Building cracks - Causes and Remedies

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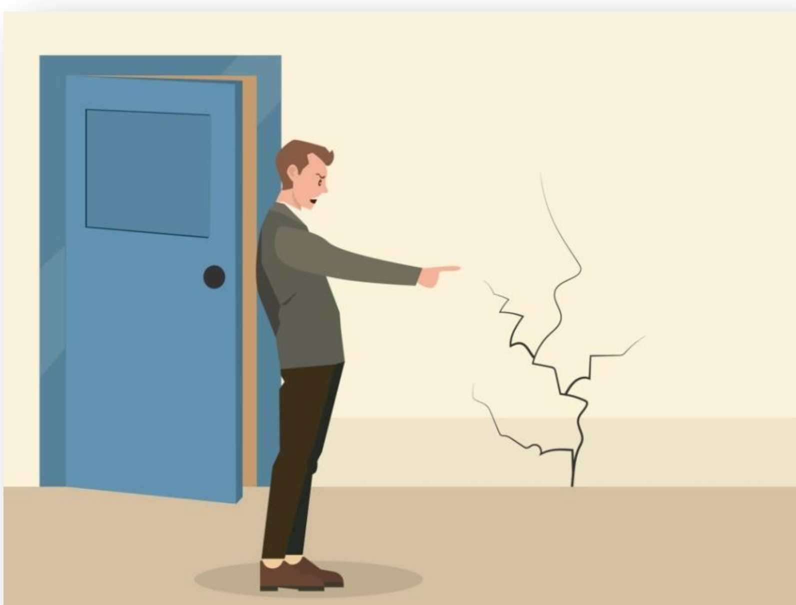
Abstract:

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?



Introduction:

Cracks in the building is a universal problem faced throughout the world. Building components develops cracks whenever stress in the components exceeds its strength. Stress in the building components could be caused by externally applied forces such as dead, live, wind, seismic loads or foundation settlement or could it be induced by internally due to temperature variations, moisture changes and chemical actions. Cracks affects the building's artistic look and it destroys the wall integrity, affects the safety of structure and even reduces the durability of structure.

PRINCIPLES OF INVESTIGATION OF CRACKS:

STEP 1 : Discussion With Client/Owner Of The Building One of the simplest and most important thing is to discuss with client or owner about the cracks on the building and gathering information from them. Ask them:

- i. When was the building constructed ? Date and year of construction?
- ii. Ask for building drawings ? And the details of constructions if available.
- iii. Ask them when the cracks first appeared? Or how long was the cracks seen ?
- iv. Check whether the client makes complaints about pieces of concrete falling, excessive deflections, large cracks, staining, water leakages?
- v. Ask them whether any repair work was carried out if yes, what was the result?

STEP 2 : Visit The Site

- i. When you visit the site, always carry proposed building drawings. Check whether the building is constructed as per the plan.
- ii. Check its present use of the structure or any change in the usage of building.
- iii. Photograph the cracks and number them
- iv. Mark the width of crack
- v. Check for any tilting of walls or tilting of any structural members, deflections, staining, water leakage, spilling, and corrosion.
- vi. Collect the samples from the site.

STEP 3 : Understand The Cracks And Its Causes

- i. Find the type of crack -Is it alive or dead crack.
- ii. Find the causes of cracks : Is it permeability of concrete, corrosion of reinforcement, moisture variation, temperature variation, poor construction practices, poor structural design and specifications, elastic deformation, creep, chemical reaction, foundation movement &settlement of soil ,growth of vegetation, additional alternation of structures.

