

CAUSES AND EVALUATION OF CRACKS IN CONCRETE STRUCTURES

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Abstract—This research work focused on checking the cause and evaluation of cracks at every stage in R.C.C structures. This paper will describe how to find out cracks size and cause of cracks. Cracks generally occur both in plastic and elastic state of concrete. I have selected this topic because less work is being done in this area in India. The repair materials and repair technique are different depending upon forms of cracks according to their positions in structure. Good crack repair methods depends on knowing the cause of cracks and selecting appropriate repair method that take these causes into account otherwise the repair would not last long. This report serves as a tool in process of cracks evaluation and causes of cracks in concrete structures. So we can say if crack repair is assumed to be building of structure than this report can be assumed as foundation of it.

Keywords— Thermal expansion, alkali-silica reactions, alkali-carbonate reactions, corrosion; cracking; drying shrinkage, heat of hydration, mass concrete, plastic & precast concrete, pre-stressed concrete, reinforced concrete, shrinkage.

I. INTRODUCTION

Concrete encompasses certain type of cracks in pre-hardening stage and develops some other types of cracks in post hardening stage in life of structure due to various reasons, even with our extreme care in prevention of cracks. When concrete becomes older cracks become causes of leakages and seepages and give entree to the moisture, oxygen, chloride, carbon dioxide etc. and other aggressive chemicals and gases into the concrete causing serious degradation of the structure and causing corrosion of steel and damage in the concrete and at a same time causing structural failure of the member. Cracking are early indications of failure of structure. Lightweight concrete shrinks more. It is vital to note that concrete does crack and this is usual. What is not normal is too much of cracks.

“Cracks can be treated as cancer in R.C.C structure, as cancer which in its primary stage is curable to a certain extent but becomes danger to life in later stage; same happens with cracks”

Depending on types and importance cracks can be of two types:-

Structural Cracks	Structural cracks are of more important and have to be dealt more carefully because neglect to this leads to un-safe structure.
Non Structural Cracks	Non-structural cracks are not of so much significance as far as safety is considered but it deals more with aesthetic point of view.

II. REASONS OF CRACKING

A. CRACKING WHICH OCCUR IN PLASTIC CONCRETE

1. PLASTIC SHRINKAGE CRACKING

It arise when the rate of evaporation of water from top layer of freshly laid concrete is greater than bleed water provided by underlying concrete due to this surface concrete contracts. Due to the restraint shown by the concrete below the drying surface concrete layer the tensile stresses are develop in the weak and stiffening plastic concrete. Due to this shallow crack of variable depth are formed at different locations whose shape can be random, polygonal pattern, or be essentially parallel to one another. These cracks may be fairly wide and can be observed the surface. The size of these cracks would vary from few inches to feet in length. Plastic shrinkage cracks begin as narrow cracks, but can become full-depth cracks later on.

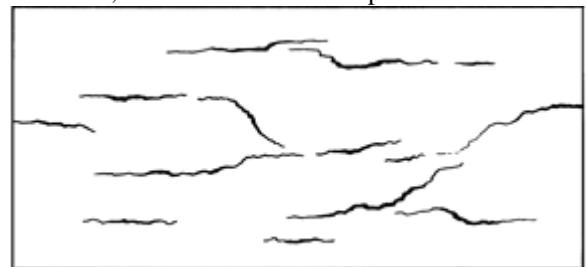


Fig.1 Above Presenting Typical View of Plastic Shrinkage Crack

Plastic shrinkage cracking occur due to:

When temperature of air above concrete is high.
When there is low relative humidity
When wind velocity above concrete is high.

Preventive measures of plastic shrinkage include use of:

Fog nozzles	to saturate the air above concrete
Plastic sheeting	to cover concrete
Windbreaks	to decrease the wind velocity
Sunshades	to decrease the surface temperature

2. SETTLEMENT CRACKING

Concrete has general tendency to settle down after initial placing of concrete and when this settlement are blocked by reinforcement, framework etc. then settlement cracks will develop. Due to restraints; cracks develops in structure which are adjacent to restraining element.

Settlement cracking increase with increase in bar size, inadequate vibration and increase in slump and decreases with increase in size of cover and addition of fibers in concrete.

