"Causes, Prevention & Repair of Cracks"

Submitted for the Partial Fulfillment

of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

2020-21

BY

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CERTIFICATE

Certified that the project entitled **"Causes, Prevention & Repair of Cracks"** submitted by **Chauhan Dhananjay – 1170431017, Tanveer Khan – 1170431036**, **Anuj Singh – 1170431010, Devansh Tripathi – 2180431003, Devesh Mishra – 1170431018**in the partial fulfillment of the requirements for the award of the degree of Bachelor of Technology (Civil Engineering) of **Babu Banarasi Das University**, is a record of student's own work carried under our supervision and guidance. The project report embodies results of original work and studies carried out by students and the contents do not form the basis for the award of any other degree to the candidate or to anybody else.

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(Civil Department)

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DEPARTMENT OF CIVIL ENGINEERING
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DECLARATION

I hereby declare that the project entitled **"Causes, Prevention & Repair of Cracks"** submitted by me in the partial fulfillment of the requirements for the award of the Degree of Bachelor of Technology (Civil Engineering), is record of my own work carried under the supervision and guidance of **Mr. Bilal Siddiqui.** To the best of my knowledge this project has not been submitted to **Babu Banarasi Das University** or any other University or Institute for the award of any degree.

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ACKNOWLEDGEMENT

In the sense of great pleasure and satisfaction I present this project entitled**"Causes, Prevention & Repair of Cracks".** Thecompletion of this project is no doubt a product of invaluable support and contribution of number of people. I would like to express my sincere thanks to my guide **Mr. Bilal Siddiqui**. (Asst. Professor, Department of Civil Engineering), for his continuous help and valuable suggestions and also providing encouraging environment, without which my project and its documentation would not have been possible. I am also grateful to my Head of Department (**Civil Department)** for his valuable help, encouragement and inspiration. The completion of any task is not only the reward to the person activity involved in accomplishing it, but also the persons involved in inspiring and guiding. I am grateful to my friends for their constant motivation and comments that has helped me to complete this report.

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Abstract

Cracks are commonly found on and in structures and are usually undesirable features naturally occurring due to age, workmanship and other natural and environmental causes. This study is set to characterize cracks with the principal aim of recommending proper maintenance and efficient repair actions. Crack occurrence in an office building (storey with basement) was investigated as a case study. Reconnaissance survey was carried out to locate and note the tools that would be required for the investigation of the cracks. Visual examination and measurement of cracks to know the cause and type of each crack were performed. Strength test of all the structural members was done using Schmidt hammer to determine the residual strength of the members on which they appear and the results were analyzed. The results of the reconnaissance survey revealed that most of the cracks are located at the left side than at right side elevation of the building. The nature of the cracks showed that 91% are dormant cracks, while 9% are active cracks. Some of the cracks extended to the plastered surface, while the rest extended to the structural elements region. Therefore, the cracks in this building were found to be caused by the drying shrinkage at the wall section, the compressive force from the beams exceeding the ultimate strength of the affected blocks, foundation settlement at the courtyard was also discovered through topographical survey, due to underground erosion of the foundation wall footing. The results of the non-destructive test (NDT) indicated that, the average strength of the structural elements is within acceptable limit.

KEYWORD- Cracks, Drying Shrinkage, Non-destructive Test, Building, And Structural Elements.

CHAPTER 1

1.1 INTRODUCTION

Cracks are signs of structural movement, during and after construction. Such movement occurs all the time, and usually its magnitude is so small that it passes unnoticed. Most buildings crack at some time during their service lives. The appearance of cracks is a symptom of distress within the fabric of the building. According to, crack is an evidence of gradual deterioration and damage to structures. Often the cracking is of little consequence and once it is established as static, simple repair by filling or re-pointing is all that is required. However, a crack may be the first sign of a serious defect which may affect the serviceability or the stability of the building .Crack is a structural defect consisting of complete or incomplete separation within a single element or between contiguous elements of construction. It can also be defined as a line along which a material is broken into parts. Every crack is an indication that the building is becoming unsafe, though the factor of safety for structural walling is high and the relative importance of many cracks is low .Rarely does a building collapse soon after the appearance of a crack, even if the crack is large, nevertheless, it is important to note this in order to prevent any undesired loss of life or property. Therefore, correctly assessing the significance of cracks is essential. Many cracks have similar appearance, though their causes are different. An engineer should have a sound knowledge of causes, effect and types of cracks likely to occur from the behavior of construction materials and construction techniques, which will enable him, proffer the appropriate prevention and remedial measures .The side effect of cracks affects the integrity, permeability, structural and mechanical properties of buildings. Cracks could be broadly classified as structural or non-structural. Non-structural cracks develop due to the inducement of internal stresses in the building materials and their depth is less, only a few mm i.e. they exist on the surface only. Typically, causes of these cracks are poor workmanship, inappropriate joint detailing, and higher shrinkage of concrete. While Structural cracks develop due to the following causes; design deficiency, construction deficiency, settlement of foundation, reinforcement corrosion, and effect of temperature variation, overloading, swelling of soil below the foundation of the structure. The nature of cracks according to can be classified as active crack which is still in progress, that is, the crack is still developing, and dormant cracks, in which the development is not observed during a considerable period of time, and then this crack is known as dormant crack. It is also important to assess causes of cracks through measurement of cracks' characteristics, which are location, nature, direction, width, depth, position and extent of cracks, and how to repair them. Cracks may appreciably vary in width from very thin hair cracks barely visible to naked eye (about 0.01 mm in width) to gaping cracks 5 mm or more in width. A commonly known classification' of cracks, based on their width is:

(a) Thin - less than1 mm in width,

(b) Medium - I to 2mm in width, and

(c) Wide - more than 2 mm in width.

The research study of the causes, effects and solutions of cracks in building is of importance and would be of benefit to the country by reducing the alarming rate of building collapse. The results of the study helped to create awareness on the types and causes of building cracks and the dangers attached if it is not arrested on time. It will also help in providing information necessary to prevent its occurrence, and at the same time emphasizing the need for periodic maintenance as a way of preventing loss of life, and property due to building collapse. The study of causes and solutions to cracks was considered in the study using a case study of a two-storey office building in the University of Ibadan, which has different categories of cracks and it is making the use of the building uncomfortable by the occupants. Appropriate remedial measures will be proposed to save the building from further deterioration and to extend the life of the structure.

Now days there is limited or reduced availability of resources for new constructions due to which civil engineers have tendency to rely on existing structures and extending the life span of the same structures. Due to this, the difficulties caused are:-

1) More repair and maintenance is requires on existing structure.

2) New technologies and experiments have to be adopted to maintain and improve existing structures and also new structures that have to be developed.

Cracking is the most common phenomenon and is often the most misunderstood when one sees crack in wall or any other part of structure, the person immediately assumes that something is wrong. This is not true always. Cracks can be primarily of many types.