STEP 4 : Monitoring And Measuring The Movements Of Cracks

- i. Using tell-tale
- ii. ii.Crack width gauge
- iii. iii.Precision calipers

STEP 5: Finding The Suitable techniques To Repair Crack

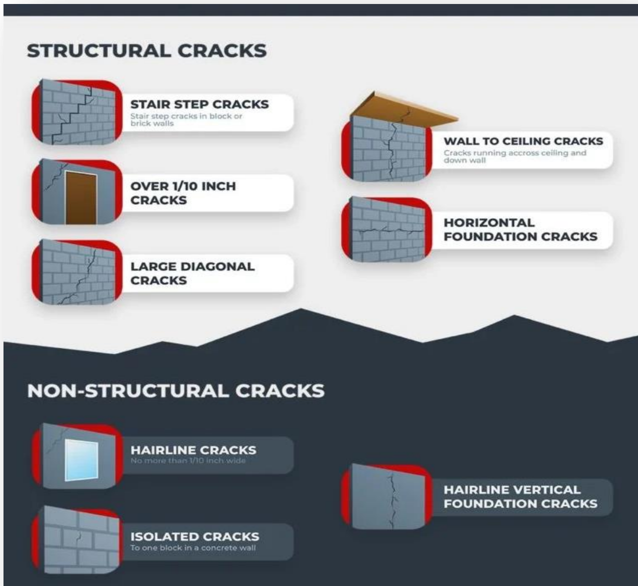
i. Epoxy injection
ii. Routing and sealing
iii. Stitching
iv. drilling and plugging
v. gravity filling
vi. drying packing
vii. polymer impregnation and underpinning

STEP 6 : Formation Of Report.

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.



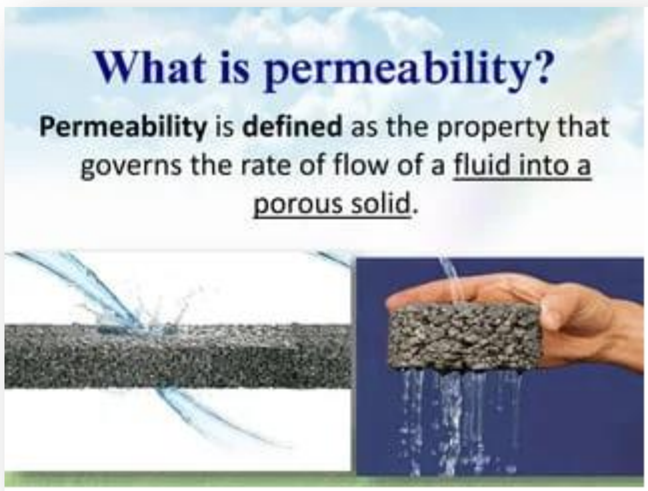
Causes:

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.

Remedial measures

The above discussion suggests suitable measure to decrease concrete permeability and hence cracks.



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.

Remedial Measures
Joints shall be considered during the design and constructed properly. For example, expansion joints, construction joints, control joints, and slip joints.

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.

Remedial Measures

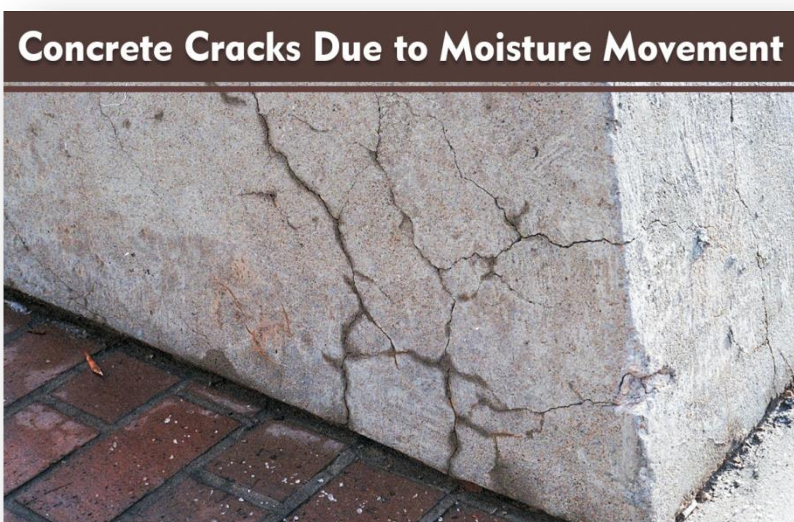
- Use low permeable concrete
- Provide adequate cover thickness
- Make sure concrete-steel bond is as good as possible. This is because concrete alone is not capable of resisting tensile forces to which it is often subjected. Otherwise, concrete may crack and allow harmful substance materials to attack steel bars.

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.

