Methodology for Prevention and Repair of Cracks in Building

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Abstract

Cracks in building are a common occurrence. It affects the stability and appearance of buildings. So, it is important to understand the cause of cracks and the effective measures should be taken for prevention. Though cracks in concrete cannot be prevented entirely but they can be prevented by using proper material and technique of construction and considering criteria. Sometimes water penetrates through cracks in building and cause severe damage to building. There are many reason of occurrence of cracks like moisture, thermal movement, elastic deformation, chemical reaction, foundation movement, vegetation and earthquake. We all dream of a house structurally safe and aesthetically beautiful but it is not so easy. So, timely identification of such cracks and adopting preventive measures is essential. In this paper, we will discuss about the methodology for prevention and repair of cracks in building. This research paper also gives information about result of Rebound Hammer Test and Ultrasonic Pulse Velocity Test for determining strength of concrete. Because strength of concrete is also an influencing factor for repairing cracks in building. So, we can say if crack repair is assumed to be building of structure then this paper can be assumed as foundation of it.

Keywords- Crack, Structural Failure, Concrete, Causes, Prevention, Repair Technique, Epoxy, Grouting

I. INTRODUCTION

Cracks are the most common problem that occurs in any type of concrete structure such as, beams, columns, etc. A building component develops cracks whenever stress in the component exceeds its strength. Stress in a building component could be caused by externally applied forces such as, dead, live, wind or seismic loads and internal forces such as, moisture changes, thermal movements and chemical reaction. There are numerous causes of cracking in concrete, but most instances are related more too concrete specifications and construction practices than by stresses due to induced forces.

Cracks are classified in two categories: Structural Cracks and Non-Structural Cracks. Structural cracks are occur due to incorrect design, faulty construction or over loading. These may endanger the safety of a building. Non-Structural cracks are mostly due to the internally induced stresses in building materials and these generally do not directly result in structural weakness. When concrete becomes older cracks become causes of leakages and seepages and give entree to the moisture, oxygen, chloride etc. and other aggressive chemicals and gases into the concrete causing serious degradation of the structure. Cracking are early indication of failure of structure. Light weight concrete shrinks more.

Depending on width of crack, these are classified into Thin (less than 1 mm in width), Medium (1mm to 2mm in width) and Wide (greater than 2mm). 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 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.

A. Size of Cracks

1) Hairline cracks: less than 0.1mm in width. No repair action is required.

2) Fine cracks: up to 1mm in width. Easily treated using normal decoration.
3) Cracks easily filled: up to 5mm in width. It can be masked by suitable linings.
4) Cracks that require opening up: 5-15mm in width. External brickwork may need repointing or in some cases, to be replaced.
5) Extensive damage: widths of 15-25mm. It requires breaking-out and replacement of wall section.
6) Structural damage: widths greater than 25mm. Structure becomes unstable and requires major repair works

B. Shape of Cracks

The various shapes of cracks are: vertical, horizontal, stepped, diagonal, straight, toothed, variable and irregular. Cracks can also be uniform type or non-uniform type. Stepped cracks tend to follow the lines of horizontal or vertical joints in buildings. A diagonal cracks indicate that structural settlement is happening, possibly due to upheaval at foundation level or some other from slippage. Vertical cracks may indicate that structural components such as bricks or blocks have failed and so can be a sign of significant stresses within the building structure. Horizontal cracks may indicate that an element such as a wall is failing and this may present a safety concern.

C. Causes of Cracks

The common causes of cracks in building are: permeability of concrete, thermal movement, corrosion of reinforcement, chemical reaction, moisture changes, creep, foundation movement, soil settlement, shrinkage, elastic deformation, overloading, environmental stresses like nearby trains, earthquakes, faulty design, bad quality materials, poor construction practices, weather effects, lots of wear and tear, poor structural design, poor specification, poor maintenance, poor workmanship, etc.

II. METHODOLOGY

A. Repair of Cracks

The repair of cracks can be achieved with the following techniques:
1) By epoxy-injection grouting
2) By routing and sealing
3) By flexible sealing
4) By stitching
5) By providing additional reinforcement
6) By drilling and plugging
7) By prestressing steel
8) By grouting
9) Dry packing
10) Overlays
11) Autogeneous healing
12) Surface coatings

Here we will discuss about most popular repair technique of cracks such as epoxy-injection method and grouting.

