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# Development of cracks in concrete, preventive measures and treatment methods: A review

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**Abstract**:*Cracks in the building is the most common problem that occur in any type of concrete structure such as beams,coloumn, etc... 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. But due to some faulty steps taken during construction or due to some unavoidable reasons different cracks starts to appear on various structural and non- structural parts of the building with due course of time. There are cracks which need to be identified at appropriate time, so proper care of such cracks can be taken .This paper gives information about various causes, prevention of cracks and treatment methods to such causes.*

**Keywords**: Epoxy resins, cracks, causes, prevention, treatment measures.

## 1. Introduction:

Concrete encompasses certain types of cracks in pre-hardening as well as post hardening stage in the life of a structure. Even with our extreme care and prevention we acquire certain cracks. when concrete become older and harder and cracks occur on the surface, such cracks becomes source of the leakage and seepage and give a passage to the moisture, oxygen, chlorides, carbon dioxide etc. and other chemicals and gases which may cause serious damage to the structure which may cause corrosion to steel and damage to concrete and ultimately structural failure of the member.

In past time also some researchers also worked out cracks, causes and remedies. Causes and evaluation of cracks done in concrete structures by Sayed Mohd Mehndi[1] in 2014, they explained about the evaluation of cracks that can be done by different techniques like crack compactor and by ultra testing machine. Building cracks-causes and remedies by Grishma Thagunna 2014[2], from this research it is found that building cracks has direct and indirect impacts and building cracks do not cause structural problem in direct way but it facilitates the activities which ultimately cause the problem. Prevention & repair of cracks in concrete structures by B.B.Gamit in 2014, they broadly classified about the structural and non structural cracks that occurs in building along with their causes and remedy. Study on control of cracks in a structure through Visual Identification & Inspection by Kishor Kunal and Namesh Killemsetty in 2014, they talk about how visual inspection of cracks can be helpful in order to identify and categorize them with respect to various parameters by taking case study of an institutional building.

Cracks can be treated as a cancer in the R.C.C structure which in its preliminary stage is curable up to a certain extent but as the time passes it becomes non curable in the later stage. Repairs can be treated only if the root cause is identified. If the cause is properly identified, satisfactory repairs can be performed and improvement and durability of the structure is ensured.

Cracks that occur before hardening, primarily due to settlement, construction movements, and excessive evaporation of water, are called plastic cracks. Plastic cracking that can be predominantly eliminated through close attention to the mixture design, material placement, and curing. Cracks that occur after the concrete has hardened may be due to variety of reasons. These may be due to mechanical loading, thermal gradients, moisture and incompatibility due to chemicals reactions.

The repairing of the concrete structures or its element has always been very difficult and adequate works and solutions have been worked out. Specialized techniques of strengthing, stiffening and repairing are necessary events which have to be performed to deal with such damaged structures. These can be due to earthquake, movements of

foundation, due to heavy impact loads and overloads. So to counteract this problem researchers have wide variety of artificial resins, especially epoxy based adhesives, which have given rise to repairs concrete works. Epoxy injection techniques were used extensively to repair cracks of highway bridges, buildings and other reinforced damaged structures such as in Alaska 1964, 1969 Santa Rosa California and 1971 San Fernando California,..[3]Etc.

## 2. Causes:

### 2.1. Due to elastic deformation:

It occurs due to material strain under stress. When two materials having two different properties built together under the effect of load then different shear stresses occur at the junction of two different materials [4]. Dead load and live load are the main cause of elastic deformation any structural component of a building.

Structural components of a building such as walls, columns, beams and slabs, generally consists of materials like masonry, concrete, steel, etc, undergo elastic deformation due to load in accordance with Hook's law, the amount of deformation depending upon elastic modulus of the material, magnitude of loading and dimensions of the components.

This deformation may occur under such circumstances such as [5]:

**2.1.1.** When the walls of a building are unevenly loaded with wide variations in the stresses in different parts, excessive shear strain is developed which may cause cracking in the walls.

