I

Name _____

Roll No. _____ Year 20 ____ 20 ____

Exam Seat No. _____

CIVIL GROUP | SEMESTER - VI | DIPLOMA IN ENGINEERING AND TECHNOLOGY

A LABORATORY MANUAL FOR MAINTENANCE AND REPAIRS OF STRUCTURES (22602)

MAHARASHTRA STATE BOARD OF TECHNICAL EDUCATION, MUMBAI
(Autonomous) (ISO 9001 : 2015) (ISO / IEC 27001 : 2013)

A Laboratory Manual for

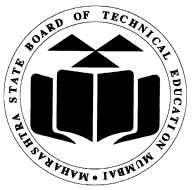
Maintenance and Repairs of Structures

(22602)

Semester – VI

(CE/CR/CS)

Maharashtra State
Board of Technical Education, Mumbai
(Autonomous) (ISO:9001:2015) (ISO/IEC 27001:2013)



Maharashtra State Board of Technical Education, Mumbai
(Autonomous) (ISO:9001:2015) (ISO/IEC 27001:2013)
4th Floor, Government Polytechnic Building, 49, Kherwadi,
Bandra (East), Mumbai -400051.
(Printed on November 2019)

MAHARASHTRA STATE
BOARD OF TECHNICAL EDUCATION
Certificate

This is to certify that Mr. / Ms. ……. Roll No……of Sixth Semester of Diploma in ……of Institute …….. (Code……..) has attained the predefined practical outcomes (PROs) satisfactorily in course **Maintenance and Repairs of Structures (22602)** for the academic year 20……to 20…..... as prescribed in the curriculum.

Place ……. Enrollment No……
Date:…..... Exam. Seat No…….....

Course Teacher **Head of Department** **Principal**

Seal of the Institute

Preface

The primary focus of any engineering laboratory/field work in the technical education system is to develop the much needed industry relevant competencies and skills. With this in view, MSBTE embarked on this innovative 'I' Scheme curricula for engineering diploma programmes with outcome-base education as the focus and accordingly, relatively large amount of time is allotted for the practical work. This displays the great importance of laboratory work making each teacher; instructor and student to realize that every minute of the laboratory time need to be effectively utilized to develop these outcomes, rather than doing other mundane activities. Therefore, for the successful implementation of this outcome-based curriculum, every practical has been designed to serve as a ***'vehicle'*** to develop this industry identified competency in every student. The practical skills are difficult to develop through 'chalk and duster' activity in the classroom situation. Accordingly, the 'I' scheme laboratory manual development team designed the practicals to ***focus*** on the ***outcomes***, rather than the traditional age old practice of conducting practicals to 'verify the theory' (which may become a byproduct along the way).

This laboratory manual is designed to help all stakeholders, especially the students, teachers and instructors to develop in the student the pre-determined outcomes. It is expected from each student that at least a day in advance, they have to thoroughly read through the concerned practical procedure that they will do the next day and understand the minimum theoretical background associated with the practical. Every practical in this manual begins by identifying the competency, industry relevant skills, course outcomes and practical outcomes which serve as a key focal point for doing the practical. The students will then become aware about the skills they will achieve through procedure shown there and necessary precautions to be taken, which will help them to apply in solving real-world problems in their professional life.

This manual also provides guidelines to teachers and instructors to effectively facilitate student-centered lab activities through each practical exercise by arranging and managing necessary resources in order that the students follow the procedures and precautions systematically ensuring the achievement of outcomes in the students.

It is absolutely necessary to maintain the building structure in order to preserve the assets and protect the building and the building occupants. Normally, the external parts of a building get weathered quickly being exposed to the natural environment. Overlooked dilapidation and inadequate maintenance in the building lead to loose mortar, tiles and bricks of external walls, spalled concrete and thereby threaten public safety. Proper building maintenance ensures that the building and the environment remain healthy, clean and a safe place to work or reside. The strengthening of elements for sustaining loads in future enhances the life, use and raise the value of structures. Regular inspection and maintenance is therefore necessary for timely identification of deteriorated building elements. However, this requires a scientific approach through the investigation of failure pattern. The civil engineering technologists are required to prevent the deterioration of different types of buildings and also to repair the damages in the building. This course is therefore designed to develop the competency to do all these activities.

Although all care has been taken to check for mistakes in this laboratory manual, yet it is impossible to claim perfection especially as this is the first edition. Any such errors and suggestions for improvement can be brought to our notice and are highly welcome.

Programme Outcomes (POs) to be achieved through Practicals of this Course.

PO 1. **Basic Knowledge:** An ability to apply knowledge of basic mathematics, science and engineering to solve the engineering problems.

PO 2. **Discipline Knowledge:** An ability to apply discipline-specific knowledge to solve core and/or applied engineering problems.

PO 3. **Experiments and Practice:** An ability to plan and perform experiments and practices and to use the results to solve engineering problems.

PO 4. **Engineering Tools:** Apply Civil Engineering related technologies and tools with its limitations.

PO 5. **The Engineer and Society:** Asses societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to practice in field of civil engineering.

PO 6. **Environment and Sustainability:** Apply civil engineering solutions also for sustainable development practices in societal and environmental contexts.

PO 7. **Ethics:** Apply ethical principles for commitment to professional ethics, responsibilities and norms of the practices also in the field of civil engineering

PO 8. **Individual and Team Work:** Function effectively as leader and team member in diverse / multidisciplinary teams.

PO 9. **Communication:** Communicate effectively in oral and written form.

PO 10. **Life-long Learning:** Engage in independent and life-long learning activities in the context of Technological changes also in the civil engineering and allied industry.

PSO1. Construction Planning and Designing: Perform optimal civil engineering construction, planning and designing activities of desired quality at optimal cost.

PSO2. Construction Execution and Maintenance: Execute civil engineering construction and maintenance using relevant materials and equipment.

Practical - Course Outcome Matrix

Course Outcomes (COs)

a. Select the relevant method of maintaining different building structures.
b. Test the structures to predict its stability.
c. Select the relevant materials for repair of structures.
d. Apply the relevant methods of repair for the masonry structures.
e. Restore the damages of building structural elements using suitable method of repair.
f. Prepare the structural audit and budget for the maintenance of structures.