1) Crack Repair By Epoxy-injection Method

Epoxy compounds are having very well compressive, tensile and bond strength. They can be used for preparing repair mortars but if used as bonding/binding materials for concrete i.e. epoxy concrete, the cost is prohibitic. Cracks as narrow as 0.05 mm can be bonded by the injections of epoxy. It is excellent material for repairing cracks because they have very good properties such as resistant against water penetration, resistant to crack formation and their very good adhesive properties. This method has been successfully used in the repair of cracks in building, bridges, and other types of concrete structures. The repair process by this method is as follow:

a) Clean the cracks

The very first step is to clean the cracks that have Contaminants such as oil, grease, dirt or fine particles. Because such contaminants prevent epoxy penetration in the cracks to be repaired. For this reason cleaning is required.

b) Sealing of the surfaces

Surface cracks should be sealed. It is used to keep the epoxy from leaking out before it has gelled. This can be done by applying an epoxy, polyester or other appropriate sealing material to the surface of the crack and allowing it to harden.

c) Install the entry and venting ports

When the cracks are v-grooved, drill holes are made in the groove of about 20mm diameter below the apex of the v-grooved section. Fittings such as pipe nipples are inserted in to the holes. But when the cracks are not v-grooved, an entry port is to be bond a fitting flush with the concrete face over the crack.

d) Mixing of epoxy

It is done either by batch or continuous methods. In batch mixing, the adhesive components are premixed according to the manufacturer's instructions, usually with the use of mechanical stirrer, like a paint mixing paddle. In the continuous method, the two liquid adhesive components pass through metering and driving pumps prior to passing through an automatic mixing head.

e) Inject the epoxy

The equipment's used for injecting the epoxy are hydraulic pumps, air actuated caulking guns or paint pressure pots. The pressure used for injection must be selected carefully. The use of excessive pressure can cause additional damage. If the crack is vertical or inclined the injection process should begin by pumping epoxy in to the entry port at the lowest level until the epoxy level reaches the entry port above. For horizontal cracks, the injection should start from one end of the crack to the other in the same manner.

f) Remove the surface seal

Once the injected epoxy has cured, the surface seal should be removed by draining or other means as appropriate.

B. Crack Repair by Grouting

Based on the grouting material used, there are three methods:

1) Portland cement Grouting

Wide cracks in gravity dams and thick concrete walls can be repaired by filling the Portland cement grout in cracks. This method is proved effective in preventing water leakage, but will not structurally bond cracked sections. In this method the very first step is cleaning the concrete along the crack by using air jetting or water jetting, then grout nipples at suitable intervals is installed, then sealing is done between the seats with sealant, then the crack should be flushed to clean it and test the seal and then grouting the whole area. To improve the properties of the grout, water reducers or admixtures may be used.

2) Chemical Grouting

Chemicals used for grouting are silicates, urethanes and acrylomides. Two or more chemicals are combined to form a gel, a solid precipitate or foam as opposed to cement grouts that consists of suspensions of solid particles in a fluid. Chemical grouts can be used in moist environments and in very fine fractures. But with some limits of control of gel time.

III. PREVENTION OF CRACKS

1) By creating slip joints under the support of RCC slab on walls, cracks by elastic deformation can be prevented.
2) Construct various joints such as expansion joints, construction joints, slip joints and control joints to prevent cracks from thermal movement.
3) Slab should be provided with thermal insulation.
4) Concrete should be of good quality. Use richer mix of cement concrete 1:1.5:3 to prevent cracks.
5) In mixing of cement concrete or cement mortar, Use minimum quantity of water, as per water cement ratio.
6) Do not use excessive cement in the mortar mix. Because as a general rule, the richer the mix is, the greater the shrinkage will be. And shrinkage is one of the major causes of occurrence of cracks.
7) Use largest possible aggregate and the materials should be of good grading and quality.
8) As soon as initial setting has taken place, the curing should be started and be continued for at least seven to ten days.
9) Fine materials which contain silt, clay and dust should not be used. The coarse sand/fine aggregate used in cement concrete and cement mortar mix should has silt and clay less than 4%.
10) Use coarse and fine aggregates after washing to reduce silt contents.
11) Strong bond between concrete and plaster prevents shrinkage cracks, if rendering is done as early as possible after removal of shuttering.
12) Due to growth of roots under foundation, cracks can occur in the vicinity of a wall. To prevent such cracks, do not let trees grow too close to the buildings, compound walls etc. Remove any saplings of trees as soon as possible if they start growing in or near of walls etc.
13) The best control measure against corrosion is the use of concrete with low permeability.
14) The structural design of the foundation should be carried out in such a manner as to achieve uniform distribution of pressure on the ground to avoid differential settlement.
15) Use good quality of building materials according to the specification.
16) The workmanship should be according to the prescribed norms and best practice in the building construction.
17) Proper monitoring is required at the time of construction.

Above points should be kept in mind while constructing buildings so that the hazard of cracks can be prevented.