**2.1.2.** When a beam or slab of larger span undergoes large amount of deflection and there is not much vertical load above the supports, ends of beam or the slab, it curls up causing the cracks in supporting masonry.

### 2.2. Due to thermal movement:

Most material gets expanded when they are heated up and contracted when they are cooled. The expansion and contraction which occur due to change in temperature condition in effective of crass sectional area.

### 2.3. Due to chemical reaction:

Chemical reaction take place when the material used to make concrete or materials that come in contact with it after it has hardened. Concrete may crack with the time as the result of slowly developing expansion reaction between aggregate and active silica and alkalis derived from cement hydration, admixtures..Etc.

### 2.4. Due to shrinkage:

Most of the building expands when they absorb moisture from atmosphere and shrinks or contracts when they become dry. Shrinkage may be of dry state or plastic state. Excessive use of water used in the mortar can cause shrinkage in the concrete used. So vibration must be performed so to avoid the shrinkage problem.

### 2.5. Due to foundation movement and settlement:

Shear cracks may occur in the building due to large differential settlement of foundation and it may also occur due to unequal bearing pressure under different parts of the structure, or due to it excess the bearing strength of the soil, or due to minimum factor of safety used in the foundation…etc.

### 2.6. Due to Earthquake:

Cracking may occur due to sudden shift in the lower layer of the earth. The voids in the earth which might have suddenly collapsed they are filled from the soil above. Many geological factors can trigger earth movements.

### 2.7. Due to vegetation:

Faster growing trees can cause cracks in walls due to expansive actions of roots growing under the foundation. The cracks which may occur in clay soil due to moisture present in the roots.

### 2.8. Due to concrete segregation:

Before the setting of and hardening of concrete take place due to deposition of coarse aggregate and fine aggregate forming the outer layer, it is not easy to maintain its stability.

Most of it will have certain de-lamination, which will cause the macro-structural concrete in the direction of pouring unevenly, besides the upper strength less than that of the bottom, making the surfaces the loosest part. Besides, de-lamination will occur beneath the concrete coarse aggregate, where the water-filled area has the largest water content, making it easy to form pores, which may often, becomes the birthplace of cracks and pores.

### 2.9. Due to the effect of interfacial transition zone:

The existence of transition zone is also an important reason of which concrete cracks. Due to the unevenness of transition zone, the original micro-cracks will be easily

developed leading to harmful cracks under the impact of external pressure.

This is mainly because, in the process of preparing fresh concrete, micro and macro bleeding effect occurs inside the concrete will produce unevenness in the moisture at different locations, which will further affect the uniformity of the transition zone [6].

**2.10. Due to creep:**

Some building items, such as concrete, brickwork and timber, which are subjected to sustained loadings not only undergo instantaneous elastic deformation, but also exhibit a gradual and slow time-dependent deformation known as creep or plastic strain. The latter one is made up of delayed elastic strain which recovers ultimately when the load is removed, and viscous strain which appears as permanent set and remains after the removal of load [7].

**3. Preventive measures [8]:**

**3.1. Prevention for elastic deformations:**

One should create slip joints under the support of concrete slab on slabs. The other solution is to provide horizontal movement joints between the top of brick panel and reinforced cement concrete beam or slab.

**3.2. Prevention for thermal movements:**

The joints should be constructed with construction joints, expansion joints, control joints and slip joints etc. these joints should be planned at the time of construction and design.

**3.3. Prevention for chemical reactions:**

If the content of sulphate in the soil exceeds 0.2 percent or in the ground water exceeds 300ppm then one should use very dense concrete or either increase richness of mix from 1:1 to 5:3. And if cracking due to corrosion is to prevented then desirable amount of concrete of richer mix for thin sections should be introduced at exposed locations.

**3.4. Prevention for shrinkage:**

Excessive amount of water which is used in concrete should be minimized. It can be with the help of vibrations so that lesser shrinkage is low. Excessive amount of cement should be minimized for lesser shrinkage.

**3.5. Prevention for settlement of soil:**

The design of foundation should be based on sound engineering principles and good practice.