Sr. No.	Practical Outcome	CO a	CO b	CO c	CO d	CO e	CO f
1	Find the causes of damages for the given building elements.	√	-	-	-	-	-
2	Prepare the check list for materials required for repair of load bearing building and framed building.	√	-	√	-	-	-
3	Prepare a check list for repair of a load bearing building and framed building.	-	-	√	√	-	-
4	Determine the compressive strength of any two structural elements such as column, beam, slab etc. for damaged or undamaged structure using Rebound Hammer.	√	√	-	-	-	-
5	Determine the extent of efflorescence in masonry or concrete for damaged or undamaged structure.	-	√	-	√	-	-
6	Determine the crack nature of any two structural elements such as column, beam, slab etc. for damaged structure using Ultrasonic Pulse Velocity test.	√	√	-	-	-	-
7	Determine the bond strength of any one structural element such as column, beam, and slab etc. using pull out test.	√	√	-	-	-	-
8	Determine the size; depth and location of reinforcing bar using Rebar locator of any two structural elements such as column, beam, slab etc. for damaged or undamaged structure.	√	√	-	-	-	-
9	Determine Maximum Chloride content in concrete in percent by weight of cement using Rapid Chloride Test of any one structural element such as column, beam, slab etc. for undamaged structure.	√	√	-	-	-	-
10	Determine the depth of carbonation of concrete using phenolphthalein indicator of any two structural elements such as column, beam, slab etc. for undamaged structure.	√	√	-	-	-	-

Sr. No.	Practical Outcome	CO a	CO b	CO c	CO d	CO e	CO f
11	Determine the moisture content using Moisture Meter of any two structural elements such as column, beam, slab etc. for damaged or undamaged structure.	√	√	-	-	-	-
12	Determine the corrosion of reinforcing bar using Half-cell Potentiometer of any two structural elements such as column, beam, slab etc. for damaged or undamaged structure.	√	√	-	-	-	-
13	Determine the compressive strength of extractor core using Compression Testing Machine of any one structural element such as column, beam, slab etc. for damaged or undamaged structure.	√	√	-	√	-	-
14	Prepare a list of material requirements and check list for repair of wall cracks as per the damages found.	-	-	√	√	-	-
15	Prepare a report on damage assessment of non-residential structures such as dams, bridges, industrial buildings etc.	-	-	√	√	-	-
16	Prepare a check list for repair and material requirement for flooring of given structure.	-	-	√	√		-
17	Prepare a check list for materials required and resources for repair of sanitary unit of the building.	-	-	√	√	-	-
18	Repair the cracks for a damaged plane concrete member of size of 100×100×500 mm or 150×150×750 mm	-	-	-	√	√	-
19	Prepare a budget estimation considering materials, task force, equipment's and methodology for the given damaged structure.	√	-	-	-	-	√
20	Determine the flexural strength of repaired beam from Practical No.18.	-	√	-	-	√	-

List of Industry Relevant Skills

The following industry identified competency through various teaching learning experiences. **Repair and maintain varies types of structures using relevant materials and methods.**

The practical experiences and relevant soft skills associated with this course are to be taught and implemented, so that the student demonstrates the following ***industry oriented relevant skills*** associated with the above mentioned competency.

1. Judgment skill of identifying the causes of damages in structure and measure it.
2. Handling the minor/major tools/equipments effectively to complete the repair work.
3. Assessment of structural strength of different component parts of existing building.
4. Interpreting the test results obtained during various test.
5. Suggest relevant materials for repair of various defects/damages for different site conditions.
6. Select feasible technology to repair various damages in structure.

Guidelines to Teachers

Teachers shall discuss the following points with students before start of practical of the subjects.

1. **Learning Overview:** To develop better understanding of importance of the subject through intellectual skills and motor skills.
2. **Know your laboratory work:** To understand the layout of laboratory, specifications of equipment/instrument/materials, procedure, working in groups, planning time etc. also to know total amount of work to be done in laboratory.
3. For difficult practicals if required, teacher should provide the demonstration of the practical emphasizing of the skills which the student should achieve.
4. Teachers should give opportunity to students for hands-on after the demonstration.
5. Assess the skill achievement of the students and COs of each unit.
6. Teachers should give relevant information (including safety measures) to students prior to visit arranged for effective utilization of time and understanding.
7. Teachers shall ensure that required equipment are in working condition before start each experiment, also keep operating instruction manual available.
8. One or two questions ought to be added in each practical for different batches. For this teachers can maintain various practical related question banks for each course.
9. If some repetitive information like data sheet, use of software tools etc. has to be provided for effective attainment of practical outcomes, they can be incorporated in Appendix.
10. For effective implementation and attainment of practical outcomes, teacher ought to ensure that in the beginning itself of each practical, students must read through the complete write-up of that practical sheet.
11. During practical, ensure that each student gets chance and takes active part in taking observations/ readings and performing practical.
12. Teacher ought to assess the performance of students continuously according to the MSBTE guidelines.
13. Teacher should distribute all the questions among the batches so as to attempt all the questions. It is recommended that every year the combination of questions must be changed for each batch.
14. As far as possible, go through NPTEL, MOOC'S, SWAYAM website and register for the certificate courses.

Note: Kindly do add specific guidelines for effective implementation of practical's depending upon your course, if needed.

Instructions to Students

1. For effective implementation and attainment of practical outcomes, in the beginning it self of each practical, student need to read through the complete write-up including the practical related questions and assessment scheme of that practical sheet.
2. Student must refer the data books, IS codes, safety norms, etc.
3. Student should not hesitate to ask any difficulties they face during the conduct of practicals.
4. Student should develop the habit of pear discussions/group discussion related to the experiment/exercise so that exchanges of knowledge /skills could take place.
5. Student shall attempt to develop related hands-on skills and gain confidence.
6. Students shall visit the nearby construction site, technical exhibitions, trade fair etc. even not included in the lab manual.
7. Students should develop the habit of not to depend totally on teachers but to develop self-learning techniques.
8. Student should develop habit to submit the practical exercise continuously and progressively on the scheduled dates and should get the assessment done.
9. It is necessary to take all types of precautionary measures by students during the visit.
10. Each student must follow the instructions given by the site engineer during the visit.
11. Special precautions must be taken for special type of work.
12. As far as possible, go through NPTEL, MOOC'S, SWAYAM website and register for the certificate courses.
13. Attach minimum four photographs of work done during site visit on separate blank page.

Note: Kindly do add specific instructions for students for effective implementation of practical depending upon your course, if needed.