Active cracks are the ones which keep on growing over in a particular direction. Other types of cracks called as Inactive cracks also called as dormant cracks which are initially not so dangerous but if left unrepaired can cause damage in the long-run. Cracks are mostly developed due to deterioration of concrete and due to corrosion of reinforcement provided due to faulty design and poor construction or by many other factors like temperature and shrinkage properties.

Cracks can be primarily divided into two main groups:-

1) Structural cracks: Structural cracks are formed due to faulty design, faulty construction which heavily risks the safety of a building. Examples of structural cracks are the cracks in beam, column, slabs and footings.

2) Non-Structural cracks: Non-Structural cracks are the result of induced stresses in building constituents and due to internal forces developed due to variation in moisture content, temperature variation, crazing etc. Examples of Non-Structural cracks are cracks on parapet wall, drive-way etc.

1.2. OBJECTIVE

The aim of this project is to introduce you to how to recognize the signs and cause of structural Damage to masonry structures and how to mitigate the damage before repairs are undertaken:

- Cracking
- Subsidence, Heave & Landslip
- Point Loading
- Thermal and Differential movement
- Lintel failure
- Corrosion of embedded steel work
- Bowing
- Lack of lateral restraint
- Walls too slender (i.e. too high for their thickness)
- Addition of extra storey's
- Increased floor loads as a result of change of use
- Vibrate
- Chemical Reaction and defective Design
- Chemical Reaction

Chapter 2

2.0. LITERATURE VIEW

Some researchers already worked on related topics of causes and remedies of cracks such as Study type of cracks in construction and its controlling done by [Kazem Reza Kashyzadeh and NedaAghiliKesheh 2012], it shortly describes about what every civil engineer should know about face of the building i.e. cracking. Causes and evaluation of cracks done in concrete structure by [SayedMohdMehndietal. 2014], they explained about the evaluation of cracks that can be done by different technique like Crack Compactor and by ultrasonic Testing. Building cracks-causes and remedies by [Grishma Thagunna 2014], 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.Gamitet al.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 [KishorKunal and NameshKillemsetty 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. Confined masonry is one of the most widely used construction systems in Latin America, Europe and Asia. Where, the masonry system performed satisfactorily during past earthquakes. The system has been in use for decades; however, not much experimental work has been done for the valuation of behavior of confined masonry. In Pakistan, confined masonry construction is popularly used after October 08, 2005 Kashmir earthquake through the affected area. In this chapter an attempt has been made to present typical properties of masonry materials used in India in section The data presented here represent mainly N-W.F.P. However, data of bricks and steel bars is collected from Material Laboratory of Department of Civil Engineering and is supposed to cover much larger area than N-W.F.P. The failure mechanism of the confined masonry is discussed in section 2.3. The behavior of confined masonry buildings during past earthquakes in Latin American and Asian countries is presented.

[Disha Salgiya1 , Utkarsh Jain2 , Shruti Tongiya3 1,3UG Student, Department of Architecture, SDPS Women's College, Indore, India 2Associate Professor, Department of Architecture, SDPS Women's College, Indore, India Volume-2, Issue-10, October-2019] Research suggested early failures in a structure may take due to poor manufacture, poor design, poor specification, and poor construction inappropriate use of materials. There may be some human factor, environmental factor, moisture effects that are responsible for deterioration of the building. A part of research also discuss about the cracks that are developed during the time period of construction of the building it causes, types, nature, effects and measures to prevent it. Research suggested that plaster work should not be started until and unless missionary work has dried up after curing. Portion of motor in parapet construction should be 1:1:16.

It is important to detect an unidentified defects and failures in every part of building and finding the measures to correct it accordingly. An engineer is responsible for keeping the minimum effect of deterioration of the building and taking all possible measures to prevent the cracks and other defects in the building.

[C. ESCHMANN, C.-M. KUO, C.-H. KUO and C. BOLLER 6th European Workshop on Structural Health Monitoring - Th.2.B.1] Unnamed aircraft system for remote building inspection and monitoring

Micro air vehicle (MAV) system used to scan building for inspection and monitoring purpose with a high resolution digital camera.MAV is capable of clicking the images at resolution allowing damages and cracking to be observed still in the mm range

Conventional means for monitoring the condition of building is by men driven inspection only. The way of monitoring provide information only about cracking condition and erosion of covering layer of concrete. For monitoring of dam, Church and multistoried building a device like many is required.

Applicable Payload

The building inspection can be done by numerous WDT method such as visual inspection, thermograph radar or laser. Although all those techniques be considered as NDT in general and also applied within civil engineering sector their implementation in flying platform is still a challenge. It is equipped with various sensors which is used by microprocessor controlled flight system for attitude stabilization navigation is done by GPS.

Inspection of building using UAV is more convenient and divided into two parts data acquisition and data post processing.

Data acquisition

MAV generally fly around the object using GPS Navigation however GPS Navigation is not fully sufficient does a combination of collision and navigation has to be developed allowing autonomous light program the camera can be set manually to set zoom,

focus and shutter release .It is not necessary for application to transmit also the high quality images in real time. For optimal flight detection of damages in both automatic and recording we can use real time video link.

Conclusion

The inspection of a building using MAV represent statistical technique which collects the data first after monitoring the building attached to.MAV gave good results in crack detection even in the structures which are difficult to examine by a civil engineer. The Fraunhofer IZFP octocoper has a size of about 1 m in diameter and mass of 25 kg which does not exceed the maximum payload .It is equipped with various sensors microprocessors and GPS. In all, improvements have to be done for data acquisition so that automation process could be expanded also the image post processing has to be improved by reducing manual workflow. However the high resolution camera attached to MAV has shown good results even under non-optimal flight condition.

[Shivani More, TejasHirlekar Volume: 04 Issue: 11 | Nov -2017] Cracking is the most puzzling problem for engineers writing is unavoidable response of any structure rats cannot be eliminated completely but we can take preventive measures so that problem of crack can be reduced as we know resources are Limited civil engineers rely on extending the life span of existing structures taking more repair and maintenance

Researchers have shown that tracks are two types' active crack and dormant cracks

Active cracks keep on growing in particular direction whereas dormant cracks which are not dangerous but if not repaired can cause damage to structures in the long run

Primary tracks are divided into two main groups

Structural cracks these are formed due to faulty designs, faulty construction which heavily risk the safety of building for example cracks in beam and slab

Conclusion

The formation of cracks cannot be completely eliminated from structures. Cracks may occur at any point during the life span of the structures cracks are unavoidable phenomenon. Through the research work we came to know that there are certain preventive measures that can be taken in order to reduce the probability having of cracks in a structure. By identifying the primary cause of cracks Engineers can ratify it. This increases the life span of the structure making it more efficient. Nonstructural cracks these are the result of prompt stress in building constituents, variation in moisture content for example cracks in driveway.

[Charles c.Roberts, Jr., Ph.D., PE] Research by Charles C Robert junior PhD PE says that cracks are indigenous and desirable feature in building He discussed about some probable causes of cracks .A new foundation has experience settling as a result of soil consolidation at the new Foundation. Groundwater can cause soil erosion reduce compressive strength and load bearing capacity of material causing cracks.