IV. TESTING OF CONCRETE IN STRUCTURES

In-situ methods of testing

Non-destructive test (NDT)	Partially-destructive tests
(1) Surface hardness test	(1) Pull-out testing
(2) Rebound hammer test	(i) Cast-in method (look-test)
(3) Ultrasonic pulse velocity test	(ii) Drilled-hole method (CAPO-test)

(4) Radioactive methods
(5) Nuclear methods
(6) Magnetic methods
(7) Electrical methods

(2) Pull-off test
(3) Penetration resistance test

We will discuss Rebound hammer test and Ultrasonic pulse velocity test which are most popular testing methods.

A. Rebound Hammer Test

A Swiss Engineer Ernst Schmidt, in 1948 developed the Rebound Hammer. This method has been acceptable worldwide for non-destructive testing of concrete structural element. The principle of this method is that the rebound of an elastic mass depends on the hardness of the surface against which the mass impinges. The hammer consists of a plunger connected with a spring driven metal mass. The plunger is held against at 90˚ to the smooth concrete surface, firmly supported and pressed. This will impart a fixed amount of energy. Upon release, the metal mass rebounds, the plunger being still in contact with concrete. The distance travelled by the metal mass or the amount of rebound is noted on a scale which gives an indication of the concrete strength. Larger is the rebound; higher is the strength of concrete.

The rebound hammer test is sensitive to local variations in the concrete; for instance, the presence of a large piece of aggregate immediately underneath the plunger would result in an abnormally high rebound number. Conversely, the presence of a void immediately underneath the plunger would lead to a very low result. For this reason, it is desirable to take 10 to 12 readings spread over the area to be tested, and their average value must be taken.

Table 1: Quality of concrete from Rebound Values, comparative hardness

Average Rebound Number	*Quality of concrete*
> 40	*Very good hard layer*
30 to 40	*Good layer*
20 to 30	*Fair*
< 20	*Poor or delaminated*
0	*Very poor or delaminated*

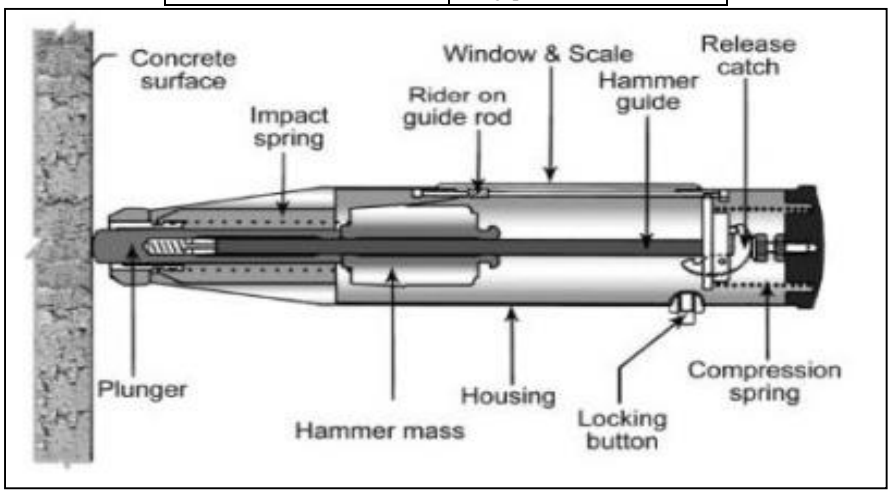

Fig. 1: Typical Rebound Test Hammer

B. Ultrasonic Pulse Velocity Test

The Pulse Velocity method involves the measurement of velocity of the electronic pulses passing through concrete from a transmitter to a receiver. The principle of this test is that the velocity of sound in a solid material is a function of the square root of the ratio of its modulus of elasticity E to its density p. The density and elastic properties are related to the quality and strength of the material. The range of pulse velocities is from 3 to 5 km/s. These pulses in the frequency of 15-175 kHz generated and recorded by electronic circuits. The apparatus of this method consists of a transmitter and a receiver which are held against two faces of concrete. The apparatus generates pulses of ultrasonic frequency which are transmitted through concrete by the transmitter. On the other face, the receiver receives the pulses and the apparatus records them. The time of travel between initial onset and the reception of the pulse measures electronically. The average velocity of wave propagation can be measured by dividing path between the transducer and receiver by the time of travel. The velocity of pulses and the strength of concrete are correlated. Lower the velocity of pulses, lower is the strength of concrete and vice versa. This method is used in detection of the development of cracks in structures such as dams. It can be also used to check deterioration due to frost or chemical reaction.

