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Building cracks – causes and remedies

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Abstract: Building cracks are most common type of problem in any type of building. So, it is important to understand the cause and the measures to be taken for prevention. Though cracks in concrete cannot be prevented entirely but they can be controlled by using adequate material and technique of construction and considering design criteria. We all dream of a house structurally safe and aesthetically beautiful but it is not so easy. Due to some faulty steps during construction or some unavoidable reasons different type of cracks starts to appear on various structural and non- structural parts of the building with the passage of time. It is not necessary that all type of cracks require serious attention but there are some typical types of crack (active cracks) that are structurally hazardous. So, timely identification of such cracks and adopting preventive measures is essential. This research work briefly describes about various direct and indirect observation methods using simple as well as sophisticated instruments to deal with such problems. It insights the process how cracks leads to ultimate structural failure. It also explains various causes of crack and their respective remedial measures. From this research it is found that building cracks has direct and indirect impacts. And also, it is found that building cracks do not cause structural problem in direct way but it facilitates the activities which ultimately cause the problem. Hence this research work come up with conclusion that different type of crack call for different repair technique depending upon cause and intensity of problem that's why it is essential to find answers of questions like why they are formed? And how they can be analyzed and prevented?

Keywords: *Building cracks, structural failure, concrete, repair technique*

Introduction:

The actual tendency in civil engineering is to extend the live-cycle of large scale structures. Due to limited or even reduced resources for new constructions it is necessary to use and rely on existing structures, which in many countries are coming to age. This tendency has two consequences: i) More frequent and more rigorous monitoring is required and ii) Concepts and strategies to maintain and to improve existing structures have to be developed. One of the main sources of information in monitoring concrete structures is crack, indicating weak zones and acting forces. But up to now there is no system available which allows to measure and analyze cracks ***objective, precise and repeatable*** (Stratmann et. al. 2008).

If they are active, they show some movement in direction, width or depth over a measured period of time. If the cracks are dormant, they remain unchanged. Some dormant cracks are of no danger, but if left unrepaired, cracks provide channels for moisture penetration, which can lead to future damage. There are two types of crack depending on the time of occurrence i.e. plastic concrete crack and hardened concrete crack.

Cracks in concrete are extremely common but often misunderstood. When an owner sees a crack in his slab or wall, especially if the concrete is relatively new, he automatically assumes there's something wrong. This is not always the case. Some types of cracks are inevitable. The best that a contractor can do is to try to control the cracking. This is done by properly preparing the subgrade, assuring that the concrete is not too wet, utilizing reinforcement where needed, and by properly placing and spacing crack control joints and expansion joints. However, sometimes cracks happen in spite of any precautions taken.

The **American Concrete Institute** addresses this issue in ACI 302.1-04. ***"Even with the best floor designs and proper construction, it is unrealistic to expect crack-free and curl-free floors. Consequently, every owner should be advised by both the designer and contractor that it is normal to expect some amount of cracking and curling on every project, and that such occurrence does not necessarily reflect adversely on either the adequacy of the floor's design or the quality of its construction."***

The cracks may be classified on the basis of their activeness, time of occurrence, their width and the components of building on which they are developed. On the basis of activeness cracks are of two type; active crack and dormant crack.

Cracking caused in plastic concrete (plastic concrete crack) occurs most commonly on the exposed surfaces of freshly placed floors and slabs or other elements with large surface areas when they are subjected to a very rapid loss of moisture caused by low humidity and wind or high temperature or both.

Drying shrinkage cracking (hardened concrete crack) is commonly associated with the loss of moisture from the cement paste constituent producing a corresponding decrease in volume, coupled with restraint by the subgrade or adjacent structural members.

According to IS: 456 2000, the surface width of crack should not exceed 0.3mm in members where cracking is not harmful and does not have any serious adverse effects upon the preservation of reinforcing steel, nor upon the durability of the structures .In the members where cracking in tensile zone is harmful either because they are exposed to moisture or in contact of soil or ground water, an upper limit of 0.2mm is suggested for maximum width of crack. For particularly aggressive environment such as the ‘severe’ category, the assessed surface width of crack should not in generally exceed 0.1mm.