Partial building cracks causes due to the defect or deterioration. According to research paper the loss of a structural Foundation support has caused cracking of dry wall in building in building interior. Typical garage floor slab have formed over a period of time research give a deep view of causes and the reason behind the cracks. Technical analysis is also required in order to know the exact cause of crack. Taking information about the history of the building like its age when the last remodeling was done etc.based on information coverage decisions are taken.[Pooja Nama1 , Ankush Jain , Rajat Srivastava and Yash Bhatia. Head of Civil Department, Career Point University, Kota, Vol. 5, Issue 5, (Part -2) May 2015,]Study by Rajat Srivastava at a l ING journal engineering research and application . According to this study crack is a complete or incomplete separation of concrete due to breaking or fracturing. A literature survey revealed that every civil engineer should know about face of the building that is cracking causes and its evaluation. Evaluation can be done by the techniques like crack compactor and ultrasonic testing. This research is divided into four parts I part discuss about the meaning of cracks identification and types of cracks. The second part discusses study , visual identification of cracks with measures to prevent it .Third part contains the techniques that can cure the cracks .The forth part stresses on the technique adopted by an engineer to prevent the cracking, suggests technical employed should be in accordance with the causes of the cracks. Cracks can be controlled if proper consideration is given to construction material and technique to be used the aim of a civil engineering is to minimize the probable chances of cracking in an structure and providing.

[Ohazurike, EmekaEvaristusaOzioko, HyginusObinnabIbe, OkechukwuPatrickc Accepted 09 Nov. 2020 Available online 07 Dec. 2020]

After careful observation it has been observed that several structural cracks are caused due to differential settlement of soil, faulty design and poor workmanship. Some of these cracks are dangerous if left and unrepaired. Hence pose a real threat of future collapse .the non-destructive smirch hammer test conducted on key structural elements of the building shows that the average compressive strength of the building the ranges between 48N/mm2

The buildings still others high structural from the bulk density of soil was found to be y=290g/cm3 =28.45N/m3. Hence the ultimate bearing capacity of soil assuming a Foundation depth of 750mm and above off 1000mm was found to be Qu=409.8kpa. The Research paper suggested that the compressive shear strength of a Foundation soil was found to be above 100kpa the cracks could not have occurred as a result of soil shear failure.

[De-Ling Liu & William W. Nazaroff Published online: 30 Nov 2010]

The work reported here contributes to the base of information about penetration through building envelopes, but additional investigations are needed to fill in important gaps. For example, it would be useful to study particle penetration through real building components, such as windows, which contain a variety of leakage paths. Additional studies in well-characterized single buildings are also needed. Studies published to date have focused on the penetration of nonvolatile particles. Fine particles often contain significant proportions of volatile constituents, such as water, organic compounds, and nitrate. The behavior of such particles and their constituents in air leakage pathways could be considerably different than that of purely nonvolatile particles.

[Chetan J. Chittel , Yogesh N. Sonawane2 1, 2 Department of Civil Engineering, RCPIT Shirpur, India Volume 6 Issue III, March 2018] Crack in a building is of common occurrence the first and most important reason of crack is the stress component .Modern structure are more tall and Slender and are constructed speedy .These types of structures are there for more liable to cracks. According to s1456200 the surface width of cracks should not exceed o.3 mm in members, where crack is not harmful and does not have any serious adverse effect upon prevention and reinforcement Steel. An upper limit of 0.2 mm is suggested to be maximum. Please study covers all aspects of causes of cracks, types of cracks and various measures that could be taken in order to prevent the cracks. This study shows that all type of graphics does not require the same consideration. Severe cracks require more focus and more attempts in order to correct them. The probable cause of cracks can be controlled at the very beginning when the construction of building starts. Proper consideration is to be given to the building material and technique to be used in the construction of the structure.

Chapter 3

3.0) CAUSES OF CRACKING

Principal causes of the occurrence of cracks in the buildings are as follows:-

3.1) Moisture variation:

Building materials majorly have pores in their burnt clay bricks, mortar, some stones etc. These materials expand on absorbing moisture and contract or shrink on drying. These movements are cyclic in nature and are caused due increase or decrease in the pore water pressure; extent of these movements also depends on molecular structure of a material. The various effects of moisture changes are:-

a) Initial shrinkage.

b) Reversible movement.

3.2) Thermal movement:

This is one of the most important causes of cracking in building. Thermal movement largely depends on several factors such as variation in temperature, co-efficient of thermal expansion and other physical properties of the components. Thermal variation in the internal walls and internal floors of the building are not much and thus do not cause much cracking. It is majorly the external walls and the roofs which are exposed to several physical factors and are subjected to substantial thermal variation that are liable to cracking.

3.3) Changes due to chemical reaction:

Due to expansive reactions between aggregates consisting of silica and alkali, concrete may crack. This alkali-silica reaction gives rise to a swelling gel, which absorbs water from other parts of concrete. This phenomenon of expansion results in cracks in the building.

3.4) Cracking caused due to vegetation:

Availability of vegetation in the vicinity of walls can cause cracks in the wall due to expansion of roots growing across and under the foundation. Tree roots spread on all the sides above the ground and when trees are in the vicinity of wall, this should always spark a suspicion.

3.5) Poor repair and maintenance:

After a certain period of time every structure needs to be repaired and maintained. Some structures do not need a very early look while some may need a very look into their deterioration problems. It is always better and wise to identify problems before they cause any damage.

3.6) Movement due to settlement of foundation:

Whenever a structure is built the left over dig is subsequently backfilled. This dig is filled unless the backfill material is properly compacted, this will eventually settle over time. This process of settling will cause poured concrete to settle. Various other factors resulting in the settlement of foundation are variation in moisture content below and across the foundation, decay of organic particles and load of the structure.

3.7) Faulty specification and poor structural design:

Every structure loses its durability over a period of time or during the time of preparation of specification for concrete, other materials. During the design of any structure every designer and architect must take into consideration the environmental aspects of the site. It is most important to also take into consideration the geotechnical factors for determination of soil type, type of foundation required, grade of concrete and steel required etc. In addition to faulty specifications, improper skills, lack of experience of contractor, unskilled workers ultimately gives rise to the deterioration of building or any structure.

Fig 3.1

3.8) Corrosion of Reinforcement:

The reinforcement steel is well protected by a properly designed and constructed concrete, this physical barrier of concrete has low permeability and high density. The cover of concrete around the reinforcement steel provides a chemical protection and this steel is safe and will not undergo corrosion as long as concrete around it is not pervious and does not allow chemicals to penetrate within the area. When the concrete around the steel is alkaline and have high pH value the corrosion of steel will not occur when a structure is well designed and structured excellent protection to reinforcement steel is provided by concrete. In cases, where the structure is not properly designed there is no excellent protection provided by the concrete to the reinforcing steel. This, in the long run has caused severe damage to the concrete structures resulting in the loss of bond, durability, stiffness and ultimately loss of strength in the whole structure takes place.

