concrete should be the minimum, consistent with requirements for proper laying and compaction. This is one of the most important single factors responsible for shrinkage and consequent cracks in concrete.

J. Compaction

As far as possible, concrete should be compacted by vibration so as to allow the use of low-slump concrete. Concreting should not be done when it is very hot, dry, and windy. If unavoidable, quick drying of concrete should be prevented.

K. Curing

Curing should be done for a minimum period of 7 to 10 days for masonry and concrete works. It should be discontinued slowly so as to avoid rapid drying. It should start immediately after the initial setting of the concrete but before the surface sheen fully disappears.

VII. DESIGN OF THE BUILDING

A. Architectural Design

Factors that affect cracking are large spans of rooms, the provision of large windows in external walls, the introduction of short return walls in external elevations, etc. Doors and window frames should not be placed flush with the plastered surface; if unavoidable, the joint should be either concealed with moulding strips or a preventive arrangement made to avoid shrinkage.

B. Structural Design

Stresses in different parts of masonry walls should be more or less uniform so as to limit differential strain and the resultant shear stress and cracking. Slabs and beams should have adequate stiffness so as to limit deflection. Flexural cracks in concrete should be limited in width to 0.30 mm for protected internal members and 0.20 mm for unprotected external members. In a rigid structure, such as rigid frames and shells, since movement joints are not feasible, thermal and shrinkage stresses should be taken care of in the design.

Fig. Diagonal crack formation

Fig. Vertical crack formation

VIII. CONCLUSION

Cracks are not a major criteria behind the failure of a structure if it is within the limit, which is suggested by the Indian standard code IS 456-2000 (i.e., plain and reinforced concrete-code of practise). Any structure or building should be designed for the limit state of collapse, but it must be checked against the limit state of serviceability, which includes cracking of the structure as well. And cracks can reduce its appearance, durability, and, some time, cause the structure to fail.

Cracks are classified into structural and non-structural categories. The structural ones are due to faulty design, faulty construction, or overloading, which may endanger the safety of buildings. The non-structural cracks are due to internally induced stresses and the environment surrounding the structure or building. Depending on the width of the crack, these are classified as "thin (2mm wide). In hot regions, water evaporates from the soil, which causes shrinkage or settlement of the soil. Shrinkage of soil or settlement of soil causes foundation cracks in plinth beams, which is not desirable as it results in collapse of any component of the building or whole structure. From an appearance point of view, it is not good as well as it does not perform a well-functioning function in the transformation of structural load to soil beneath the structure. By observing the case study on crack treatment, it is important to keep maintaining structures from time to time, or else it leads to injury, and in addition, costs will increase for future problems in structures that might arise. Cracks are repaired on the basis of their extent of formation and the cause behind their formation. On that basis, we select the method of repairing the crack and the crack repair product. Cracks are formed due to fluctuations in water level and the type of soil that is present on site; these two combinations depend on the situation and can cause cracks, sometimes major and sometimes minor, i.e., black cotton soil and water level fluctuations.

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