Cracking in reinforced concrete structures of various types can be divided into two main groups:

1. Non-structural cracks:

These type of crack occur mostly due to internally induced stresses in building material and normally do not endanger safety but may look unsightly, create impression of faulty work or give feeling of instability. Crack on wall, parapet wall, driveway are called non-structural cracks.

2. Structural cracks:

Structural cracks results from incorrect design, faulty construction or overloading and may endanger the safety of a building. The cracks in beam, column, slab and footing are considered as structural cracks.

Causes:

1. Permeability of concrete.

As deterioration process in concrete begins with penetration of various aggressive agents, low permeability is the key to its durability. Concrete permeability is controlled by factors like water-cement ratio, degree of hydration/curing, air voids due to deficient compaction, micro-cracks due to loading and cyclic exposure to thermal variations. The permeability of the concrete is a direct function of the porosity and interconnection of pores of the cement paste.

2. Thermal movement:

Thermal movement is one of the most potent causes of cracking in buildings. All materials more or less expand on heating and contract on cooling. The thermal movement in a component depends on a number of factors such as temperature variations, dimensions, coefficient of thermal expansion and some other physical properties of materials. The coefficient of thermal expansion of brickwork in the vertical direction is fifty percent greater than that in the horizontal direction, because there is no restraint to movement in the vertical direction.

Thermal variations in the internal walls and intermediate floors are not much and thus do not cause cracking. It is mainly the external walls especially thin walls exposed to direct solar radiation and the roof which are subject to substantial thermal variation that are liable to cracking.

3. Corrosion of Reinforcement

A properly designed and constructed concrete is initially water-tight and the reinforcement steel within it is well protected by a physical barrier of concrete cover which has low permeability and high density. Concrete also gives steel within it a chemical protection. Steel will not corrode as long as concrete around it is impervious and does not allow moisture or chlorides to penetrate within the cover area. Steel corrosion will also not occur as long as concrete surrounding it is alkaline in nature having a high pH value.

Concrete normally provides excellent protection to reinforcing steel. Notwithstanding this, there are large number of cases in which corrosion of reinforcement has caused damage to concrete structures within a few years from the time of construction resulting in loss of mass, stiffness and bond in concrete and therefore concrete repair becomes inevitable as considerable loss of strength takes place.

4. Moisture Movement:

The common cause of cracking in concrete is shrinkage due to drying. This type of shrinkage is caused by the loss of moisture from the cement paste constituent, which can shrink by as much as 1% per unit length. These moisture-induced volume changes are a characteristic of concrete. If the shrinkage of concrete could take place without any restraint, the concrete would not crack. It is the combination of shrinkage and restraint, which is usually provided by another part of the structure or by the subgrade that causes tensile stresses to develop. When the tensile stresses of concrete are exceeded, it will crack. Cracks may propagate at much lower stresses than are required to cause crack initiation.

Most of the building materials with pores in their structure in the form of intermolecular space expand on absorbing moisture and shrink on drying. These movements are cyclic in nature and are caused by increase or decrease in inter pore pressure with moisture changes. Initial shrinkage occurs in all building materials that are cement/lime based such as concrete, mortar, masonry and plasters. Generally heavy aggregate concrete shows less shrinkage than light weight aggregate concrete.

5. Creep

Concrete when subjected to sustained loading exhibits a gradual and slow time dependent deformation known as creep. Creep increases with increase in water and cement content, water cement ratio and temperature. It decreases with increase in humidity of surrounding atmosphere and age of material at the time of loading. Use of admixtures and pozzolona in concrete increases creep, amount of creep in steel increases with rise in temperature.

6. Poor Construction practices.

The construction industry has in general fallen prey to non-technical persons most of whom have little or no knowledge of correct construction practices. There is a general lack of good construction practices either due to ignorance, carelessness, greed or negligence. Or worse still, a combination of all of these. For a healthy building it is absolutely necessary for the construction agency and the owner to ensure good quality materials selection and good construction practices. All the way to building completion every step must be properly supervised and controlled without cutting corners.