Remedial measures

- Provide movement joints
- Use minimum possible quantity of water for mixing cement concrete or cement mortar
- Compact concrete properly; vibrated concrete suffers lesser shrinkage compare with manually compacted concrete
- Finally, avoid the use of excessive cement.



5. Creep:

Concrete when subjected to sustained loading exhibits a gradual and slow time dependent deformation known as creep. Creep increases within crease 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 admixture sand pozzolona in concrete increases creep, amount of creep in steel increases with rise in temperature

Remedial measures

- Use minimum possible quantity of water.
- Employ large coarse aggregate.
- Provide compression reinforcement if possible
- Avoid formwork removal at early ages.
- Cure concrete properly.
- Assign proper cross section for the concrete element.

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 super vision 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.

Remedial measure

- monitoring construction process properly.
- Utilize good quality materials at the time of construction.

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 groundwater 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.

Remedial measures

Architects, Structural Consultants and Specifiers shall consider the following measure to avoid cracking and subsequent deterioration of structures:

- Proper specification for concrete materials and concrete.
- Proper specifications to take care of environmental as well as sub - soil conditions.
- Constructible and adequate structural design.
- Proper quality and thickness of concrete cover around the reinforcement steel.
- Planning proper reinforcement layout and detailing the same in slender structures to facilitate proper placing of concrete without segregation.
- Selection of proper agency to construct their designs.

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.
Moreover, regular external painting of the building to some extent helps in protecting the building against moisture and other chemical attacks.
Waterproofing and protective coating on reinforcement steel or concrete are all second line of defense and the success of their protection will greatly depend on the quality of concrete.
Leakages should be attended to at the earliest possible before corrosion of steel inside concrete starts and spalling of concrete takes place.
Furthermore, Spalled concrete will lose its strength and stiffness. besides, The rate of corrosion increases because the rusted steel is entirely exposed to aggressive environment.
Finally, it is not only essential to repair the deteriorated concrete but it is equally important to prevent the moisture and aggressive chemicals to enter concrete and prevent further deterioration.

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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.

Remedial measures

- Use low alkali cement
- Employ pozzolana

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 crawl space, 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 sub soil. Uniform settlement up to some tolerance does not cause the problem but differential settlement is something that results in severe crack problem.

Below are some examples of cracks that are very common and can be seen in buildings in Sulaimanya city:

Example No. 1:

Repairing and filling of floor cracks in Sulaimany International Airport warehouses due to heavy load on the floor, using special epoxy type (EPO PASTE) then covering the entire floor with special epoxy type (self FLOW EP300).

Epo Paste

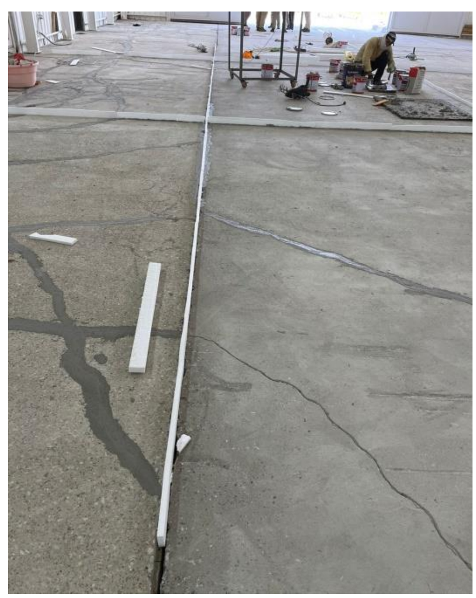
Two component, solvent free, corrosion preventing anchorage and repair epoxy paste

Product Description

EpoPaste is two components, solvent free, moisture tolerant, fast set, corrosion preventing, anchorage and repair epoxy paste adhesive. EpoPaste is a two component product. Components are black and white in color, when Mixed at 1:1 ratio turn into a uniform grey color paste that bonds to asphalt, concrete and steel surfaces.

Technical Data

Property:	
Bond strength to concrete (3hrs @ 25 ^{0}C):	Greater than the tensile strength of concrete.
Bond strength to asphalt (2hrs @ 25 ^{0}C):	Greater than the tensile strength of asphalt.
Compressive strength	> 90MPa
Tensile strength :	> 40MPa
Abrasion Resistance ASTM C779	0.24mm/30 mins.
Gel time :	10 minutes




SelfFlow EP300 Self- leveling epoxy flooring system

Product Description

SelfFlow EP300 is a modified two components, solvent free, special epoxy resin based self levelling floor coating.

