Parametrical Study on Building Cracks and Repair Measures

M.Mohamed Abbas[1], S.Sathiyapriya[2], M.Safeen Abdulla[3], M.Sivapraksh[4] and Ms.P.Latha[5]

[1,2,3,4] *Student, Department of Civil Engineering, Periyar Maniammai Institute of Science and Technology, (Deemed to be University), Vallam, Thanjavur, Tamilnadu, India.*

[5]*Asst Professor, Department of Civil Engineering, Periyar Maniammai Institute of Science and Technology, (Deemed to be University), Vallam, Thanjavur, Tamilnadu, India*

***Abstract* —This Investigation gets into the causes, effects and prevention of building cracks with Estimation. Cracks are kind of defects which occur into building structure that rendered building unsightly and decrease building stabilities. May be cracks has structural failure or non-structural failure that may act, moderate or several. The size and characteristics of cracks ranges from 0 – 25 mm were considered for investigation. Physical inspections of building were made in some selected areas with the support of photographs. Based on literature and site investigation poor workmanship, poor supervision, poor material, faulty design and overloading, environmental problems, faulty construction, foundation settlement, lack of soil test, inappropriate mix were identified as the reason for cracks in building. Cracks may be significantly vary in width from thin hair crack rarely visible to naked eye to gaping crack depending upon the crack width. The categorized cracks were dealt technically in the aspect of severity of damage and repair possibility. The Ultrasonic pulse velocity & Rebound hammer test were done for test results of the building. The results were interpreted with the existing literature and possible causes were identified. Based on the rigorousness of the problem the possible repair solution was offered for the cracks with detailed Cost Estimation.**

***Index Terms* — Building cracks, Ultrasonic test & Rebound hammer test, Remedial measures, Cost estimation**

I. INTRODUCTION

Occurrence of various cracks patterns in the building during construction, and after completion when it is subjected to super imposed load or during the service life, is a common phenomenon. A building component develops cracks whenever the stress in the component exceeds its strength. Stress in the building component could be caused by externally applied forces, such as dead, live, wind and seismic loads, foundation settlement etc. or it could be induced internally due to thermal movement, moisture changes elastic deformation, chemical reaction etc. Building cracks are a global problem. The component will crack if the stress applied on it exceeds its strength. Component stress can be produced by a variety of external forces, including foundation subsidence, seismic loads, wind, dead, and active loads. It can also be caused on inside by changes in humidity, temperature, and chemical variables.

1.1 UNDERSTANDING THE CRACKS

Structural Cracks: These might affect the building's safety because they result from incorrect design, poor construction, or overloading. One example is the significant cracking of an RCC beam (reinforce concrete course).

Non-structural Cracks: These are mostly caused by internally produced stresses in a structure, although they can be unsightly, give the impression of poor workmanship, or even give the sense of instability in some circumstances owing to moisture seeping through them. Non-structural cracks, such as a vertical fracture in a long compound wall caused by shrinkage or thermal movement, can damage interior finishes, raising the cost of maintenance, or they might corrode the reinforcement, impairing the stability of the structure over time.

II. LITERATURE REVIEW

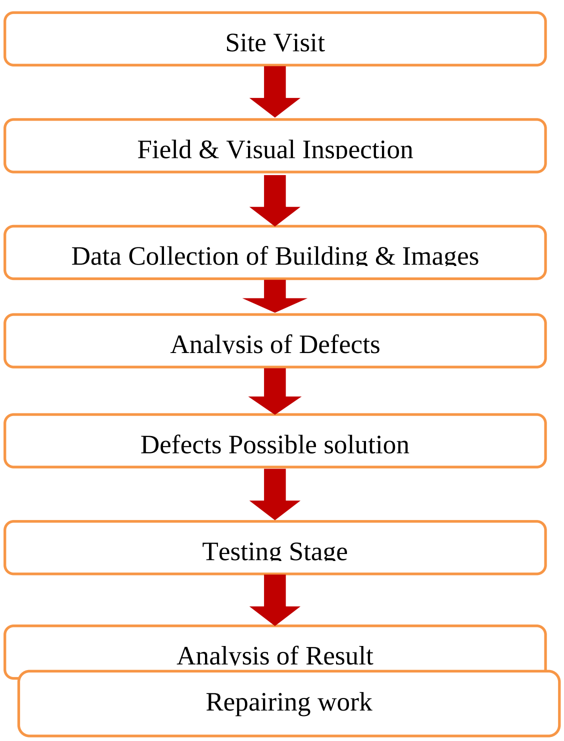
Anitya S. Zanke, (01-12-2020) gives a various types of cracks start to appear on the non-structural and structural part of any construction. These cracks are the result of some unwanted or faulty steps taken during construction. Sometimes, cracks can be a serious concern about the safety of any construction.