Fig 3.2

3.9) Subsidence damage

Extensions and Bays

- Extensions and bays can 'rotate away' due to subsidence
- Quite often the foundations are a different from the main structure
- Tapering cracks appear at or near the junction of the projection

Fig 3.3

3.10) Trees and drains:

Trees

- Vegetation growing close to the building can cause clay shrinkage by removing moisture from the soil through their root systems.
- A mature oak can draw up to 1000 liters per day
- As the moisture content of the soil changes so the volume changes and any associated cracking may open and close (cyclical movement)
- Granular soils are generally not affected by the presence of vegetation

Drains and leaks

- Did the drains become defective due to subsidence or did leaking drains cause erosion or softening of clay followed by foundation movement
- Erosion and washing away of fines (footballs in the box)
- Soak ways too close to a building or failing
- Softening of cohesive clay soil (turn to jelly)
- CCTV to establish the condition
- Resin Liner or replacement

3.11) Inadequate Foundations:

- Generally, only a problem found on older properties and may affect all or only part of the structure (problems with garages, porches and bay windows and conservatories are particularly common).
- Strip foundations too narrow to adequately support imposed loads resulting in differential movement.
- Shallow foundations built within the shrinkable clay zone or on loose or poor made ground.

Fig 3.4

3.12) Heave

- The upward movement of the **site**, normally due to expansion of a previously desiccated or shrunken clay as it rehydrates.
- Often associated with removal of trees prior to the construction of the building.
- Before tree removal, assessment of the risk may be necessary – follow the rule of thumb below.

a) If the tree is the same age or younger than the building there is no risk of heave.

b) If trees are older than an adjacent building i.e. the building was constructed on a desiccated soil there is a possible risk of heave.

Fig 3.5

Opposite to Subsidence with tapered stepped diagonal cracking wider at the bottom

3.13) Landslip:

- **Downward Movement of sloping ground** resulting from the action of self-weight stresses and imposed loading (weight) exceeding the strength of the **'toe'**
- **Three key factors**
- Weight
- Water
- Toe stability

3.14) Point Loading:

- Structural alterations to a building (removal of internal walls, enlargement of external windows or doorways etc.) or change of use can cause stress concentrations within localized areas of supporting brickwork
- Associated concentrated loading of foundations may exceed safe bearing capacity of the underlying soil and cause additional '**settlement'**
- Loading levels mean this is rarely a significant problem in two storey domestic construction but can be in Victorian or Georgian town houses with four or more stories where narrow brickwork piers carry excessive concentrated vertical loads.

3.15) Corrosion:

- Wall Tie failure on cavity walls
- Steel lintels, railings or beams inserted into masonry

No Wall ties causing bowing and 'peeling'

Wall Ties

Wall Tie corrosion

3.16) Vibration & Earthquake:

- Granular soils are susceptible to consolidation by vibration and may cause subsidence
- Clay soils are rarely affected by vibrations
- Vibrations generally only cause minor structural damage such as cracked plaster etc. However earthquake can be devastating leading to collapse
- Damage may exacerbate the problems associated with other defects e.g. settlement of fill to rubble filled walls, lack of lateral restraint to external walls etc.

3.17) Lateral Restraint:

- Would normally be an inherent design fault
- Lack of restraint is the most common cause of bowing or leaning walls
- Traditionally restraint is provided by the bonding in of internal and party walls
- Modern construction utilizes the diaphragm action of the floors by connecting them to the walls with metal straps.

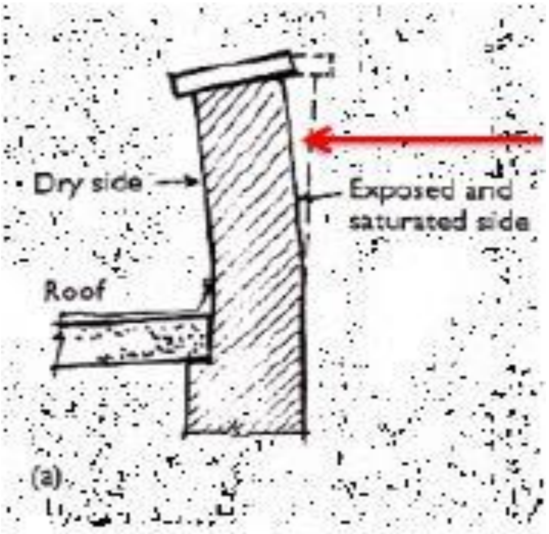
External and internal view

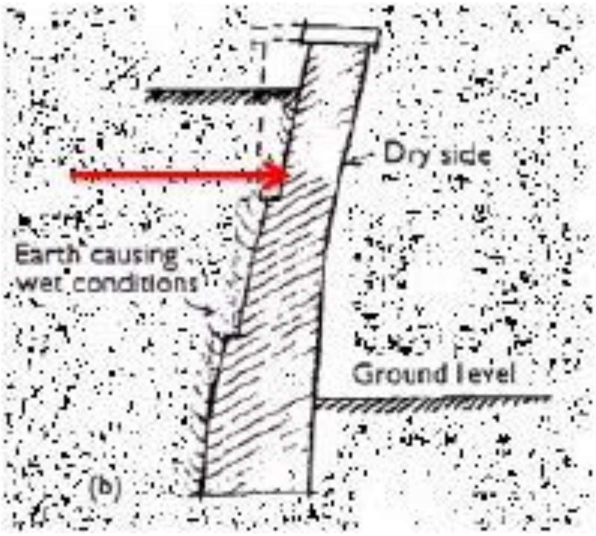
External Bowing wall **Internal cracking adjacent to bowing**

3.18) Chemical Reactions:

- Clay bricks contain soluble sulphate salts which may appear as efflorescence on the surface. When wet they react with the Portland cement within the bedding mortar producing a significant increase in volume
- This expansion of the mortar can cause spalling, bowing of the wall and cracking of applied surface finishes such as render, pebbledash etc.

- Differing moisture conditions to opposite sides of a wall can result in differential movement. Parapet walls, earth retaining walls, chimney breasts are very susceptible to damage.





Parapet Wall **Retaining Wall**

Chimney Stack

Chapter 4

4.0. METHODOLOGY

The commonly observed crack pattern in building can be group as, cracks in:

- Walls,
- RCC members,
- Renderings and plasters,
- Concrete and terrazzo floors, and
- Roof terrace

Each of these has been covered in this chapter along with preventive measures and feasibility of repairs in specific cases. However, main emphasis is given on prevention of cracks, as in many cases there may be no satisfactory method of repairing the cracks after they have appeared.

4.1) Cracks in walls

Cracks in walls can be further grouped as:

- In masonry structure
- In RCC frame structure
- In free standing walls

4.1.1 In Masonry Structure:

Commonly observed cracks in masonry structures are:

(i) Cracks at ceiling level in cross walls: In load bearing structures, where a roof slab undergoes alternate expansion and contraction due to temperature variation, horizontal cracks may occur (shear cracks) in cross walls, due to inadequate thermal insulation or

Protective cover on the roof slab. To prevent such cracks, the following measures may be adopted.

Slip joint (Para 3.4.9) should be introduced between slab and its supporting wall, as well as between slab and cross walls.