**3.6. Prevention for earthquake:**

While construction the building it should be on firm ground. Tie up the building with the connecting beams at different level such as foundation level, door level, and roof level.

**3.7. Prevention for vegetation:**

Do not grow trees too close to the foundation of building. Remove any saplings of trees as soon as possible if they start growing in or near the walls.

**3.8. Prevention for creep:**

Following measures should be taken to avoid creep:

- Concrete should be used which has low shrinkage and low slump.
- One should avoid of performing brickwork over flexural RCC member such as beam r slab before removing centering and allow time of interval for at least 2 weeks between removal of centering and construction of partition.

**4. Treatment measures:**

Cracks in the concrete structures should be treated as on the basis of identifying the crack types and if the cracks are harmful and it should be properly designed when needed.

**4.1. Surface filling method:**

For cracks of width of micro-cracks less than 0.2mm, it is the most simple technique used and to apply brush polymer or to apply elastomeric sealant on the surface in order to prevent moisture content, carbon dioxide and other harmful materials. But the main drawback is that it belongs to repair only shallow surfaces and not deep cracks and cracks not suitable to water pressure.

**4.2. Pressure grouting method:**

This method is mainly applied to fill deep cracks with width bigger than 0.3mm. Grouting materials can be injected fill such cracks with the help of pressure grouting equipment. Presently the main grouting materials which are used to fill are epoxy resins, polyurethanes, slurry and other chemical materials. The equipment which is used is YJ-automatic pressure grouting machine. Although it is more complex than surface filling method yet it is more used since it gives better result.

**4.3. Caulking method:**

This method is mainly used when cracks have width greater than 0.5mm. While filling the material it should be properly cleaned in the form of U shape or in the form of V shape and accordingly it should be filled. Filling material which is to be applied can be divided into plastic material such as PVC cement, plastic ointment and butyl rubber and rigid material such as polymer cement mortar [9].

**4.4. Epoxy resins grout:**

This is the most common polymer material used to fill gravity feed crack repairs. It should be formulated to very low viscosity and low surface tension and resins should be applied so that it can easily penetrate through cracks under the action of gravity. The material which is having viscosities below 200 centipoise should be preferred to a minimum content.

While using this method cracks should be properly cleaned and should be free from dust. If required some routing techniques must be required to facilitate pouring of resins. While cleaning the surface which is having dust if water is applied for it then it should be properly dried for 24hr because the moisture if present in the crack it will obstruct the flow of resins. The pouring of resins should be continued till the cracks go in absorbing after which the excess resins may remove with the help of flat rubber squeeze.

**5. Research findings:**

**Dennis L Bean (1985)** submitted a report on how to use epoxy resins as grouting material. In his findings he said that it is possible to restore the tensile strength of cracked concrete structural elements by injection of a adhesive material through injecting it into the cracked concrete. Some things should be considered while injecting the filler material such as width, depth, temperature, presence of moisture …etc. He concluded that, for small jobs caulking gun method is convenient method for repairing cracks. But for large jobs pressure pot or epoxy resins would be preferred so that the volume of resins can be injected through and with the short amount of time required [13].

**D P Singh(1992)** carried out test on epoxy based bounded external steel reinforcement in the form of steel plates or in the form of strips which have proved to be reliable structural elements not as in lab purpose but as for practical considerations. In his findings he concluded that design may be performed as in usual manner as there is no slip or there is no shifting between external steel and concrete used. And epoxy based reinforcements system is competitive, time saving and economical for such reinforced damaged structures. Also this technique is quite satisfactory for repairing earthquake damaged structures.

**Hartmut Fischer(2010):** In his findings, he said that self healing is not intended to deal with poor design , development flaws but they are caused by damage due to external factors. Thus self healing should provide opportunities for increase in durability, reliability and it should reduce its overall cost. Thus in order to counteract with cracks self repairing methods were developed such as Thermally stipulated repair in which damage which are jointed will be triggered by thermal stimulation where the system not only allows the flow of material but also wetting up of crack surfaces and fixing them together in a heating-cooling cycle. Other methods have also been discussed such as non thermal stimulation, Synthetically Designed Autonomously
Self-Repairing Systems, Viscoelastic Recovery and Healing, Self-Healing by Phase Changes and Volume Expansion, Mimicking Nature..Etc. However the latest method to fill the cracks is liquid filled capsules in coating system or in flexible laminates[14,15]. This method in not being used as much is needed to investigate. Hence he concluded that self healings system is the universal method.