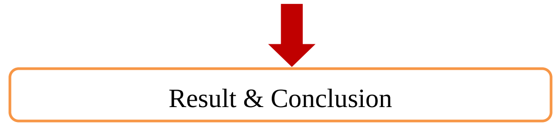
Cracks do not risk the safety directly, but they encourage some acts which cause major safety problems. Therefore, it is very important to detect cracks before they create any serious safety issue and take preventive measures.

Utkarsh Jain, et.al. (01-10-2019); Defects in a building are very common and a major problem that needs to be addressed. We must immediately investigate the cause of such defects whenever they occur. These flaws can be seen as a result of poor masonry work, poor structure maintenance, or poor construction methods.

Agu ransford tetteh ye liang, (April 2020); There are numerous causes of concrete structure cracks. They can have an impact on the 2 appearance, point to significant structural loads, or they can indicate a lack of durability. Cracks can either indicate serious issues or the full extent of the damage. The kind of structure and the kind of cracking determine its significance. For instance, water retention structures may not tolerate cracks that are acceptable for buildings. The selection of repair methods that take into account the underlying causes and knowledge of the causes are essential for successful crack repair.

III. METHODOLOGY





IV. CAUSES OF CRACKS IN BUILDING STRUCTURE

1. Environmental Problem: The environment in which we live greatly contributes to the failure of building structures. As a result, when designing a structure, the surrounding environment ought to be taken into consideration. The structure is susceptible to failure if not. Consider the following aspects of the environment.

(i) Rock Blasting Environment: If a structure is designated in a location that is very close to where rock is being blasted, the entire structure may become weaker as a result of the vibration caused by the blasting. If the environment is not taken into consideration when the structure is designated, there may be a problem.

(ii.) Earth Quake Environment: A building can be moved up, down, horizontally, or in any direction during an earth quake, which is caused by a sudden release of a tremendous amount of energy within the earth. Sand and clays typically have a greater ground motion than rocks do. Waste dumps or reclaimed land are the worst. In areas prone to earth tremors and quakes, buildings should be constructed to modern earth quack resistance standards. These buildings should not collapse, but they should be able to withstand a minor earthquake without being damaged. Geologists and seismologists should be hired to conduct a geoseismic experiment in an area where the earth moves, and the problem's source should be considered during the design phase.

2. Faulty Design: This is a significant cause of cracks in the building as well as errors that result from inadequate professional guidance and experience in the creation of conceptual, detailed, and working drawings. This is because of an incorrect assumption about loading; erroneous reliance on the values specified in the design codes or their misinterpretation, as well as inaccurate claims made by manufacturers and standard details, For instance, when designing a structure with an irregular shape, certain assumptions about analysis and design may be made that are not always in line with how loads are applied and distributed.

3. Faulty Execution: Incorrect mixing of the aggregates, inadequate curing, inadequate bonding, an inappropriate water-to-cement ratio, mortal shrinkage, and other issues can result from a lack of professional supervision and poor workmanship during construction.

4. Poor workmanship: There is a function of the workers on the site. For example, if there are inexperienced workers on the site during construction, they might use stronger mortar for bonding the block to prevent it from cracking. However, experience has demonstrated that Mortal must be constructed to be somewhat weaker than the block. If cracks do occur despite the use of weaker mortal, they are typically fine and referred to as hair thin cracks that are centered around each block rather than being wide and more extensions. This allows for a relaxation of stresses by redistributing the force within the wall.

5. Poor Supervision: A qualified professional should be appointed to oversee the project during its execution to ensure that the worker on site adheres to the standard code's construction guidelines; otherwise, poor supervision will result in poor project execution (consultant duties).

6. Inadequate Curing: The process of maintaining the fresh concrete in a uniform temperature and moisture content is known as curing. To prevent cracking due to shrinkage during hot weather, fresh concrete should be properly cured for 28 days with water, nylon, or wet sand; however, if a professional is completely absent during construction, the curing process may not take place after casting of the concrete.

7. Inadequate of bonding of blocks: There are many ways of setting blocks during construction, out of which are stretcher bond, Flemish bond, English bond and header bond.

(a.) Stretcher bond Each coarse consist of stretcher with exception of a half but which must be placed at the stopped end of a wall at each alternate coarse so that the work will break joint.

(b.) Flemish bond this comprises alternate header and stretcher each course. There are two kind of Flemish bond, double Flemish bond and single Flemish bond.

(c.) English bond this consist of alternative course of headers and stretchers due to the lack of inadequate bonding in English bond, it gives English bond its characteristics strength.

(d.) Headers bond Each course of a wall consists of headers only it is used chiefly in the construction of footing wall which are shapely curved, where the long faces of stretcher would unduly, break the line of the curse stretchers bond is the most common type use in India.