Content Page

List of Practicals and Progressive Assessment Sheet

Name of the Student: _____ Roll No: _____

Sr. No.	Title of the Practical	Page No.	Date of performance	Date of submission	Assessment marks (10)	Dated sign. of teacher	Remarks (if any)
1*	Find the causes of damages for the given building elements.	1					
2	Prepare the check list for materials required for repair of load bearing building and framed building.	9					
3	Prepare a check list for repair of a load bearing building and framed building.	17					
4*	Determine the compressive strength of any two structural elements such as column, beam, slab etc. for damaged or undamaged structure using Rebound Hammer.	24					
5*	Determine the extent of efflorescence in masonry or concrete for damaged or undamaged structure.	33					
6	Determine the crack nature of any two structural elements such as column, beam, slab etc. for damaged structure using Ultrasonic Pulse Velocity test.	42					

7	Determine the bond strength of any one structural element such as column, beam, and slab etc. using pull out test.	51					
8	Determine the size; depth and location of reinforcing bar using Rebar locator of any two structural elements such as column, beam, slab etc. for damaged or undamaged structure.	59					
9*	Determine Maximum Chloride content in concrete in percent by weight of cement using Rapid Chloride Test of any one structural element such as column, beam, slab etc. for undamaged structure.	67					
10*	Determine the depth of carbonation of concrete using phenolphthalein indicator of any two structural elements such as column, beam, slab etc. for undamaged structure.	74					
11	Determine the moisture content using Moisture Meter of any two structural elements such as column, beam, slab etc. for damaged or undamaged structure.	82					

12	Determine the corrosion of reinforcing bar using Half-cell Potentiometer of any two structural elements such as column, beam, slab etc. for damaged or undamaged structure.	91					
13	Determine the compressive strength of extractor core using Compression Testing Machine of any one structural element such as column, beam, slab etc. for damaged or undamaged structure.	100					
14	Prepare a list of material requirements and check list for repair of wall cracks as per the damages found.	108					
15*	Prepare a report on damage assessment of non-residential structures such as dams, bridges, industrial buildings etc.	121					
16	Prepare a check list for repair and material requirement for flooring of given structure.	130					

17	Prepare a check list for materials required and resources for repair of sanitary unit of the building.	137					
18	Repair the cracks for a damaged plane concrete member of size of 100 × 100 × 500 mm or 150 × 150 × 750 mm.	147					
19*	Prepare a budget estimation considering materials, task force, equipment's and methodology for the given damaged structure.	156					
20	Determine the flexural strength of repaired beam from Practical No.18.	164					
Total							

Note: 1 A judicial mix of minimum 12 or more practical need to be performed, out of which practical marked as * are compulsory.

Note: 2 To be transferred to Proforma of CIAAN-2017.

Practical No. 1: Detection of Causes of Building Damages

I Practical Significance:

The defects occurring in the building are in the form of cracks, deflection, erosion etc. These defects affect the usability and stability of the structure. The causes of such defects are necessary to identify prior to any mis-happenings. This practical is able to access the structure for its serviceability. Also it helps to report the present condition of the damaged/undamaged structure. It leads to take prior judgment of conducting non-destructive testing for the accessed structure.

II Relevant Program Outcomes:

PO 11. Basic knowledge: *An ability to apply knowledge of basic mathematics, science and engineering to solve the engineering problems.*

PO 12. Discipline knowledge*: An ability to apply discipline - specific knowledge to solve core and/or applied engineering problems.*

PO 13. Engineering tools: *Apply relevant civil technologies and tools with an understanding of the limitations.*

PO 8.Individual and team work: *Function effectively as leader and team member in Diverse /multidisciplinary team*

III Relevant Course Outcomes:

a. Select the relevant method of maintaining different building structures.

IV Practical Outcome:

Find the causes of damages for the given building elements.

V Competency and Practical Skills:

This practical is expected to develop the following skills for the industry identified competency, ***"Maintain different types of building structures."***

1. Visual observation skill.
2. Assessment of defects in structures.
3. Analyzing the problems.

VI Relevant Affective domain related:

a. Follow safety practices.
b. Practice good housekeeping.
c. Demonstrate working as a leader/ team member.
d. Follow ethical practices.

VII Minimum Theoretical Background:

The damage incurred to the building is usually in the form of major and minor cracks. Major cracks could be structural cracks which cause immense damage to the structure. Major damage to the building is usually caused by the natural calamities. But there are various factors that can cause damage to the buildings.

Factors causing damage in the structures: Erosion, Earthquake, Natural Calamities, Violence, Fire, Lack of maintenance, Insufficient Structural Design.

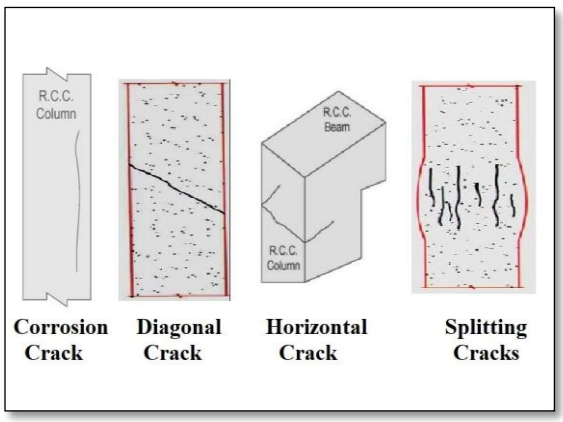
Types of Damage/Collapse of Concrete Work in RCC Buildings: The following types of damages are quite common in reinforced concrete buildings.

1. Sliding of Roofs off the Supports.
2. Falling of Infill Walls.
3. Crushing of Column Ends and Virtual Hinging.
4. Short Column Effect.
5. Diagonal Cracking in the Columns.
6. Diagonal Cracking of Column Beam Joint.
7. Pulling Out of the Reinforcing Bars.
8. Collapse of Gable Frames.
9. Foundation Sinking and Tilting.
10. Brown rot decay and timber decay of flat roof.

Types of Damage/Collapse of Masonry Work in RCC Buildings: The following types of damages are quite common in reinforced concrete buildings:

1. Sulphate attack results in chipping and spalling of bricks and formation of cracks in joints and rendering.
2. In Efflorescence, the soluble salts get dissolved and appear in the form of fine whitish crystals on the surface of brickwork.
3. Corrosion of Iron or steel embedded in brickwork due to the presence of dampness.
4. Swelling and shrinking of brickwork is takes place due to absorption and evaporation of water.
5. Blistering is the development of one or more local swellings on the finished plaster surface.
6. Cracking may be due to development of one or more fissures not assignable to structural cause.
7. Flading is the scaling away of patches of plaster surface due to lack or loss of adhesion with the previous coat.
8. Peeling is the removal of substantial areas of plaster work from the background.

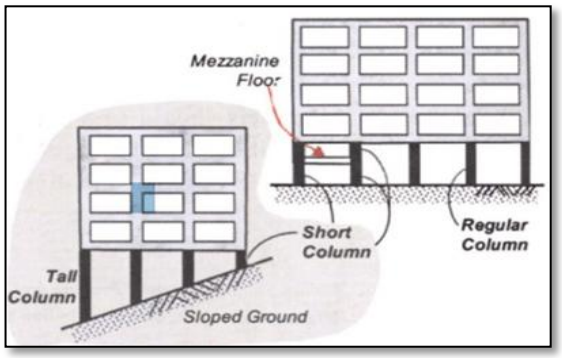
VIII Experimental Set-up:



(a) Forms of Cracks.

(b) Crushing of Column.