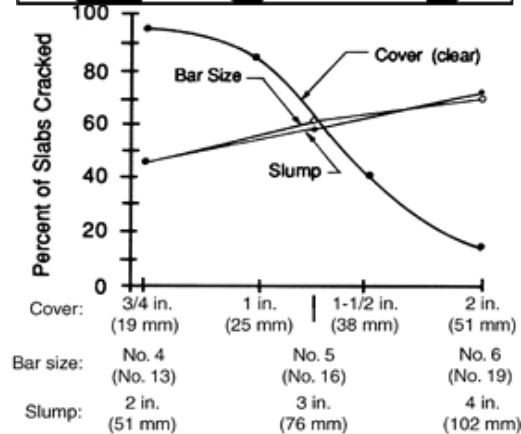
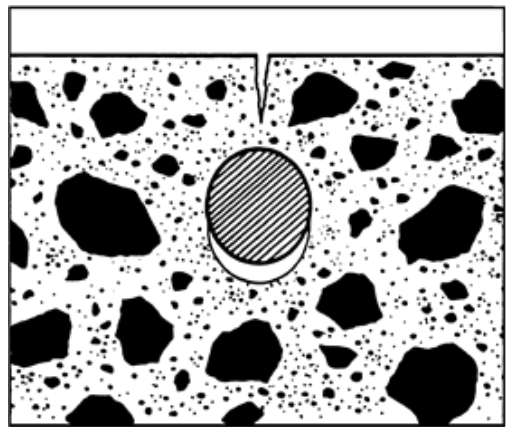


Fig above Presenting Typical View of Settlement Crack

B: CRACKING OF HARDENED CONCRETE

1: DRYING SHRINKAGE

Concrete has greater volume when it is in dried form and its volume decreases on drying; decrease in volume is due to loss of water. When decrease in volume of concrete is restrained by reinforcement bars then cracks are established called Plastic shrinkage cracks. Tensile stresses are developed within structure due to combination of shrinkage and restraint provided by another part of the structure. As we know that concrete is weak in tension so when tensile stress which is developed during restraint exceeds tensile strength of concrete then cracks start to develop. These cracks are detected at the surface which go deep later on as time passes. Factors which affect drying shrinkage are type of aggregate and W/C ratio. Stiff aggregate offers more resistance to shrinkage. Contraction joints and correct detailing of the reinforcement reduce shrinkage cracking.

2: THERMAL STRESS

Thermal stresses are produced when there is normal expansion and contraction of concrete due to surrounding change in air temperature. It was observed that concrete length variations are about 0.5 inch per 1000 linear feet at an atmospheric temperature of about 80 °F. When there is no provision of thermal expansion concrete will crack. This type of crack forms as a source of seepage in water retaining structures. Cracks developed from tensile stresses get accelerated by consumption of Portland cement.

Method to reduce thermal induced cracking involves practice of jute bags to cover concrete and keep watering it at least three times a day in hot countries like India.

3: CHEMICAL REACTION

Chemical reactions which occur due to reaction of concrete in its firm state with materials used to make concrete or by materials that came in contact with it. Chemical reaction inside

concrete can be due to water filled inside water retaining structure, foundation that came in contact with soil or due to air pollutant which reacts with concrete. Concrete gets cracked when concrete reacts with aggregate containing active-silica and alkalis resulting from cement hydration. When the alkalis in cement react with aggregate particles a reaction film of alkali-silica gel is produced around the aggregate. If this gel is exposed to moisture it will expand causing an increase in the volume of the concrete mass which finally results in cracking. Remedial measures include use of aggregates which do not take part in reaction.

Certain carbonate rocks take part in reactions with alkalis produce expansion and cracking. Sulfates from soil when react with cement paste Calcium Sulfoaluminate is formed, which may be root cause in increase in volume of concrete. This increased volume of concrete causes development of closely spaced cracks and ultimately deterioration of the concrete. Sulfate-resistant cements are very beneficial in reducing this problem. Using concrete with a low w/c ratio is important to have adequate protection against severe sulfate attack.

4: WEATHERING

Weathering is wear and tear of structures caused by freezing, drying and wetting of concrete. Concrete can be easily damaged by freezing of water both in elastic stage and plastic stage. Freeze water inside concrete results in increase in volume of concrete. The increased volume of concrete results in cracking of concrete.