Some of the main causes for poor construction practices and inadequate quality of buildings are given below:

- Improper selection of materials.
- Selection of poor quality cheap materials.
- Inadequate and improper proportioning of mix constituents of concrete, mortar etc.
- Inadequate control on various steps of concrete production such as batching, mixing, transporting, placing, finishing and curing
- Inadequate quality control and supervision causing large voids (honey combs) and cracks resulting in leakages and ultimately causing faster deterioration of concrete.
- Improper construction joints between subsequent concrete pours or between concrete framework and masonry.
- Addition of excess water in concrete and mortar mixes.
- Poor quality of plumbing and sanitation materials and practices.

7. Poor structural design and specifications

Very often, the building loses its durability on the blue print itself or at the time of preparation of specifications for concrete materials, concrete and various other related parameters.

It is of crucial that the designer and specifier must first consider the environmental conditions existing around the building site. It is also equally important to do geotechnical (soil) investigations to determine the type of foundations, the type of concrete materials to be used in concrete and the grade of concrete depending on chemicals present in ground water and subsoil.

It is critical for the structural designer and architect to know whether the agency proposed to carry out the construction has the requisite skills and experience to execute their designs. Often complicated designs with dense reinforcement steel in slender sections result in poor quality construction. In addition, inadequate skills and poor experience of the contractor, ultimately causes deterioration of the building.

8. Poor Maintenance

A structure needs to be maintained after a lapse of certain period from its construction completion. Some structures may need a very early look into their deterioration problems, while others can sustain themselves very well for many years depending on the quality of design and construction. But early identification of probable problems and correcting them within time is wise idea rather.

9. Movement due to Chemical reactions.

The concrete may crack as a result of expansive reactions between aggregate containing active silica and alkali derived from cement hydration. The alkali silica reaction results in the formation of swelling gel, which tends to draw water from other portions of concrete. This causes local expansion results in cracks in the structure.

10. Indiscriminate addition and alterations.

There have been some building collapses in our country due to indiscriminate additions and alterations done by interior decorators at the instance of their clients. Generally, the first target of modifications is the balcony. Due to the requirement to occupy more floor area, balconies are generally enclosed and modified for different usages. Balconies and canopies are generally cantilever RCC slabs. Due to additional loading they deflect and develop cracks. As the steel reinforcement in these slabs have less concrete cover and the balcony and canopy slab is exposed to more aggressive external environment, corrosion of steel reinforcement takes place and repairs become necessary.

11. Foundation settlement

The place where concrete commonly subsides is near a house. Whether the home is built on a basement or crawlspace, the over-dig is subsequently backfilled. Unless the backfill material is compacted in lifts as the over-dig is filled, it will settle over time. This settling will cause any concrete poured atop it to settle along with it. The other reasons for foundation to settle are change in moisture content of soil below or around the foundation, overload of super structure and decay of organic matters present in subsoil. Uniform settlement up to some tolerance does not cause the problem but differential settlement is something that results in severe crack problem.

Remedies

The remedial measures to deal with crack are of two types; one is to prevent crack and another to cure crack. As per the saying “Prevention is better than cure" we should always try to avoid such problem by using adequate construction material and technique, proper design, and efficient supervision.

The things to be taken care of to avoid crack can be listed as:

- Check for predicted extreme temperature variance during the first 24 hours of expected placement
- Review the mix design to ensure the mix is using the lowest water content for workability/performance purposes. Excessive water in the mix may contribute to the possibility of shrinkage.
- Review the mix design to ensure the maximum size of course aggregate is used. This will help to minimize the water used in the mix.
- Review the mix design to ensure the contractor is familiar with finishing technique for the cementitious material in the mix. Cementitious materials may increase or decrease the rate of bleed water migration to the surface. This, in turn, may shorten or lengthen the window of time for ease of finish ability
- During the pre-placement meeting; review the plan for subgrade preparation. The subgrade should be properly compacted at required moisture content. This preparation will ensure the subgrade will be able to uniformly support the slab as well as not draw moisture form the slab during placement
- Have a plan in place for curing the concrete for the specified period. This curing plan should include steps for both initial curing of the concrete during placement while in a plastic state as well as after concrete has hardened.
- There are chemical admixtures that may help to reduce the amount of drying shrinkage.
- There are synthetic fibers that may help control the extent of early drying shrinkage crack
- Construction on expansion/contraction joints so that temperature effect can be neutralized.