(c) Peeling Paint.



(d) Short Column Effect.

Figure 1: **Types of Damages in Concrete or Masonry.**

IX Resources required:

Sr. No.	Particulars	Specification	Quantity	Remark
1	Note pad, Pencil, etc.	--	1 No. Each	Per group of 5-7 students.
2	Hammer, chisel, etc.	--	1 No. Each	Per group of 5-7 students.
3	Magnifying glass.	--	1 No.	Per group of 5-7 students.
4	Safety aids- Helmet, Gloves, shoes etc.	--	1 No. Each	Per student.

X Procedure:

1. Arrange the site visit to any damaged or partly damaged structure available in the nearby area of college premises.
2. Collect the information of building in advance to be inspected in the form of architectural drawings, structural details, foundation plan, specifications of material used, geotechnical details, building loads etc. if available.
3. Survey the overall stability condition of the building by visual inspection of each structural element of building i.e. beam, column, slab, flooring, walling etc. Take the necessary photographs of each defect observed to visualize and analyze the causes.
4. Verify the physical condition of the structural elements in terms of original layout and joints if any.
5. Note down the defects observed in terms of surface cracks, structural deterioration, and concrete failure for each of the above mentioned concrete elements of the building in the observation table given herewith.
6. List out the probable cause/s against each defects observed mentioning the present condition of the particular structural element.

7. Remember that the observations taken in this practical will be used as basic data for practical no. 2 and 3.

XI Precautions to be followed:

1. Wear the relevant safety aids i.e. helmets, goggles, shoes etc. during visit to the building.
2. Be aware of plaster removal, structural fall, electric shock if any during visit undertaken.
3. Enter the failure susceptible area with prior discussion of native/resident peoples.

XII Actual procedure followed: *(Use blank sheet if provided space is not sufficient).*

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XIII Resources used:

	Name of Resource	Broad Specifications		Quantity	Remark
		Make	Details		
1					
2					
3					
4					

XIV Precautions followed:

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.....
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XV Observations:

a. Name of the Building:……

b. Address of the building:…….

c. Date and time of visit:……

d. Type of building/structure:……

e. Year of construction:…….

Sr. No.	Name of structural/building element	Defects/damages observed	Probable causes of defects/damages
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Note: The above observations are to be used as basic data for practical no. 2 and 3.

XVI Results:

1. The most of defects/damages henceforth are observed in the visited building are of ……. (structural/nonstructural) type.
2. As per the causes of defects/damages, there …….(is/is not) need of conducting Non-Destructive Tests (NDT).
3. The defects and damages observed during visual inspection and rapid investigation are …….. (repairable / un-repairable).

XVII Interpretation of results: *(Give meaning of the above obtained results).*

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XVIII Conclusions and Recommendations:

(Actions/decisions to be taken based on the interpretation of results).

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XIX Practical Related Questions:

***Note**: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions.*

1. Write the physical condition such as denseness/cohesiveness, moisture content of soil strata nearby the building by taking visual observation.
2. Differentiate between structural and non-structural cracks (min. two points).
3. Name the tools used for checking the qualities such as presence of cavities, vacuum entrapped within the plaster of various components of building.
4. Name minimum two building parts on which the defects occurred due to temperature variation if any.
5. Justify the need of drawings for rapid investigation of damages of the building.
6. Give minimum two reasons of spalling of plaster.
7. Enumerate at least two causes of failure of structural joint.
8. List minimum four common defects to be occurred due to improper workmanship at site.
9. Suggest the precautions to be taken by households to minimize the occurrence of defects in visited building.

(Note: Each batch should attempt three questions and not to be repeated the same questions by other batches)

Space to Write Answers

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XX References / Suggestions for further Reading:

Sr. No.	Title of Book/Website Links	Author	Publication
1.	Building Repair and Maintenance Management.	P.S.Gahlot, Sanjay Sharma	CBS Publishers & Distributors Pvt. Ltd., New Delhi, 2016 ISBN: 81-239-1243-9.
2.	Maintenance and Repair of Buildings.	P.K.Guha	New Central Book Agency (P) Ltd., New Delhi, 2011, ISBN: 81-7381-073-7.
3.	Building: Structural Audit, Repairs and Restoration.	Arun Kelkar	Majestic Publishing House, Thane, 2015 ISBN: 978-93-83678-93-8.
4.	Hand Book of Causes and Prevention of Cracks.	SP-25:1984	Bureau Of Indian Standards, 1985, Fourth Reprint March 1999, ISBN 81-7061-015-X.
5.	https://www.researchgate.net/publication/287517311_General_Building_Defects_Causes_Symptoms_and_Remedial_Work/link/5939802145851532061 8de15/download		
6.	https://nidm.gov.in/PDF/safety/earthquake/link13.pdf		
7.	https://theconstructor.org/structural-engg/damage-collapse-concrete-buildings/407/		

XXI Suggested Assessment Scheme:

Performance Indicators		Weightage (%)
Process related:15 Marks		**60%**
1	Safety precautions followed.	30 %
2	Adding raw materials effectively with discussion.	30 %
Product related:10 Marks		**40%**
3	Noting discussion for checklist.	10%
4	Answers to practical related questions.	20%
5	Submission of report in time.	10%
Total: 25 Marks		**100%**

List of Student Team Members (Roll No.)

1. ……
2. ……
3. ……
4. ……
5. ……

Marks Obtained			Dated sign of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 2: Checklist of Repairing Materials

I Practical Significance:

The identified defects in the building may extend up to its severity. Therefore it's necessary to repair through proper maintenance. In the line, various materials should be borrowed to initiate the repairing process. The materials selection is significant to achieve maximum benefits; hence it should be opted out as per defects/damages. This practical leads you to the systematic approach of making availability of such materials required for the building maintenance.

II Relevant Program Outcomes:

PO 1. Basic knowledge: *An ability to apply knowledge of basic mathematics, science and engineering to solve the engineering problems.*

PO 2. Discipline knowledge*: An ability to apply discipline- specific knowledge to solve core and/or applied engineering problems.*

PO 8. Individual and team work: *Function effectively as leader and team member in Diverse /multidisciplinary team*

III Relevant Course Outcomes:

a. Select the relevant method of maintaining different building structures.
c. Select the relevant materials for repair of structures.

IV Practical Outcome:

Prepare the check list for materials required for repair of load bearing building and framed building.

V Competency and Practical Skills:

This practical is expected to develop the following skills for the industry identified competency, ***"Maintain different types of building structures."***

1. Intellectual and thinking skill.
2. Judgment of material selection.
3. Justification of selected materials.

VI Relevant Affective domain related:

a. Follow safety practices.
b. Practice good housekeeping.
c. Demonstrate working as a leader/ team member.