Concrete can be protected against weathering by use of the low w/c ratio, tough aggregate and adequate curing of concrete.

5: CORROSION OF REINFORCEMENT

Corrosion to reinforcement is a sign rather than a reason for concrete damage. Corrosion occurs due to electrochemical oxidation of reinforcement bars in existence of moisture and electron flow inside metal. After corrosion the volumes of reinforced bars get increased. Due to increase in volume of reinforced bars a bursting radial stress is produced around bars which results in local radial cracks around bars.

Remedial technique comprises of epoxy coating of bars, use of richer grade of concrete and by use of corrosion inhibitors.

6: POOR CONSTRUCTION PRACTICES

When construction is not done correctly cracks start to originate in structure called cracks due to wrong construction practice. In this the most common is additional of water to increase workability. Addition of water plays an important role in decreasing concrete strength, increasing concrete settlement and increasing drying shrinkage of concrete. Another problem which comes under this is when less curing is done or curing is eliminated early stages.

7: STRUCTURAL OVERLOADS

Concrete gets damaged due to structural overload which is very easy to detect. Precast member like beam and are generally subjected to this type of load. Most unfortunate things about cracks is due to structural overload are that cracks are detected at early stages.

These types of cracks can be prevented if designer limit the load on structure.

8: ERRORS IN DESIGN AND DETAILING

Errors in detailing & designing result in cracking of concrete. These problems are mostly seen in re-entrant corners near door and windows opening in building. Problems which also came in consideration include incorrect detailing of reinforcement steel bars and other problems like restraint of members, lack of

adequate contraction joints and incorrect design of foundations etc.

III. EVALUATION OF CRACKING

A: DIRECT AND INDIRECT OBSERVATION

In this method first we note thickness of crack on a sketched of structure. Then grid are marked on the surface of the structure and crack widths are measured by this instrument to an accuracy of about 0.025 mm. This instrument comprises of a small hand-held microscope with a scale on the lens closest to the surface being viewed as shown in (Fig. 3.1.1) below. However it is generally more convenient to estimate crack thicknesses using a clear card which have lines of specified thickness marked on it, as shown in (Fig. 3.1.2) below.



Fig. 3.1.1—Comparator for measuring crack thicknesses

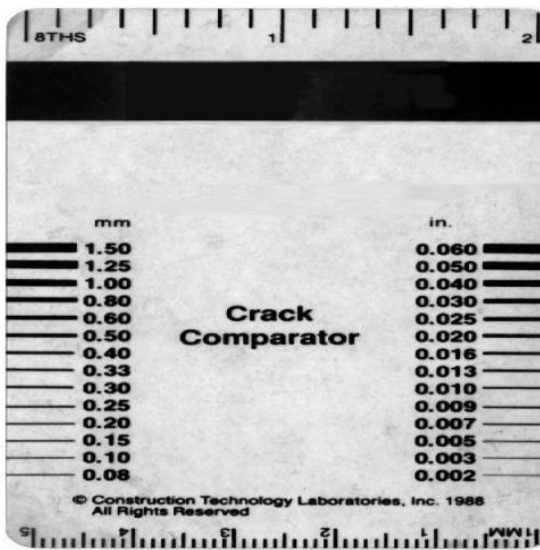


Fig. 3.1.2—Card used to measure crack thickness

Any movement of the surface across the crack should also be documented. Observations such as reinforcement which exposed to environment, surface wear and tear and rust mark on reinforcement bars should be noted down on the sketch. Internal conditions of the crack at definite locations can be observed with the use of flexible shaft fiber- scopes or rigid bore scopes.

B: NON-DESTRUCTIVE TESTING

Nondestructive tests can be performed to estimate the presence of internal cracks and voids and the depth of penetration of cracks detectable at the surface. Tapping the surface with a hammer is simple method to recognize laminar cracking near

the surface. A hollow sound specifies one or more cracks below and parallel to the surface being hammered. Infrared imaging equipment although expensive but found effective in recognizing regions in which concrete has cracks. The presence of reinforcement bars can be determined using a pachometer (Fig. 3.2.1).