The slab should either project for some length from the supporting wall or the slab should bear only on part width of the wall (fig.). On the inside, wall plaster and ceiling plaster should be made discontinuous by a groove about 10 mm in width.

(ii) Cracks at the base of a parapet wall: An instance of very frequent occurrence of thermal

A crack in buildings is the formation of horizontal crack at the support of a brick parapet wall or brick-cum-iron railing over an RCC cantilevered balcony. Factors, which contribute to this type of cracking, are:

Thermal coefficient of concrete is twice that of brickwork and thus differential expansion and contraction cause of horizontal shear stress at the junction of the two materials. Drying shrinkage of concrete is 3 to 4 times that of brick masonry.

- Parapets are generally built over the concrete slab before the latter undergone its drying shrinkage fully, and

- Parapet or railing does not have much self-weight to resist horizontal shear force at its support caused by differential thermal movement and differential drying shrinkage.

The following measures may be adopted to reduce the severity of such cracking.

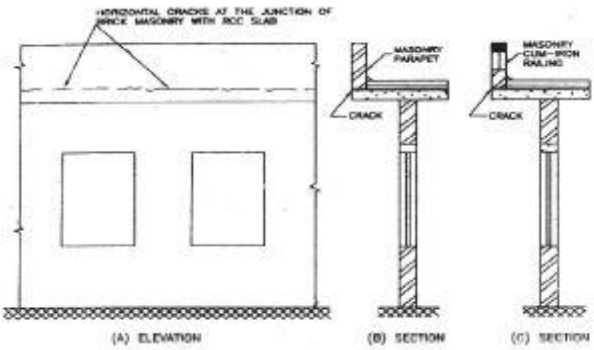
a) Concrete for slab should be of low shrinkage and low slump.

b) Construction of masonry over the slab should be deferred as much as possible (at least one month) so that concrete undergoes some drying shrinkage before construction of parapet.

c) Mortar for parapet masonry should be 1 cement: 1lime: 6 sand and a good bond should be ensured between masonry and concrete.

d) Plastering on masonry and RCC work should be deferred as much as possible (at least one month) and made discontinuous at the junction by providing V groove in plaster. This way the cracks if they occur, will get concealed behind the groove and will not be conspicuous. Alternatively, a 10 cm. Wide strip of metal mess or lathing may be fixed over the junction to act as reinforcement for plaster.

e) .In case of brick-cum-iron railing, cracks could be avoided by substituting the brickwork (of which there are only a few courses) with a low RCC wall, supporting RCC railing.



Horizontal cracks at the base of brick masonry parapet (or masonry cum iron railing) supported on a projecting RCC slab.

iii) Horizontal cracks in the topmost story below slab level:

These cracks are due to deflection of slab and lifting up of edge of the slab, combined with horizontal movement in the slab due to shrinkage. These cracks appear a few months after construction and are more prominent if the span is large. These cracks are mostly confined to the top most storey because of light vertical load on the wall due to which, end of slab lifts up without encountering much restraint. In the lower stories, lifting of the corners is prevented by the vertical load of the upper stories. Sometimes horizontal cracks develop in the topmost storey of a building at the corners, due to lifting of the slab at corners on account of deflection of slab in both directions. These cracks could be avoided by providing adequate corner reinforcement in the slabs. When large spans cannot be avoided, defection of slabs or beams could be reduced by increasing depth of slabs and beams so as to increase their stiffness. Adoption of special bearing arrangement (fig.) and provision of groove in plaster at the junction of wall and ceiling will be of some help in mitigating the cracks.

4.2) Retrofitting:

Retrofitting means providing something with a component or feature not fitted during manufacture or adding something that it did not have when first constructed. It is often used in relation to the installation of new building systems, such as heating systems, but it might also refer to the fabric of a building, for example, retrofitting insulation or double glazing.

The process of retrofitting involves the careful balancing of different elements and their effects on the overall performance of a building. A change in one part of a building can affect another, and sometimes this is only apparent after irreversible defects have occurred.

For example:

- Sealing buildings to improve their air-tightness can cause condensation problems.

- Insulating a roof without also ventilating it can cause decay of timber structure.
- Internal wall insulation will remove the benefits of thermal mass which may have a detrimental effect on fuel usage.
- External wall insulation will prevent the thermal store of heat from solar gain to be utilized within the building.
- Poorly installed cavity wall insulation can create cold spots that then have damp problems that are extremely difficult to rectify.

Jacketing column Jacketing is a technique used to increase the strength of existing structural members (e.g. Columns, Beams etc.) by providing a “Jacket” of additional material around the existing member. Columns are designed to transfer loads from top to bottom. Now due to long age or non-calculated excessive loadings or change of functions, there might be different loading than designed for on the columns in order to support this extra loadings, the sizes of columns will have to be increased. This extra layer of reinforcement and concrete over and above the completed column is known as jacketing of column. It is generally used in case of buildings after earthquakes or very old buildings to increase its life.

Strengthening of individual footings

Generally, strengthening of the foundations might be needed due to the alterations in serviceability of the buildings. One method of strengthening can be carried out by constructing a concrete jacket to the existing footings. Strengthening foundations by installing jackets can be achieved either without increase in bearing area at the base or increasing it, whenever the soil has inadequate bearing capacity. Below mentioned procedure is for soil with adequate bearing capacity.

Steps to be followed are-

Step1 – Excavate the surcharge soil around the footing.

Step2 – Roughen the top surface of the base slab for proper bond between the poured concrete and existing one

Step3 – Drilling holes in the existing concrete of footing to install dowels.

Step4 – Fastening the new steel bars with the dowels using steel wires. The diameter and number of steel bars should be according to the design.

Step5 – Coating the external footing surface for proper bond between new concrete and old concrete.

Step6 – Completing the Jacketing of the footing by pouring new concrete in the steel cage.

4.3). 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 presstressing steel
8) By grouting
9) Dry packing
10) Overlays
11) Autogenously healing
12) Surface coatings

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

4.4) 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 prohibited. Cracks a 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.

4.5) Crack Repair by Grouting:

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

a) 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.

b) Chemical Grouting

Chemicals used for grouting are silicates, urethanes and acrylamides. 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.

Identification of Cracks and their Causes

In reconnaissance survey, the building inspection was carried out to diagnose the cracks in the building, by looking at the whole building from a distance, walking round the building, and observation of each room to locate the cracks, and detail measurement of each crack, and their location in the building. The desk study was performed using the architectural design plan to:

Check the layout of the building and location of each structural member. It was used to create the identification codes and the detailed observation procedure. Each floor was divided into two wings WING A (named as A) and WING B (named as B). The rooms were named as "R", the walls were named as W1 (Wall 1), W2 (Wall 2), etc. The cracks were named as CR 1, CR 2, etc.