VII Minimum Theoretical Background:

Various materials are used depending upon types of repairs. For non-structural repairs, polymer-based crack fillers, mortar admixtures, waterproofing compounds, bonding agents, paint additives, water repellants, rust removers, shotcreting, guniting etc. are used at the discretion of the repair consultant keeping in view the future life of the building. For structural repairs, specialised products and services are utilised. The products basically consists rust removers, repair compound based on styrene butadiene rubber, acrylic co-polymers, plasticisers, super fluid micro concretes, epoxy bonding agents, injection grouting systems, readymade polymer plasters as per the discretion of the repair consultant.

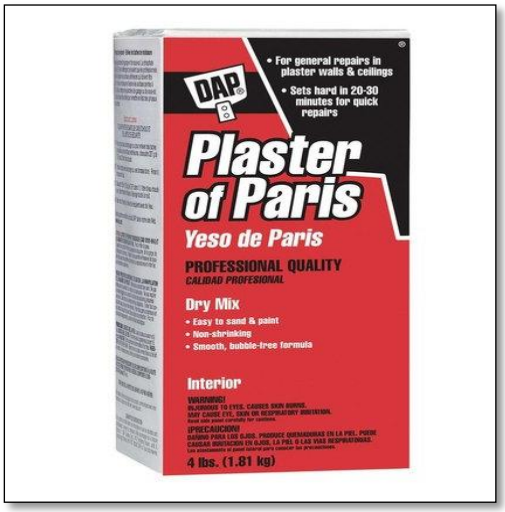
Since there are tasks that need to be completed on a more and on a less frequent basis, it is recommended for a building to create a daily facility maintenance checklist and a

monthly facility maintenance checklist. There are various types of materials which are used for the repair of concrete structures. For instance, unmodified Portland cement mortar or grout, latex modified Portland cement mortar or concrete, quick setting non-shrink mortar, and polymer concrete. The choice of such materials is based on their performance and cost. In addition to repair material compatibility with damaged structure and ease of application.

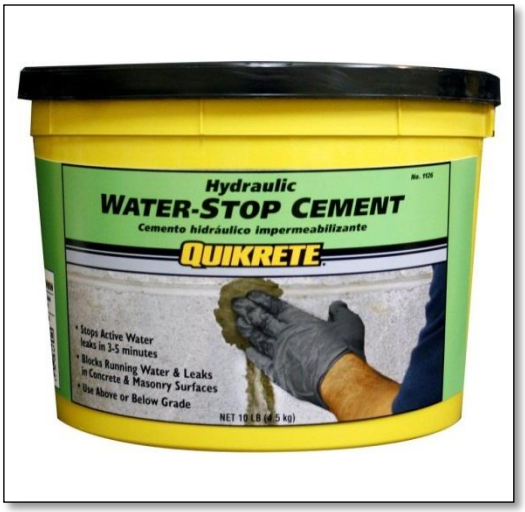
Selection Criteria for Repair Materials

- Ease of application.
- Cost.
- Available labor skills and equipment.
- Shelf life of the material.
- Pot life of the material.
- Type of damage.
- Compatibility of the repair material with damaged concrete.
- Appearance of finished surface.
- Co-efficient of thermal expansion of the material.
- Co-efficient of permeability of the material.
- Corrosion resistance property of the material.
- Durability of such concrete repair material.
- Speed of concrete repair.

VIII Experimental Set-up:



(a) Plaster of Paris.



(b) Water Resisting Cement.

(c) Grouting Compound.

(d) Crack Filling Sealant.

Figure 1: Basic Types of Building Repairing Materials.

IX Resources required:

Sr. No.	Particulars	Specification	Quantity	Remark
1	Note pad, Pencil etc.	--	1 No. Each	Per group of 5-7 students

X Procedure:

1. Read the observations taken in the Experiment No. 1 thoroughly.
2. Discuss in the group of 4-5 students on each of observed defect and suggest the material required for its repairing.
3. List out most suitable materials required against all the defects separately for load bearing or framed structure whichever is applicable.
4. Take several opinions of each group finally with viable technical justification.
5. Prepare the list of materials based on feasibility (tentative market price, machinery expenses, labor charges etc.).

XI Precautions to be followed:

1. It is necessary to consider practical applicability of materials for each defect.
2. Each material suggestion should be under technical consideration stating its specifications.

XII Actual procedure followed: *(Use blank sheet if provided space is not sufficient).*

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XIII Resources used:

Sr. No.	Name of Resource	Broad Specifications		Quantity	Remark
		Make	Details		
1					
2					

XIV Precautions followed:

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XV Observations:

Sr. No.	Name of structural/building element	Defects/damages observed	Materials Required for Repairing
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

XVI Results:

1. The most of materials required for repairing the building under consideration are …….. (cement or concrete based / brick or soil based / wooden or timber based / others) type.
2. As per discussion, the materials in the prepared checklist may be …….. (easily available / difficult to available) in the market.

XVII Interpretation of results: *(Give meaning of the above obtained results).*

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XVIII Conclusions and Recommendations:

(Actions/decisions to be taken based on the interpretation of results).

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XIX Practical Related Questions:

Note*: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions.*

1. Write five types of building repairs materials.
2. Give minimum five important criteria's to be considered for material selection for repairing work.
3. Give minimum three construction sealants applicable to crack repairs.
4. State any two essential characteristics of material useful for guniting or grouting work.
5. State minimum two market brands for each repairing materials such as additives, admixtures, solutions or liquids.
6. State pre-requisite steps to be adopted before the application of repairing materials to the target surface.
7. 'The repairing materials should be easily available in the market', justify the statement.
8. Suggest minimum two materials used for prevention of leakage of water.
9. State two advantages and disadvantages of solid and liquid form of repairing materials.

(Note: Each batch should attempt three questions and not to be repeated the same questions by other batches)

Space to Write Answers

XX References / Suggestions for further Reading:

Sr. No.	Title of Book/Website Links	Author	Publication
1.	Building Repair and Maintenance Management	P.S.Gahlot , Sanjay Sharma	CBS Publishers & Distributors Pvt. Ltd., New Delhi, 2016, ISBN: 81-239-1243-9.
2.	Maintenance and Repair of Buildings	P.K.Guha	New Central Book Agency (P) Ltd., New Delhi, 2011, ISBN: 81-7381-073-7.
3.	Building: Structural Audit, Repairs and Restoration	Arun Kelkar	Majestic Publishing House, Thane, 2015 ISBN: 978-93-83678-93-8.
4.	https://theconstructor.org/concrete/materials-repair-concrete-types-selection/9064/		

XXI Suggested Assessment Scheme:

Performance Indicators		Weightage (%)
Process related:15 Marks		**60%**
1	Safety precautions followed.	30 %
2	Visual observation and Recording of observations.	30 %
Product related:10 Marks		**40%**
3	Analyzing the causes of defects/damages.	10%
4	Answers to practical related questions.	20%
5	Submission of report in time.	10%
Total: 25 Marks		**100%**

List of Student Team Members (Roll No.)