Table 2: Quality gradings of concrete (As per IS: 13311 Part 1)

Ultrasonic pulse velocity km/s	*Quality of concrete*
Below 3.0	*Doubtful*
3.0 to 3.5	*Medium*

3.5 to 4.5	*Good*
Above 4.5	*Excellent*

V. RESULTS

A. Cracks Repair in Building by Grouting Method

We used Portland cement grouting method to repair cracks in our selected site. Injection of slurry or a liquid solution into a soil or rock formation is termed as grouting. The injected material is referred to as the grout. The Ordinary Portland Cement used in grouting should be as per IS: 269 and sand and water should be as per IRS Concrete Bridge Code. With the approval of the Divisional Engineer, admixtures can be added to impart non-shrinkable properties and to improve flow ability of grout. The water-cement ratio (by weight) for the grout should be 0.4 to 0.5, when crack width exceeds 0.5mm, the lower ratio should be used. Pressure grouting equipment is used to inject grout in the cracks. We used Air Compressor with a capacity of 3 to 4 cum/per minute. The grouting pressure should be 2 to 4 kg/cm^2. After grouting, curing should be done for 14 days. Once the grouting work is done all the grouting equipment including the slurry and mixing drums, nozzles, pipes etc. should be thoroughly washed to prevent damage of the equipment. After the work has been completed, it should be inspected thoroughly by the Engineer In charge and should be kept under observation for a period of 6 months or more for its behaviour after grouting. Although it is time consuming method yet it is more used because it gives better result. The result of grouting method restores and increases the strength of cracked component.

Fig. 2: Repair of cracks by Grouting method

B. Rebound Hammer Test Result

Average rebound number for horizontal hammer position and corresponding compressive strength is presented in table 3.
The table shows that compressive strength of concrete increases with increasing rebound number except for sample no. 4. For this particular sample rebound number was found to be high comparative to its low compressive strength. This was considered an experimental error and this sample was excluded in further calculations. In this concrete grade M-25 was used and the surface condition was dry. The direction of Rebound was horizontal. Rebound hammer is a handy and portable device. The operation of Rebound Hammer is simple. Therefore it can be a convenient method for field identification of concrete. This method is widely used in estimating compressive strength of concrete. The average Rebound number and related quality of concrete is given in table below.

Table 3: Average Rebound number and compressive strength

Sr.No.	*Average corrected Rebound value*	*Compressive Strength (N/mm^2)*	*Direction of Rebound*	*Grade of concrete*	*Quality of concrete*
1	*42*	*44*	*Horizontal*	*M-25*	*very good hard layer*
2	*40*	*41*			*Good layer*
3	*39*	*39*			*Good layer*
4	*29*	*22*			*Fair*
5	*38*	*37*			*Good layer*
6	*37*	*35*			*Good layer*
7	*35*	*32*			*Good layer*

8	*33*	*29*			*Good layer*
9	*32*	*27*			*Good layer*
10	*31*	*25*			*Good layer*

C. Ultrasonic Pulse Velocity Test Result

The ultrasonic pulse velocity readings are given in table 4. At the time of testing the average temperature of atmosphere was 32˚. As per 13311 (part-1) : 1992 RA 2008 clause No. 6.1, the pulse velocity of saturated concrete may be up to 2% higher than that of similar dry concrete. In general, drying concrete may result in somewhat lower pulse velocity. At temp. Between 30-60 ˚C, there can be reduction of in pulse velocity up to 5%.

Table 4: Readings of Ultrasonic Pulse Velocity Test

Sr.No.	*Grade of concrete*	*Distance (m)*	*Transit Time (microsecond)*	*Ultrasonic Pulse Velocity (km/sec)*	*Probing Method*	*Surface condition*	*Quality of concrete*
1	*M-25*	*0.600*	*155.9*	*3.85*	*Cross Probing*	*Dry*	*Good*
2		*0.600*	*104.4*	*5.75*			*Excellent*
3		*0.600*	*147.9*	*4.06*			*Good*
4		*0.600*	*144.9*	*4.14*			*Good*
5		*0.600*	*180.9*	*3.32*			*Medium*
6		*0.600*	*160.6*	*3.74*			*Good*
7		*0.600*	*141.7*	*4.23*			*Good*
8		*0.600*	*162.6*	*3.69*			*Good*
9		*0.600*	*154.9*	*3.87*			*Good*
10		*0.600*	*150.1*	*4.00*			*Good*

Fig. 3: Ultrasonic Pulse Velocity Test

VI. CONCLUSIONS

This research work concludes that though it is impossible to guarantee against cracking yet attempts can be made to minimize development of crack. Some prevention could be taken care of during the construction process itself. Any lack of attentiveness can lead to a cause for damage in the building in its future, which can also lead to the failure of structure. And also, not all type of crack requires same level of attention. Cracks may occur due to various reasons, as discussed earlier. The occurrence of cracks cannot be stopped but particular measures can be taken to restrict them to reduce the level and degree of consequences. The potential causes of crack can be controlled if proper consideration is given to construction material and technique to be used. Generally speaking, for causes and prevention of cracks in particular case it is necessary to make careful observations. 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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