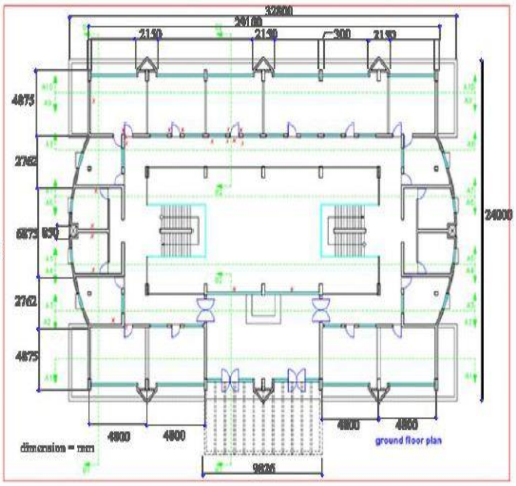
Other structural elements which are Floor Slabs, Beams, and Columns were coded as FL, BM, and Col respectively .It was used to create design manifest for recording the observation of the cracks and design manifest to record Rebound Hammer Readings .Other areas of investigation include critical visual observation of key areas of the building such as; the pattern of cracks' defects on load bearing/shear walls, floor slab, beams, columns, examination of floor finishes and walls, the examination of column interface with ground floor slab to establish possible foundation settlement, the study of available relevant architectural plan, in order to affirm the consistency of the design concepts interpreted in detailed drawings and finished construction. The tools used for the study were

(a) Measuring tape: to determine the depth and width of cracks.

(b) Needle or Needle-typed wire: to determine the depth of cracks.

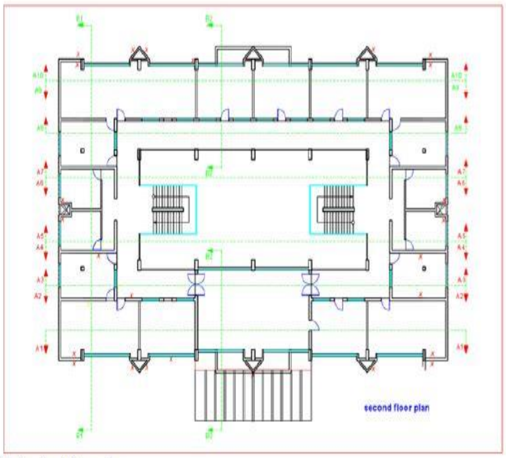
(c) Tell-tale tool: to determine the nature of the cracks/monitor the cracks.

(d) Schmidt Hammer: to determine the strength of the structural elements (Floor Slab, Beams, and Columns of the building). Survey/Investigation of the cracks was done to investigate on what might have caused the occurrence of each crack in the building. The cracks were grouped based on the findings, which are drying shrinkage, architectural design fault, foundation settlement, and movement due to creep.



X = Location of the cracks

Fig. Ground floor plan of the building



X = Location of the cracks

Fig.2.Second floor plan of the building

Chapter 5

5.1). 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.

18) Drying shrinkage is one of the most important factors that majorly cause cracking, hence, several chemical admixtures should be put to use to reduce the amount of drying shrinkage.

19) Also some synthetic fibers that may help in the reduction of drying shrinkage must be put to use.

20) Proper repair maintenance and construction of expansion and contraction joints should be done so that the effect of variation in temperature is neutralized.

21) Keep a track of the review of mixed design in order to ensure that maximum size course aggregate, is used which will help to minimize the water content used in the mix.

22) Keep a track of the review of mixed design to ensure that lowest possible water content is used in the mix for workability purposes.

23) Also ensure that the contractor is quiet familiar with the design and technique of using different materials and equipment's during mixed designs. The various remedial and preventive measures that should be undertaken to cure crack are listed below:

5.1.1) Use of fine aggregates:

Use of aggregates which are too fine and largely contains too much of clay or silt, not graded well should be avoided. The permissible percentage of clay and silt in fine aggregate should not be more than 3%.

5.1.2) Use of coarse aggregates:

The allowable permissible size of coarse aggregate should be decided as per job requirements. Also for concrete work coarse aggregates used should be well graded so as to obtain high durability and density. The fine content in coarse aggregate should not exceed 3%.

5.1.3) Stitching:

Stitching is a process of drilling of holes on both the sides of crack in which grouting is done with the help of U-shaped metal units that covers the crack. When cracks are formed the tensile strength is comparatively lost, in order to gain this lost tensile strength stitching is used, along with the drilling of holes, this process also involves cleaning the holes and filling the holes with the grout having enormous bonding strength.

5.1.4) Dry packing:

It is the process of placing of low moisture content mortar which is further followed by tamping the placed mortar into a particular area and also helps in producing a close bond and contact between the concrete and the mortar.

5.1.5) Injection of Epoxy:

This method is very useful for repairing dormant or non-moving cracks in slabs, walls, columns and piers. It is considered as one of the most economical methods is very much capable of maintaining the comp active strength of concrete. Pumping of epoxy in vertical cracks should be in such a way that epoxy should start entering the lowest elevation until the level of epoxy reaches the level of entry port above. This process is repeated until the crack has been completely filled with epoxy. In case of filling of horizontal crack, the process of injecting of epoxy starts from one end of the crack to the other end of the crack in the same way. Due to maintenance of required pressure, the crack is filled.

5.1.6) Plugging and drilling:

This process consists of drilling through the full length of crack and filling or grouting it in the shape of a key. This technique is majorly applicable when orientation of cracks is in the form of straight lines, and is accessible at one end. This method is mostly used for repairing vertical cracks in retaining walls. Generally, a hole of 50-75mm diameter should be drilled in this process.

5.1.7) Sealing and routing:

This method is preferably used in conditions which require repair and maintenance and where repair of structures is not necessary. In this process the crack is enlarged along its face which is exposed, which is followed by filling with a suitable sealant. This is the common and the most economical technique as compared to other procedures like epoxy injection. Though routing and sealing can be done on vertical surfaces as well as on the curved surfaces it is mostly applicable to flat horizontal surfaces such as slabs, pavements.

5.1.8) Sealing cracks with gravity filling:

Resins and monomers having comparatively low viscosity can be widely used to seal cracks by gravity filling. Urethanes having high molecular weight and some low viscosity epoxies have been successfully used previously. This process typically consists of cleaning the surface by water blasting or air blasting through this method it is practically understood that lower the viscosity of the filling the finer the cracks can be easily filled.

5.1.9) Impregnation of polymer:

The most commonly used monomer in this method is methyl methacrylate. This system is highly used for effective repair of some cracks. The monomer system used in this is a liquid monomer which will eventually polymerize into solid.

5.2) TESTING OF CONCRETE IN STRUCTURES:

In-situ methods of testing

a) Non-destructive test (NDT)

b) Partially-destructive tests

a.1) Surface hardness test

2) Rebound hammer test

3) Ultrasonic pulse velocity test

4) Radioactive methods

5) Nuclear methods

6) Magnetic methods

7) Electrical methods

b.1) Pull-out testing

(i) Cast-in method (look-test)

(ii) Drilled-hole method (CAPO-test)

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.

5.2.1. 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.