8. Improper mixing of aggregates: When mixing aggregates, an improper water-to-cement ratio can result in segregation or leaking, this will eventually result in weak-hardened concrete. A leap slump test, which is performed on-site prior to casting, requires that wellmixed concrete be able to stand.

9. Faulty material: The materials used in construction, such as concrete, steel, timber, and sand, are another contributor to cracks. Inappropriate selection, treatment, and careless handling during construction could result in the failure of this material. The entire structure will inevitably fail if this material fails.

V. EXPERIMENTAL INVESTIGATION

Field Investigation The purpose of this investigation was to determine the compressive strength and structural adequacy of concrete in the structure, as a result of visible cracks and doubt in the quality of concrete

Rebound Hammer Test 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.

Figure 5.1 Rebound Hammer Testing on Wall

Table 1. Average Rebound number and Compressive strength for Column

Column No	Average corrected Rebound value	Compressive Strength (N/mm^2)	Grade of concrete	Quality of concrete
A1	42	44		Hard layer
A4	40	41		Good layer
A5	39	39		Good layer
B1	29	22	M 25	Fair
B4	38	37		Good layer
B5	37	35		Good layer
C4	35	32		Good layer
C5	33	29		Good layer

Ultrasonic Pulse Velocity Test This method is used to determine the integrity of structural concrete. 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.

Figure 5.2 Rebound Hammer Testing on Wall

Column No	Grade of concrete	Dist.	Transit Time (micro second)	Ultrasonic Pulse Velocity (km/sec)	Surface	Quality of concrete
A1	M25	0.6	155.9	3.85	Dry	Good
A4		0.6	104.4	5.75		Excellent
A5		0.6	147.9	4.06		Good
B1		0.6	194.9	2.84		Doubt
B4		0.6	180.9	3.32		Medium
B5		0.6	160.6	3.74		Good
C4		0.6	141.7	4.23		Good
C5		0.6	162.6	3.69		Good
D4		0.6	154.9	3.87		Good
D5		0.6	150.1	4.00		Good

Table 2. Readings for Ultrasonic pulse velocity test

VI. REPAIR PROPOSALS

Column Jacketing:

For this B1 Failed due to excessive loading, so the column needs to strengthen using column jacketing method. It is a technique of retrofitting and as the name suggests jacketing is the process in which additional materials are to structural components to increase their strength and durability. Means giving protective layer to the component is called as RC jacketing. RC Jacketing of structural column is widely known method and is the most popularly used for strengthening building. The process of jacketing is an ideal solution for retrofitting structure.

Procedure of providing RC jacketing on Column:

Step 1: Cleaning and roughening the surface.

Step 2: Installing dowels for fastening the stirrups.

Step 3: Installing dowels for fastening the lower main steel.

Step 4: Installing dowels for fastening the upper main steel.

Step 5: Installing the new stirrups and steel bars.

Step 6: Coating the surface with epoxy.

Step 7: Pouring the new concrete layer.

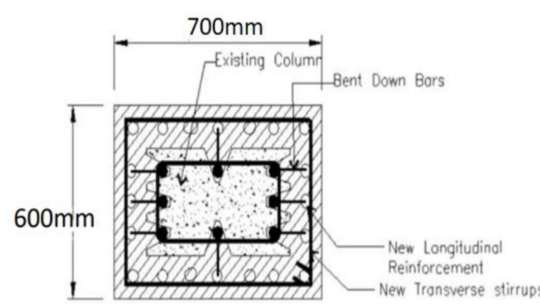


Figure 3.Column jacketing

Epoxy Injection easing The Section of The Beams

This solution for keeping the factor of safety equals 3.0 as it is required by Buildings Code Requirements for Reinforced Concrete. In this solution a new layer of reinforcement should be fitted around the beams and a layer of concrete pumped using shot Crete.

As an alternative for this solution, steel plates can be installed and fixed with beams by using epoxy resin bonded to increase the strength of the beams for the flexure and shear strength. After reviewing the proposed solutions and the conditions of the building, the solution of epoxy injection was selected.

Beams repair work

As mention before epoxy injection solution was selected. The following steps were followed to carry out the repair work:

Surface preparation:

The cracks should be cut and cleaned properly. Any contamination should be removed by flushing with water or some especially effective solvent. Then the solvent should be blown out with compressed air, or adequate time should be given for air drying. The surfaces should be sealed. This keeps the epoxy from leaking out before it gelled. A surface can be sealed by brushing an epoxy over the surface of the crack and allowing it to harden. If extremely high injection pressures are needed, then the crack should be cut into a V-shape, filled with an epoxy, and should be stroke off flush with the surface. The entry ports should be installed thereafter.