If buildings are built without considering above mentioned measures it is obvious that different types of crack will start to appear sooner or later. Hence in such case the cracks are required to be cured before they cause serious problem. It is very important to read the characteristics of crack and analyze carefully by experts in order to come up with most effective and sustainable solution to deal with different concrete crack problem. The scientific method of determining cause of cracking is:

- State problem
- Make observation:

  The important points to be considered in this step are-
  -structural or non-structural crack
  -crack details i.e. orientation, location, length, width, depth, shape, frequency, age
  -crack location within a member
  -environmental exposure condition
  -type of member
  -appearance

- Form hypothesis i.e., possible cause
  Depending on observations made the basic idea of possible causes are made with the help of expert's opinion.
- Test the hypothesis by performing tests, making calculations, making more extensive observation
  The surface cracks are detected by dye penetration method, using optical comparator or by visual inspection and some simple measurement.
  The sub surface cracks that do not show on the surface are detected by ultrasonic wave method, magnetic particle method, electric potential method and using Digital Rissmess System (DRS)
- Analyze the results and iterate if necessary
- Form conclusion

The various techniques to cure crack are as below:

Epoxy injection

Cracks as narrow as 0.002 in. (0.05 mm) can be bonded by the injection of epoxy. The technique generally consists of establishing entry and venting ports at close intervals along the cracks, sealing the crack on exposed surfaces, and injecting the epoxy under pressure. Epoxy injection has been successfully used in the repair of cracks in **buildings**, bridges, dams, and other types of concrete structures (ACI 503R). However, unless the cause of the cracking has been corrected, it will probably recur near the original crack. If the cause of the cracks cannot be removed, then two options are available.

Routing and sealing

Routing and sealing of cracks can be used in conditions requiring remedial repair and where **structural repair** is not necessary. This method involves enlarging the crack along its exposed face and filling and sealing it with a suitable joint sealant. This is a common technique for crack treatment and is relatively simple in comparison to the procedures and the training required for epoxy injection. The procedure is most applicable to approximately flat horizontal surfaces such as floors and pavements. However, routing and sealing can be accomplished on vertical surfaces (with a non-sag sealant) as well as on curved surfaces (pipes, piles and pole).

Stitching

Stitching involves drilling holes on both sides of the crack and grouting in U-shaped metal units with short legs (staples or stitching dogs) that span the crack. Stitching may be used when tensile strength must be reestablished across major cracks. The stitching procedure consists of drilling holes on both sides of the crack, cleaning the holes, and anchoring the legs of the staples in the holes, with either a non-shrink grout or an epoxy resin-based bonding system

Drilling and plugging

Drilling and plugging a crack consists of drilling down the length of the crack and grouting it to form a key. This technique is only applicable when cracks run in reasonable straight lines and are accessible at one end. This method is most often used to repair vertical cracks in retaining walls. A hole [typically 2 to 3 in. (50 to 75 mm) in diameter] should be drilled, centered on and following the crack.

Gravity Filling

Low viscosity monomers and resins can be used to seal cracks with surface widths of 0.001 to 0.08 in. (0.03 to 2 mm) by gravity filling. High-molecular-weight methacrylate, urethanes, and some low viscosity epoxies have been used successfully. The lower the viscosity, the finer the cracks that can be filled. The typical procedure is to clean the surface by air blasting and/or water blasting. Wet surfaces should be permitted to dry several days to obtain the best crack filling.

Overlay and surface treatments

Fine surface cracks in structural slabs and pavements may be repaired using either a bonded overlay or surface treatment if there will not be further significant movement across the cracks. Unbounded overlays may be used to cover, but not necessarily repair a slab. Overlays and surface treatments can be appropriate for cracks caused by one-time occurrences and which do not completely penetrate the slab.

- Surface treatment
- Overlays

Conclusion:

This research work concludes that though it is impossible to guarantee against cracking yet attempts can be made to minimize development of crack. And also, not all type of crack requires same level of attention. The potential causes of crack can be controlled if proper consideration is given to construction material and technique to be used. In case of existing cracks, after detail study and analysis of crack parameters, most appropriate method of correction should be adopted for effective and efficient repair of crack.

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