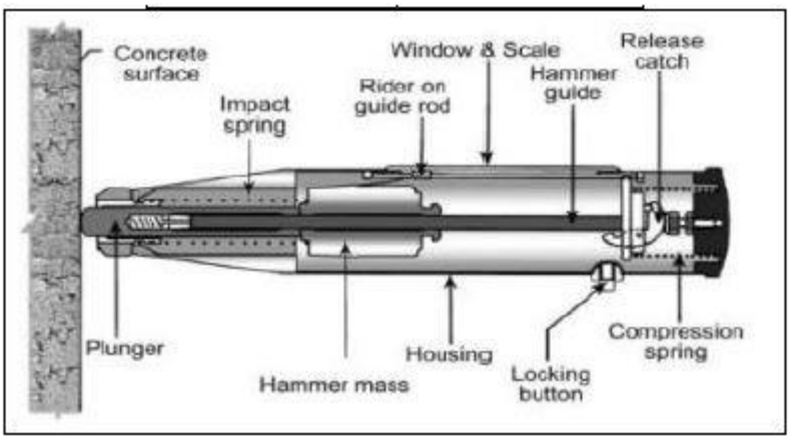


Fig. 1: Typical Rebound Test Hammer

5.2.2. 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.

5.3 RESULT AND DISCUSSION:

RESULT

5.3.1. 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/cm2. 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 behavior 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. : Repair of cracks by Grouting method

5.3.2. Rebound Hammer Test Result:

Average rebound number for horizontal hammer position and corresponding compressive strength is presented in table. 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.

Sr.No	Average corrected Rebound value	Compressive Strength (N/mm2)	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

Table: Average Rebound number and compressive strength

5.3.3. 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%

Fig. : 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

5.4. DISCUSSION:

1. Brief Discussion on the Building Understudy Emmanuel Egboga building has 53 rooms, and four floors, which are basement floor (named as FB), ground floor (named as F0), first floor (named as F1), and second floor (named as F2) as shown in Plate 1. The structural frame members consist of 129 beams, 92 columns, and 240 walls in total. It is covered at the roof with aluminum roofing sheets, and contains roof gutter for proper drainage. It also contains retaining wall that links the basement floor to the ground floor. The predominant nature of cracks observed was dormant. The dirty surface of the cracks also indicated that they were dormant.

Plate 1. Front view of the building

The parts of the building caused by drying shrinkage are: F0-A-R4-W4, F1-A-R4-W1, F2-A-R2- W6.The cracks were caused by shrinkage of the plastering, since it is a surface crack; the shrinkage may be due to use of high ratio of cement to sand, and inadequate curing. Shrinkage crack occurs during the first dry spell after plastering. Their measured values were shown in Tables 2 and 3, and picture in Plate 2.The proffered solution is that, this type of crack could be left unattended up to the normal time for renewal of finishing coat when this will get filled up, or the surface is scrap and refill with good mix ratio of cement and sand and proper curing.

Fig: Picture of random cracks due to drying shrinkage

The second type of cracks observed (F0-Female Toilet-W1, F0-Male Toilet-W1, F1-Male Toilet-W2, F1-Male Toilet-W3, F0-A-R4-W4) were primarily on the sand Crete wall under a 7.3m span flanged beam. The cracks on F0-Female Toilet-W1, F0-Male Toilet-W1, F1-Male Toilet-W2, and F1-Male Toilet-W3 were similar in their cause. It was observed that the long spanned beam (7,226mm=7.3m), rested on the non-load bearing wall for support due to sagging at the mid-span thus subjecting the wall to stresses that it was not designed to sustain (See Tables 2 and 3, and Plate 3). The sagging effect of the beam may be as a result of faulty design or inadequate reinforcement provided during construction. The suggested solution is to introduce a column (preferably a steel section) to support the beam along the mid span while the cracked wall should be removed and replaced with load bearing wall. In addition, two columns should be erected from the basement to support the slab at the lobby of the toilet entrance.

The type of crack shown in Plate 4 occurred at wallF0-A-R4-W4 (External View). This type of crack generally occurs when windows and room spans are very large. The horizontal cracks at the window lintel level (See Table 2 and Plate 4) are due to pressure exerted on the wall by slab, because of drying shrinkage and thermal contraction. This pressure resulted in bending of the wall, which caused cracking at a weak section, that is, at the lintel level of the window openings.

These cracks could have been avoided if slip joint at beam supports on the walls have been provided, to permit movement without encountering much restraint. The cracks can be repaired by filling with a mastic compound after widening and cleaning the cracks. These cracks if repaired with strong mortar have a tendency to occur again.

The third type of cracks observed at F0-B-R4-W1-CR1, F0-B-R4-W1-CR2, F0-B-R4-W1-CR3, F0-B-R4-W1- CR4, Door Frame, Ground floor Walkway were caused by foundation settlement

Plate 5: Picture of Crack on room 4 and ground floor's walkway, wing B, due to foundation settlement

Plate 6: Picture of cracks on room 4, wing B, due to foundation settlement

It was discovered through topographical survey, that lack of drainage at the open courtyard allows percolation of water into the soil and thus this crack undermines the sand under the floor and including the wall strip footing. This could be said to be responsible for the cracks in the region, for the cracks occurred due to settlement of soil at the region of the courtyard. The settlement also caused crack along the wooden frames of the door, which distorted the frame making it difficult to close and open the door. For Ground Floor Walkway, the crack was caused by poor drainage of water due to heavy runoff getting into the foundation at this region. The terrazzo floor settled under human traffic load (live load) and cracked across the corridor to the adjacent room. Such a settlement generally not being uniform in different parts resulted in cracking of the ground floor walkway. The provision of appropriate drainage and reconstruction of the wall footing and the floor in the affected area will eradicate the cracks and prevent future ones. Cracking due to shrinkage of wood can be concealed with the help of architraves and will not present much of a problem. For cracking due to slack between holdfasts, the only satisfactory remedy is to dismantle the masonry so as to remove the frame and to reaffix with seasoned frame after securely fastening the holdfasts to the frame.

Plate 7: Picture of crack due to differential stress

Plate 8: Picture of crack due to differential stress

The fourth type of observed cracks at F0-B-R4-W1-CR5 (External View), F2-A-R2-W3 (Internal and External view), F2-A-R6-W3 (Internal and External view), F2-B-R2-W3, F2-B-R7-W3. (Internal and External view) was caused by movement due to creep. The crack on F0-B-R4-W1-CR5 (External View) is a diagonal crack (See Tables 2 and 3, Plate 7), which occurred as a result of differential stress and strain between different regions of the wall. It can be seen that portions of wall beside the window act as pillars and are stressed much more than the portions below the window.