Technical Data

Property:	
Density	1.5 Kg/ lit
Percentage total solids	100%
Color:	Various colours on request
Thinning	none
Compressive strength **To ASTM C579 &BS6319, part 2**	~ 75 N/ mm² (28 days / +23°C)
Flexural Strength To ASTM D790	~ 30 N/mm² (28 days / +23°C)
Bond strength	> 1.5 N/mm²
Shore D Hardness	~76 (7 days / +23°C)
Taber abrasion-test 1 kg CS 10 1000 rev. **ASTM D638-98, BS6319, Part7**	~80 mg
Tensile strength: **To ASTM D638-98, BS6319, Part7**	≥ 30 N/mm² @ 14 days
Consumption	1.0 – 1.3 Kg/m^2 with 1 mm thickness
Water and Oil absorption	None

Example No. 2:

Repairing of the cracks of a ceiling due to not using enough Additional bars in the beams by using (SuperFlex PU500) as a crack sealant , and then coating the substrate by (SuperCoat PU100) as a polyurethane coat.

Super Flex PU500

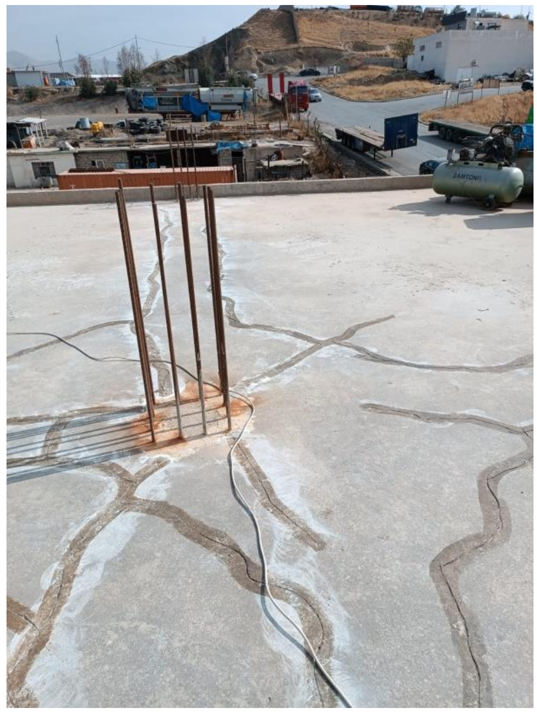
polyurethane based one component sealant, resistance to surface movements and traffic

Product Description

Super Flex PU500 is single component modified polyurethane sealant that cures by reacting with the air humidity to form a tough and highly elastic low modulus sealant. SuperFlex PU500 has a very wide service temperature range. Suitable for vertical and horizontal joints.

Technical Data

Property	
Color	Various
Density	1.35 -1.40 gr/ cm^3
Shore Hardness	40 ± 5
Service temperature	-30ºC to to 120ºC
Shock temperature	120ºC
Application temperature:	+5 up to 50ºC
Adhesion in peel	>32 N
Touch free time	2 hrs. @25ºC& 55% RH
Cure rate	2-3 mm / day
Flexibility	>600%
Tensile strength at 100% elongation	>2.5MPa
Modulus @ 100% (ISO8339)	Ca 58psi (0.4 MPa)
QUV accelerated weathering test (UVB-Lamps) & 4 hrs. COND@50ºC	Passed after 2000 hrs.
Thermal resistance	Passed 100 days @80ºC



SuperCoat PU100
Highly elastic Polyurethane liquid membrane for waterproofing and protection

Product Description
SuperCoat PU100 is single component high quality polyurethane based waterproof coating material and it is ready to use. Cures by reaction with ground and air moisture. SuperCoat PU100 can be applied on dry concrete, fibrous cement, mosaic cement roof tiles, ceramic, wood, corroded metal, and galvanized steel.