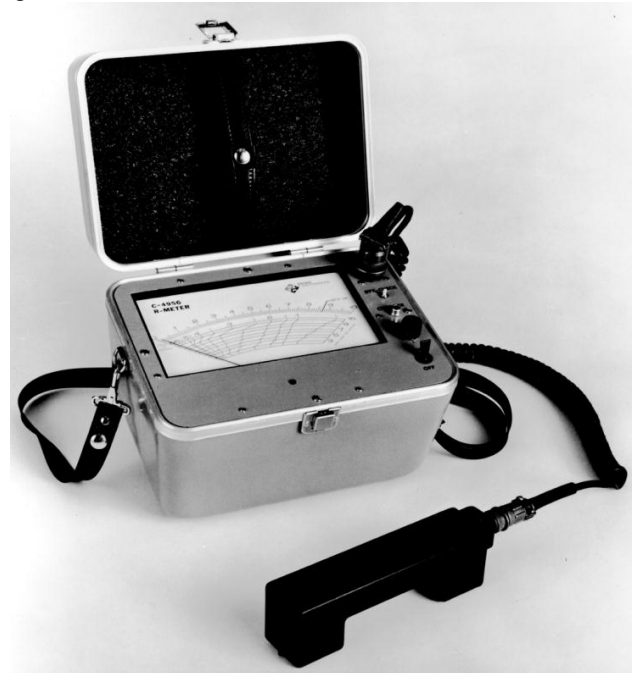


Fig. 3.2.1—Pachometer reinforcing bar indicator

Pachometers show the presence of steel bars and allow the experienced user to determine depth and the size of reinforcing steel. In some cases however it required to remove the concrete cover to pinpoint the bar sizes or to measure cover especially in areas of congested reinforcement. Results of Pachometers are observed by use computer algorithms and magnetic fields to provide a visual picture of the reinforcing bars layout in the scanned area. This device is very useful in detecting reinforcement bars, measure concrete cover, and estimate the position and reinforcement size.

If cracking is due to Corrosion then concrete above bars are removed and bars are saw directly. Corrosion potential of steel bars is measured by half-cell. Generally copper-copper sulfate half-cell is used to measure extent of corrosion in reinforcing steel.

By use of ultrasonic non-destructive test equipment it is possible to detect cracks. A mechanical wave is transmitted to one face of the concrete member and received at the opposite face as shown in (Fig. 3.2.2). The time taken by wave to travel through the member is measured electronically. Pulse velocity can be evaluated if the distance between the transmitting and receiving transducers is known.

When it is not possible to place transducers on opposite face then it can be placed on the same face (Fig. 3.2.2(a)). In this technique analysis of results is not so easy. If more time is taken by wave to travel from transducer to receiver then section is said to be cracked one. Higher the wave velocity shows the good quality of the concrete. The interpretation of result can be improved to great extent by use of an oscilloscope that provides a visual representation of the received signal (Fig. 3.2.2(b)). In fully flooded crack section interpretation of result is difficult hence this instrument is of no use.

concrete can be found out from compressive strength tests but cores containing cracks should not be used to conclude concrete strength.

Photographic test result of cracked concrete can tell us about material that causes cracking, *w/c ratio* relative paste volume and distribution of concrete components, age of cracks, secondary deposits on fracture surfaces.

D: REVIEW OF DRAWINGS AND CONSTRUCTION DATA

Construction drawing and detailing of reinforcement bars should be studied to confirm that the concrete thickness and quality. Serviceability requirement check is also necessary so that non-structural cracks are evaded in structure. The actual loads which are coming on structure should be checked against designed load. If actual loads coming on structure exceeds design load then we have to either re-design section or look in the direction of restoration of structure.

IV. PROPOSED FILTRATIONS AND SUGGESTIONS

The first step involves visual observation of cracks. In second step we find location and pattern of cracks. In third we find out root cause of cracks. Fourth steps involves cracks measurements for which different instruments are used such as Ultrasonic Pulse Velocity—To identify Void and measure Cracks depth, Cracks Microscope and Digital Crack Measuring Gauge—To locate and find width of cracks, Crack Monitor, Concrete Endoscope and Fiber Scope—To monitors the changes in cracks, Petrography—Evaluate crack due to fire damage, and Thermal imaging camera—To detect leakage and voids inside concrete. In all the technique mentioned above Cracks Compactor is most efficient in measuring small cracks. Ultrasonic testing is more costly than Crack Compactor and used for measuring all types of cracks.