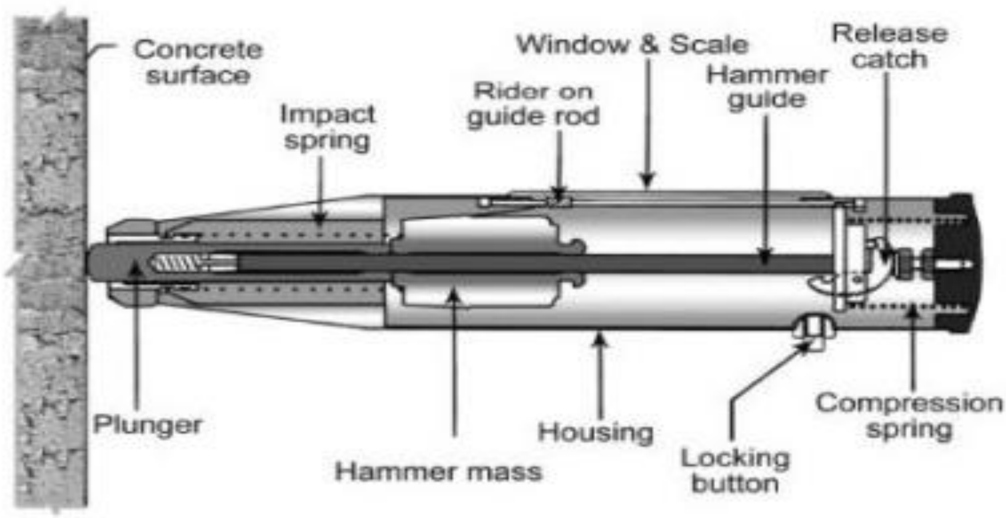
Thus, as a result of differential stress, vertical shear cracks occurred in the wall. To minimize these cracks, too much disparity in stress in different walls or parts of a wall should be avoided. If RC slabs, RC lintels over openings and masonry in plinth and foundation have good shear resistance, cracking in question would not be very significant. The proffered solution for crack on F0-B-R4-W1-CR5 can be sealed up with mortar mix ratio of 1 Cement: 1 lime : 6 Sand in the dry season or 1 Cement:2 Lime:9 Sand in the rainy season, with the avoidance of sharp sand for plastering it, and proper curing should be done for up to 7-10 days. For F2-A-R2-W3/ F2-A-R6-W3 (Internal and External view), F2-B-R2-W3/F2-B-R7-W3 (Internal and External view) as shown in plate 8, these cracks are of the same pattern, which occurred at the internal and external view is a sign of total crack of the wall , on a load bearing structure having mostly sand concrete block walls for supporting loads of roof beam and other roof loads, roof gutter, long-span aluminum roof covering, timber purling, timber strut, timber wall plate, and wind load because of these loads, in course of time, RC columns undergo some shortening due to elastic deformation, creep and shrinkage and because of difference in the strains in RC columns and masonry; vertical shear crack appeared at junction of the two materials. The preferred solution for F2-A-R2-W3/ F2-A-R6-W4 (Internal and External view), F2-B-R2-W3/F2-B-R7-W3 (Internal and External view) is that, the cracked region could be repaired by first removing the cracked or affected portion of the block, and replaced with good quality, high strength block, properly cured and allowed to dry so as to undergo initial shrinkage and then bonded to the column with the use of correct mix ratio mortar 1 cement: 2 lime: 9 sand, and curing should follow to avoid shrinkage by thermal effect. Secondly, since the wall is built right up to the soffit of the roof beam, horizontal joint should be opened out, and filled up with some joints about 10mm in width formed at the top of the wall.

B. Rebound Hammer Reading Test (DISCUSSION):

A Schmidt hammer was used to assess the strength of the structural. The strength of each structural member was obtained by taking the average of seven recorded values of Schmidt. Hammer Reading. The Non- Destructive Schmidt Hammer Test conducted on the building under appraisal comprises of the basement, ground, first, and second floor.

The rebound of an elastic mass depends on the hardness of the surface against which its mass strikes. When the plunger of the rebound hammer is pressed against the surface of the concrete, the spring-controlled mass rebounds and the extent of such a rebound depends upon the surface hardness of the concrete. The surface hardness generates the rebound which is directly related to the compressive strength of the concrete. The rebound value is read from a graduated scale and is designated as the rebound number or rebound index. The compressive strength can be read directly from the graph provided on the body of the hammer. The re-bound reading on the indicator scale has been calibrated by the manufacturer of the rebound hammer for horizontal impact, that is, on a vertical surface, to indicate the compressive strength. When used in any other position, appropriate correction as given by the manufacturer is to be taken into account.

The summary of the results of the Rebound Hammer Readings conducted on the structural elements of the building under study are indicated. The minimum compressive strength required in 28 days is 25Nmm2. The minimum compressive strength required in one year is 31Nmm2. The adequacy of a reinforced concrete structural element to support loads imposed on it, is determined by the compressive strength of concrete, dimension properties, reinforcement constituent and tensile strength of the reinforcement bars. For the buildings under investigation, Grade 25 concrete with 28day compressive strength of 25Nmm2 is considered appropriate and adequate. This is expected to attain 31Nmm2in one year of the concrete age, and then marginally increase over the years. From the non-destructive Schmidt hammer rebound readings obtained for the structural elements, the average strength of the building varies between 36.8 and 48.2Nmm2 respectively, this is within acceptable limit, and it is therefore satisfactory.



5.5CONCLUSIONS

After careful observation and study of the cracks in the building, their causes and a few solutions that could be applied to rehabilitate the building, including test of strength on structural members, it was concluded that most of the cracks are as a result of human carelessness in all the stages of construction. From the research survey, it was observed that each of the building team has great part to play in the cause of cracks in the building, and the results clearly revealed that most of the cracks in the building structure are not dangerous, except the case of the toilets at the ground floor, first floor, and the four corners of the edge of the second floor, and roof slabs, which need urgent intervention and repair. Urgent repair will prevent future collapse of the building. The appropriate remedy to crack failure is such that its nature and causes should be investigated and established before repair; otherwise wrongly treated cracks will reappear after sometime. However, causes of cracks investigation should be more concerned with what, rather than who is at fault. This will help to rectify and improve on designs, supervision, and construction of buildings to avoid building problems.

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.

Cracks may occur due to several reasons as discussed above. The formation of cracks cannot be completely eliminated nor completely stopped but several measures can be undertaken to prevent their consequences. Several prevention factors should be taken care of during actual construction process itself. Lack of careful observations and lack of attentiveness can lead to a cause for deterioration in the building in the long-run, which ultimately leads to the failure of structure. Through this research work we came to a conclusion that it is impossible to find ways against cracking yet attempts can be made to minimize the formation and development of cracks in the structure. By observing several cracks and tendency of cracking we also concluded that not all type of cracks require same level of attention.

Taking into consideration proper repair and maintenance, adequate construction materials, proper techniques, the potential causes of crack can be minimized to a large extent. Out of the several preventive and remedial measures of cracking discussed above the most appropriate method should be adopted for different types of cracks for gaining the most effective and efficient structure as a whole.

This paper is divided into four parts. First part comprises of basic introduction about cracks and about the previous attempts which are made by the research scholars, second part contains the case study, visual identification of cracks and causes with preventive measures and third part contains techniques to cure crack. The potential causes of crack can be controlled if proper consideration is given to construction material and technique to be used. If we focus on the major causes to cracks in our building and take their preventive measures initially, we will able to minimize the problem of cracking in our structure. From the above case study we have concluded that 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. 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.

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