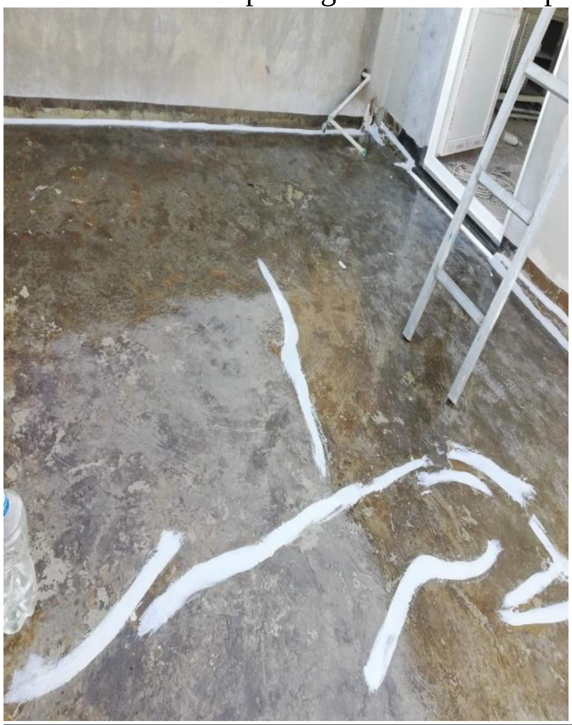
Technical Data

Property	
Color	Various
Density	1.4 gr/ cm^3
Stand on	+23ºC 16/24 hours
Service temperature	-30ºC to +90ºC
Surface temperature	+5ºC to +40ºC
Hardness shore ASTM D2240, DIN 53505, ISO R868	65 (7 days)
Tensile strength at break ASTM D412, DIN 53504	> 6 MPa @ 25ºC
Elongation ASTM D412, DIN53504	>600% @23ºC
Crack bridging ASTM C1305	Pass
Solid matter ratio	Approx. %90

Example No. 3:

Repairing of the cracks on the top roof .
Reason of cracks : casting in the windy day (poor construction practices).

Same method of repairing is used as example no. 2.





In general 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 aplastic 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 abovementioned 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

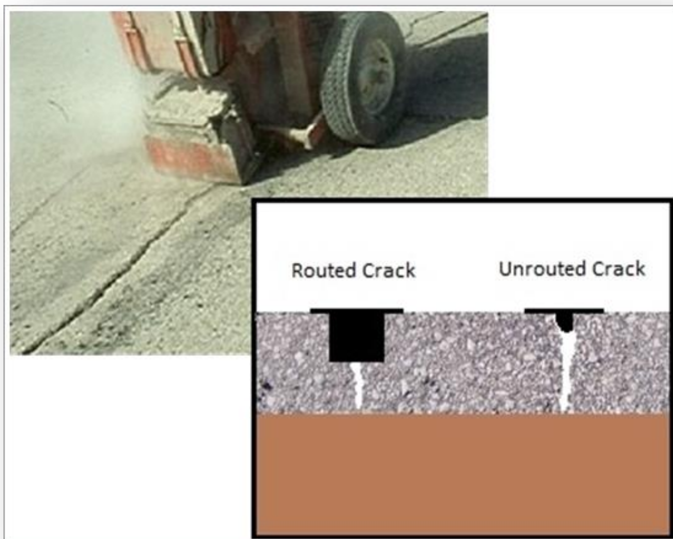
The various techniques to cure crack are as below:

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.

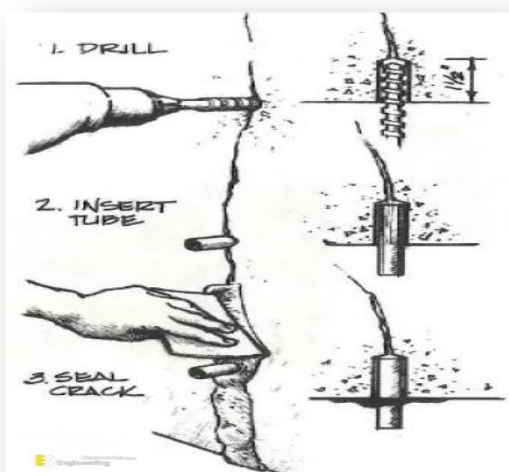
Routing and sealing

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 2to 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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