Fixing of injection ports/nozzles:

There are three ways to do this. Fitting of nozzles to be inserted in drilled holes should be made by drilling a hole into the crack for 8 mm dia injection packers @ 200 to 300 mm c/c, penetrating below the bottom of the V-grooved section. A fitting such as a pipe nipple should be inserted or tire valve stem should be inserted into the hole and bonded with an epoxy adhesive. A vacuum chuck and bit will help to keep the cracks from being plugged with drilling dust. The second method is by bonded flush fitting. When the cracks are not V-grooved, a common method of providing an entry port is to bond a fitting flush with the concrete face over the crack. Last method is by interruption in seal. Another way to allow entry is to omit the seal from part of the crack. This method uses special gasket devices that cover the unsealed portion of the crack and allow injection of the adhesive directly into the crack.

Mixing:

Mixing the two components of epoxy injection grout of base and hardener should be done in a suitable container with heavy duty slow speed drilling machine with paddle attachment. Mixing should be made for 2 to 3 minutes to obtain a uniform colour.

Injection of Epoxy:

For smaller area or isolated crack a hand pump may be used for injection. Hydraulic pumps, paint pressure pots, or air-actuated caulking guns can be used for larger cracked areas. The pressure should be selected carefully, because too much pressure can extend the existing cracks and cause more damage. If cracks are clearly visible, injection ports can be installed at appropriate interval by drilling directly into the crack surface. The surface of the crack between ports is allowed to cure. For vertical cracks, pumping of epoxy into the entry port should start at the lowest elevation until the epoxy level reaches the entry port above. Then the lower injection port is caped and the process is repeated at successively higher ports until the crack has been completely filled in. For horizontal cracks, injection starts from one end of the crack to the other in the same way. When the pressure is maintained, the crack is filled completely. For injection from underside of ceiling of flat roof a lot of pressure is being exerted. Hence care should be taken while injecting from underside.

S.No	Description of Item Of Work	No's	L	B	D	Counts	Unit	Unit Rate	Amount (Rs)
a	B1 -Column - Jacketing Concrete volume	1	0.20	0.20	10.00	0.40	m^3	6500	2600.00
b	B20- Beam Epoxy injection	1	0.23	0.45	2.60	0.27	m^3	8000	2152.80
c	Epoxy injection on inner walls	4	3.00	10.00	0.12	13.80	m^3	1250	17250.00
d	Epoxy injection on outer walls	4	3.00	10.00	0.12	13.80	m^3	1250	17250.00
e	Slab - Polymer Modified agent (Hall)	2	3.40	9.00	-	61.20	m^2	200	12240.00
f	Anti-corrosive primer	1	-	-	-	10.00	lit	500	5000.00
g	400-micron polyethylene sheet	1	11.50	15.00	-	172.50	m^2	60	10350.00
h	Reinforcement 10 & 12 Dia	-	-	-	-	500.00	kg	75	37500.00
	TOTAL COST								104342.80
i	Preparatory works							15%	15651.42
j	Service items							13%	13564.56
k	Other Civil Works							20%	20868.56
l	Painting works							10%	10434.28
m	Labour Cost							25%	26085.70
n	SUPERVISIONS CHARGE							15%	15651.42
	TOTAL COST FOR REPAIR WORK Rs.								206598.74

Removal of the Surface Seal:

After the injected epoxy has cured, the surface seal is being removed by grinding or some other appropriate means.

ESTIMATED COST FOR THE REPAIR

Figure 4. Estimation of Repair proposal

VII. SUMMARY AND CONCLUSION

- G+2 Residential building had been investigated, and all the failure symptoms observed is reported. Some failures were at preliminary stage, but most of them were at alarming stage.
- Such symptoms must be repaired and rehabilitated as early as possible. Effective solution to repair the failure is proposed. The repair and rehabilitation steps can be further applied to other sites with similar failures observed.
- 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.
- Different methods involved in the repair of cracks are obtained and it is learnt to know the suitability of repairing methods for various cracks.
- A treatment is given for cracks on the roof of residential building to control the permeability and to make the joints water tight.
- The versatile diagnostic devices, clearly indicating the specific problems in the concerned RC members, In addition, they also indicate the degree of seriousness of the problem.
- Prevention of cracks for the buildings is also suggested such as design the members to handle all anticipated loads, protect and cure concrete properly
- The formation of cracks can be prevented if proper care and supervision is taken and if the cracks are still formed then the suitable measures can be taken to treat them.
- Epoxy based resins is one such resins if properly used to treat cracks then epoxy treatment serves good as compare to the damaged parts.
- The occurrence of concrete cracks is mainly due to structural defects of the concrete itself.
- The probable causes of crack can be controlled if proper consideration is given to construction material and techniques to be used.
- 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.
- For framed structure structural audit is necessary so that appropriate remedial measures can be recommended for all types of structural defects and damages .So that it continues to serve strength and serviceability requirement.
- For any structure it is necessary to carry out structural audit at least once in the five years. For structure older than 15 years structural audit should be carried out once in 3 years.

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