1. ……
2. …….
3. …….
4. …….
5. …….

Marks Obtained			Dated sign of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 3: Checklist for Building Repairs

I Practical Significance:

As the defects in the building may result in damage or failure of the building structure; therefore it's necessary to repair such defects through proper maintenance. In this line, the repairing process should be followed with technicality. It is necessary to repair up to maximum extent of particular defect/damage, so that serviceability of particular building component gets fulfilled. This practical leads you to highlight the repairing work of various building elements.

II Relevant Program Outcomes:

PO 1. Basic knowledge: *An ability to apply knowledge of basic mathematics, science and engineering to solve the engineering problems.*

PO 2. Discipline knowledge*: An ability to apply discipline- specific knowledge to solve core and/or applied engineering problems.*

PO 8. Individual and Team Work: *Function effectively as leader and team member in Diverse /multidisciplinary team*

III Relevant Course Outcomes:

b. Test the structures to predict its stability.
c. Select the relevant materials for repair of structures.
d. Apply the relevant methods of repair for the masonry structures.

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IV Practical Outcome:

Prepare a check list for repair of a load bearing building and framed building.

V Competency and Practical Skills:

This practical is expected to develop the following skills for the industry identified competency, ***"Maintain different types of building structures."***

1. Intellectual and thinking skill.
2. Judgment of selection of suitable repair methodology.
3. Justification of selected method/process.

VI Relevant Affective domain related:

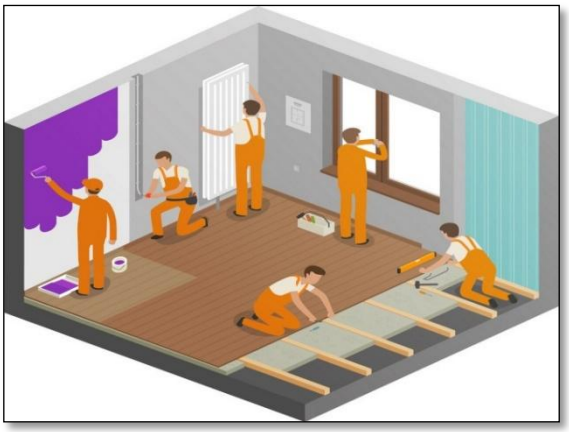
a. Follow safety practices.
b. Practice good housekeeping.
c. Demonstrate working as a leader/ team member.

VII Minimum Theoretical Background:

The methods used for repairing concrete structure. The methods are:

1. Strengthening of building elements
2. Repairs by epoxy
3. Repairs of hair cracks by grouting
4. Epoxy concrete
5. Repairs of floors
6. Repairs of columns
7. Repairs of Corroded R.C.C. Slabs.

VIII Experimental Set-up:



(a) Repairing work of a building elements.

(b) Pressure grouting.

(c) Epoxy pressure injection to slab.

(d) Methods of crack repair.

Figure 1: Check List of Repairs

IX Resources required:

Sr. No.	Particulars	Specification	Quantity	Remark
1	Note pad, pencil etc.	--	1 No. each	Per group of 5-7 students.

X Procedure:

Read the observations taken in the Experiment No. 1 thoroughly.

1. Make group of 4-5 students and discuss each of observed defect and suggest the method or process required for complete repairing work.

2. Write the brief process to remove defect or to repair damage for above observations.

XI Precautions to be followed:

1. The suggested method should incorporate the necessary minor tools or equipment if any.
2. The practical applicability to each suggested method should be ensured for each defect.

XII Actual procedure followed: *(Use blank sheet if provided space is not sufficient).*

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XIII Resources used:

	Name of Resource	Broad Specifications		Quantity	Remark
		Make	Details		
1					

XIV Precautions followed:

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XV Observations:

Sr. No.	Name of structural/building element	Defects/damages observed	Details of repairs required
1			
2			
3			
4			

5			
6			
7			
8			
9			
10			

XVI Results:

1. The repairing method for number of defects in concrete framework of accessed building is …….. (grouting / plastering / renewal).
2. The suggested method of repairing …… (requires / does not require) minor tools and equipment.

XVII Interpretation of results: *(Give meaning of the above obtained results).*

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XVIII Conclusions and Recommendations:

(Actions/decisions to be taken based on the interpretation of results).

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XIX Practical Related Questions:

Note*: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions.*

1. Justify the need of minor repairs of the building.
2. Differentiate the major repairs with respect to minor repairs.
3. State five conditions under which renewal of structure is better than its repair.

4. List out minimum three tools required for repairs of crack in concrete and masonry work.
5. Write two uses of epoxy in repairing work.
6. Calculate the probable material cost or labor cost required for the repairs of any one element of the building visited in practical no. 1.
7. Suggest minimum two methods to repair the crack/gap at the junction of concrete and masonry.
8. Is curing necessary for the concrete repairs? If yes, state minimum two types of repairing material and time of curing for such material.
9. State minimum two types of chemicals used for repairing with respect to brand, form of packaging and supplier.

(Note: Each batch should attempt three questions and not to be repeated the same questions by other batches)

Space to Write Answers

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XX References / Suggestions for further Reading:

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1.	Building Repair and Maintenance Management.	P.S.Gahlot, Sanjay Sharma	CBS Publishers & Distributors Pvt. Ltd., New Delhi, 2016, ISBN: 81-239-1243-9.
2.	Maintenance and Repair of Buildings.	P.K.Guha	New Central Book Agency (P) Ltd., New Delhi, 2011, ISBN: 81-7381-073-7.
3.	Building: Structural Audit, Repairs and Restoration.	Arun Kelkar	Majestic Publishing House, Thane, 2015 ISBN: 978-93-83678-93-8.
4.	Hand Book of Causes and Prevention of Cracks.	SP-25:1984	Bureau Of Indian Standards, 1985, Fourth Reprint March 1999, ISBN 81-7061-015-X.
5.	https://theconstructor.org/concrete/materials-repair-concrete-types-selection/9064/		

XXI Suggested Assessment Scheme:

Performance Indicators		Weightage (%)
Process related:15 Marks		**60%**
1	Safety precautions followed.	30 %
2	Handling raw materials effectively with discussion.	30 %
Product related:10 Marks		**40%**
3	Noting discussion for checklist.	10%
4	Answers to practical related questions.	20%
5	Submission of report in time.	10%
Total: 25 Marks		**100%**

List of Student Team Members (Roll No.)

1. ……
2. …….
3. …….
4. …….
5. …….