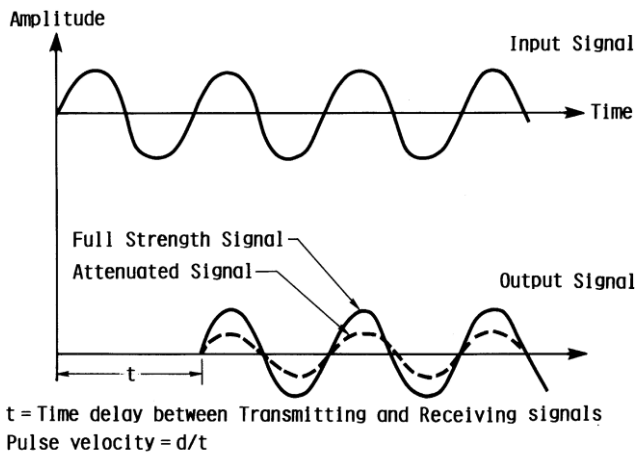
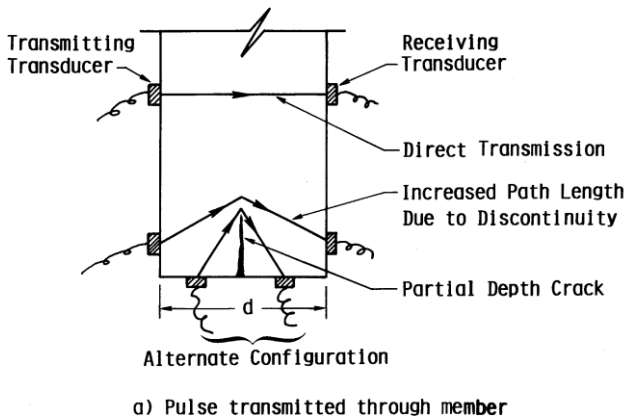


Fig. 3.2.2—Ultrasonic testing: through-transmission

C: TESTS ON CONCRETE CORES

Concrete cores give necessary information about cracks which are taken at different positions. It also gives correct information about thickness and depth of cracks. Strength of

S. NO	CRACKS PATTERNS / SYMPTOMS	POSSIBLE CAUSES/DIAGNOSIS	FURTHER WORK UP /TEST
1	Rust stain on surface	Ferrous Compound Present in concrete	Chemical analysis, cover check and carbonation test of sample
2	Water routed through cracks in concrete	Movement of joints in R.C.C member	Check the Rebar Detail
3	Cracks in cover concrete, Rebar exposed, Concrete spalls	Corrosion of Rebar caused by chlorides	Cover check, Loss of Rebar, Carbonation and Chloride test
4	Cracks between RCC and Masonry	Thermal expansion & Contraction	Check bond between RCC and masonry
5	Horizontal cracks	Corrosion of embedded Rebar	Check the Rebar near the crack for corrosion
6	Cracks at definite intervals	Rebar too near the surface, corrosion of rebar.	Cover check
7	Vertical tapering cracks in masonry near vertical joint.	Foundation substrate/supporting member movement	Reverse calculation of shear strength of beam section
8	Map pattern	Alkali Silicate Reaction, Early drying out condition, concrete having high cement content, poor curing after casting, excess compaction by vibrators.	Chemical analysis of constituents
9	Diagonal cracks in beam near support	Overload inadequate section of beam, inadequate stirrups.	Reverse calculation of shear strength of beam section
10	Vertical cracks in beam near mid span	Overload, inadequate section of beam, inadequate longitudinal Rebar	Reverse calculation of shear strength of beam section

V. CONCLUSION

The paper is divided into three parts. First Part contains different causes of cracks, Second part contains evaluation of cracks and the Last part contains my inference drawn on cracks. This paper on a whole focuses on possible causes and evaluation of cracks in R.C.C structures. Evaluation of cracks can be done by different technique like Crack Compactor and by ultrasonic Testing. In all these mentioned technique Crack Compactor technique is most efficient technique for measuring small cracks, Ultrasonic Testing device is more costly than Crack Compactor and should be used for slightly big evaluation of cracks. Pachomerer is used in determining concrete cover, size and location of reinforcement. In evaluating material causes of cracking Photographic examination is used.

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