**Ying Luo, Ziping Wang, Baiqiaing Xu(2012)** conducted his findings in accordance with Stack Migration Imaging Technology which is an advanced imaging technique used in geophysical exploration. This technique was employed to detect the cracks inside the concrete structures. Ultrasonic transducers were utilized as both actuators and sensors to generate and receive stress waves in the concrete. In his findings the result showed that SMIT has advantage over ultrasonic machine. SMIT can detect not only the small cracks, but can also produce the imaging of the damage within the cross section of the specimen from one side. The migration technology has the potential for identifying the different types of failures such as matrics cracks and delamination in anisotropic structures.

**Mayur Shantilal Vekariya (2013)** In his findings he said that, Micro-cracks is the main cause to structural failure. One way to deal costly manual maintenance and repairs is to adopt method as self -healing mechanism in concrete. Another method can also be adopted as repair mechanism which is currently being investigated i.e.bio-mineralization of bacteria in the concrete. He emphases on the material i.e. Calcite mineral precipitating bacteria for repairing the concrete and plugging the pores and cracks in the concrete. Synthetic polymers such as epoxy treatment are also being used as repair material. He finally concluded

that Microbial concrete technology have been proved to be the better technique than any other conventional method since it has eco- friendly nature and self-healing abilities.

**Syed Mohd Mehndi (2014)** carries out investigation that what are different types of cracks, what are the causes and the methods to how to evaluate such cracks. Various instruments are present to know about the cracks such as crack compactor, ultra sonic testing machine, Pachometer etc. He also concluded his findings by which instrument are more economical to use.

**Kishore Kunal, Namesh Killemsetty(2014)** describes that there are various types of cracks which occur in the building and accordingly at proper time cracks can be minimized depending upon the cracks width . They described how epoxy resins is grouted into the cracks and how it is to be filled in it. They carried out investigation on cracks pattern and treatment measures to fill such cracks and techniques used accordingly.

**Pooja Nama, Ankush Jain, Rajat Shrivastava and Yash Bhatia (2015)** carried out certain investigations that how the cracks are classified such as in beams, columns and slabs. And various types of cracks such as structural cracks and non structural cracks and concluded that if proper consideration is taken then cracks can be controlled. And depending on the type of cracks visualized and accordingly the technique is taken so that it can be minimized.

**Zhou Jing-Cheng,LI Xing-Fu(2015):** He concluded that cracks is mainly due to structural defects of concrete itself. Various others factors can be such as internal and external stratification during the process of pouring of concrete, the existence of various transition zone and multiphase porous system of concrete. These are the various factors on which cracks in concrete take place which he concluded in his findings [18].

**Suresh Chandra Patnaik (2016)** focuses on fact that any nonstructural dormant crack of any cementious, or polymer modified cementious will be more suitable. The epoxy is the best material for injection into cracks in structural members. But for densifying and treatment of honeycombs, the cementious grouts will not only be suitable but also economical. The active cracks need to be treated with a Polyurethane sealant. But if the cracks are located in water retaining structures or in damp locations then polyurethane injection is the best option.

## Conclusion:

This paper comprises of four parts. First paper gives information about the introductory part of cracks. Second part says about causes of cracks i.e. what are the reasons by cracks are generated, what are the various causes which enhances cracks formation. Third part says about how the prevention can be done so that the cracks are not generated. And fourth part gives information about, what are the treatment measures by which the cracks can be treated as such. Lastly it can be concluded that if proper care and supervision is taken then the formation of cracks can be prevented and if the formation still occurs then according the cracks suitable measures can be done to treat it. Epoxy based resins is one such resins if properly used to treat cracks then epoxy treatment serves good as compare to the damaged parts.

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