Marks Obtained			Dated sign of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 4: Rebound Hammer Test

I Practical Significance:

When the structural element (beam, column, beam slab, wall, floors, doors-windows etc.) are having defects (cracks, plaster spalling, reinforcement corrosion etc.); then it is suggested to check its strength. If the tested strength is known; then further one can take judgment of repairs and maintenance. This practical helps to undertake the strength determination of building components in damaged or undamaged structure under consideration by using portable rebound hammer.

II Relevant Program Outcomes:

PO 1. Basic knowledge: *An ability to apply knowledge of basic mathematics, science and engineering to solve the engineering problems.*

PO 2. Discipline knowledge*: An ability to apply discipline - specific knowledge to solve core and/or applied engineering problems.*

PO 3. Engineering tools: *Apply relevant civil technologies and tools with an understanding of the limitations.*

PO 8. Individual and Team Work: *Function effectively as leader and team member in Diverse /multidisciplinary team*

III Relevant Course Outcomes:

a. Select the relevant method of maintaining different building structures.
b. Test the structures to predict its stability

IV Practical Outcome:

Determine the strength of any two structural elements such as column, beam, slab etc. for damaged/undamaged structure using Rebound Hammer Test as per IS:13311-Part-II-1992.

V Competency and Practical Skills:

This practical is expected to develop the following skills for the industry identifiedcompetency, ***"Maintain different types of building structures."***

1. Visual observation skill.
2. Judgment of appropriate use of instrument.
3. Handling of portable instruments.
4. Interpretation skill of the obtained results.

VI Relevant Affective domain related:

a. Follow safety practices.
b. Practice good housekeeping.
c. Demonstrate working as a leader/ team member.
d. Follow ethical Practices.

VII Minimum Theoretical Background:

The non-destructive tests are the group of useful methods to evaluate the strength of construction materials without causing damage.

It is not always possible to do destructive tests for the materials of construction like concrete, block and clay bricks, etc. particularly when they are already laid. They are independent tests sufficient to make the structural engineering decisions after establishing figurative substantiation through its application. Rebound hammer test procedure is used to examine the hardness of concrete particularly when you want to carry out repairs of RCC structure.

NDT Methods for Concrete Structures:

1. Rebound hammer test.
2. Ultrasonic pulse velocity test.
3. Penetration and Pullout Techniques.
4. Radio-active and Nuclear method.
5. Electrical method.
6. Magnetic method.
7. Surface Hardness Test.
8. Dynamic or Vibration Tests.
9. Acoustic Emission Techniques.

Rebound Hammer Test: This method is based on the principle that the rebound of an elastic mass depends on the hardness of the concrete surface against which the mass strikes. The operation of the rebound hammer is shown in figure-1. When the plunger of rebound hammer is pressed against the concrete surface, the spring controlled mass in the hammer rebounds. The amount of rebound of the mass depends on the hardness of concrete surface.

Interpretation of Rebound Hammer Test Results: The correlation between compressive strength and rebound number can be done as per the graph given below in figure 1. The strength of structure can be assessed from such correlation. In general, the rebound number increases as the strength increases.

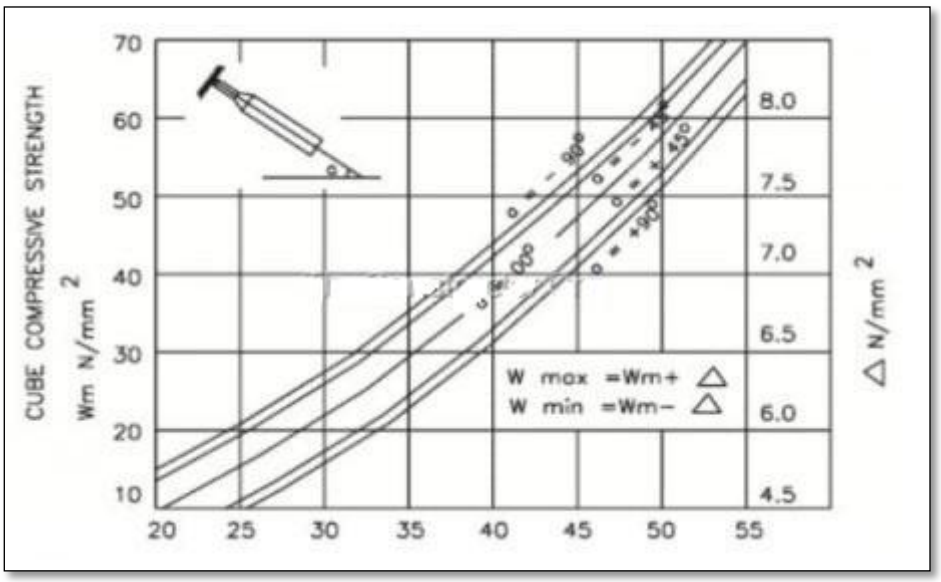
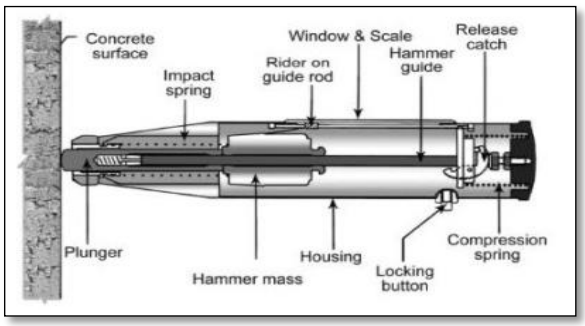


Figure 1: Correlation between Rebound Number and Compressive Strength

Table.1: Quality of Concrete for different values of rebound number

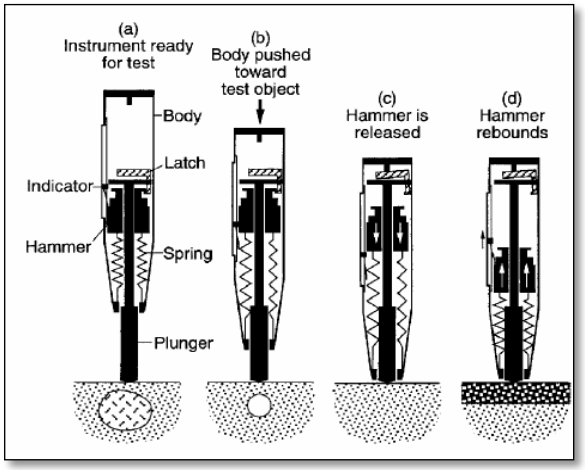
Sr. No.	Average Rebound Number. (RN)	Overall Quality of Concrete.
1	RN = 0	Delaminated
2	RN<20	Poor
3	RN = 20 to 30	Fair
4	RN = 30 to 40	Good
5	RN>40	Very Good

VIII Experimental Set-up:

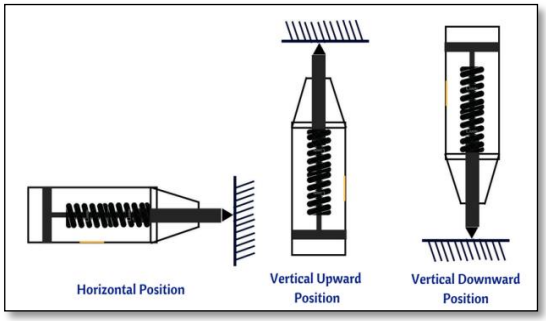


(a) Components of Rebound Hammer

(b) Use of Rebound Hammer



(c) Stepwise Process of Rebound Hammer Test



(d) Modes of Application of Rebound Hammer

Figure 2: Rebound Hammer Test

IX Resources required:

Sr. No.	Particulars	Specification	Quantity	Remark
1	Rebound Hammer.	As per IS: 13311-Part-II-1992.	1 No.	Per group of 5-7 students
2	Grinding wheel or rough stone.	Sufficient for Cleaning loose material.	1 No.	Per batch
3	Pencil or marker.	---	1 No.	Per group of 5-7 students

X Procedure:

1. Check the rebound hammer against the testing anvil before commencement of a test to ensure reliable results.
2. Identify the building having defects or without defects i.e. damaged or undamaged structure in the vicinity of college/campus.
3. Identify the point of impact at least 20mm away from the edge or sharp discontinuity and mark with pencil/marker.
4. Clean the target surface of concrete or masonry work using appropriate method.
5. Keep the plunger of rebound hammer touching to surface in horizontal, vertical or inclined position as per suitability of site condition.
6. Press the casing of hammer so that the impact spring around the hammer will wind up around the plunger as shown in above figure 2.
7. Release the dashpot button or release pin; so that the hammer mass attached to guide rod will impact on the target surface. Based on the resistance offered by surface in terms of hardness, this mass will rebound back Due to backward movement of attached mass, the pointer on graduated scale will move accordingly.
8. Measure the reading on the graduated scale by which the mass is rebound back as Rebound Number or Rebound Index.
9. Repeat the above steps at least five more times on the same point of same surface with same position to get more accurate observations by taking average of all observations.
10. Find out the strength of tested building element using correlation graph given in figure 1 and overall quality of tested concrete using table 1.

XI Precautions to be followed:

1. The testing anvil for checking rebound hammer should be of steel having Brinell hardness of about 5000 N/mm^2. The supplier/manufacturer of the rebound hammer should indicate the range of readings on the anvil suitable for different types of rebound hammers.
2. Ensure that the target surface should be smooth, clean and dry.
3. Take care that the loose surface (if any) should be rubbed off with a grinding wheel or stone, before testing.
4. Don't conduct the test on the rough surface resulting from incomplete compaction of concrete, loss of grout, spoiled or tooled surface.

XII Actual procedure followed: *(Use blank sheet if provided space is not sufficient).*

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XIII Resources used:

Sr. No.	Name of Resource	Broad Specifications		Quantity	Remark
		Make	Details		
1					
2					
3					
4					

XIV Precautions followed:

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XV Observations:

a. Location of Building: ……

b. Number of floors in Building: **..**…….

c. Condition of Building: ……. (Damaged / Undamaged).

Sr. No.	Name of structural/building element *(any two)*	Position of Hammer	Rebound Number or Rebound Index					
			1	2	3	4	5	6
1	Beam							
2	Column							
3	Slab							

Calculations:

1. Average Rebound Number for building element: (beam, column, slab etc.).

a) For Beam, N = …… = …… No**.**

b) For Column, N = …… = ……. No**.**

c) For Slab, N = ……..= ……..No**.**

2. The compressive strength for building element (beam, column, slab etc.) from correlation graph.

a) For Beam = …… N/mm^2**.**

b) For Column = …… N/mm^2**.**

c) For Slab = …….. N/mm^2**.**

XVI Results:

1. The Rebound Number and Compressive strength of the tested Beam is found to be …… and ……. N/mm^2 respectively**.**
2. The Rebound Number and Compressive strength of the tested Column is found to be …… and ……. N/mm2 respectively.
3. The Rebound Number and Compressive strength of the tested Slab is found to be …… and ……. N/mm2 respectively.

XVII Interpretation of results: *(Give meaning of the above obtained results).*

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XVIII Conclusions and Recommendations:

(Actions/decisions to be taken based on the interpretation of results).

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XIX Practical Related Questions:

Note*: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions.*

1. State the significance of Rebound Number of concrete.
2. Write minimum two factors affecting the variation in rebound number.
3. List out minimum two tools you have used for the preparation of concrete surface before going for rebound hammer test.
4. In which case, rebound number will be less i.e. in dry or wet condition of surface. Give reason.
5. In which case, rebound number will be less i.e. in horizontal position or inclined position of hammer. Give reason.
6. Give minimum four methods of Non-Destructive Testing for masonry structures.
7. State the type of rebound hammer you have used for this test i.e. analog/digital type, along with its cost and manufacturer.
8. Write two advantages and two disadvantages of rebound hammer test.
9. State the time required to conduct the rebound hammer test on one building element.

(Note: Each batch should attempt three questions and not to be repeated the same questions by other batches)

Space to Write Answers

XX References / Suggestions for further Reading:

Sr. No.	Title of Book/Website Links	Author	Publication
1.	Building Repair and Maintenance Management.	P.S.Gahlot, Sanjay Sharma	CBS Publishers & Distributors Pvt. Ltd., New Delhi, 2016, ISBN: 81-239-1243-9.
2.	Maintenance and Repair of Buildings.	P.K.Guha	New Central Book Agency (P) Ltd., New Delhi, 2011, ISBN: 81-7381-073-7.
3.	Building: Structural Audit, Repairs and Restoration.	Arun Kelkar	Majestic Publishing House, Thane,2015, ISBN: 978-93-83678-93-8.
4.	Hand Book of Causes and Prevention of Cracks.	SP-25:1984	Bureau Of Indian Standards, 1985, Fourth Reprint March 1999, ISBN 81-7061-015-X.
5.	https://theconstructor.org/concrete/rebound-hammer-test-concrete-ndt/2837/		
6.	http://www.iitk.ac.in/ce/test/IS-codes/is.13311.2.1992.pdf		

XXI Suggested Assessment Scheme:

Performance Indicators		Weightage (%)
Process related:15 Marks		**60%**
1	Safety precautions followed.	30 %
2	Conduct of test and recoding of observations.	30 %
Product related:10 Marks		**40%**
3	Analyzing the recorded observations..	10%
4	Answers to practical related questions.	20%
5	Submission of report in time.	10%
Total: 25 Marks		**100%**

List of Student Team Members (Roll No.)

1. ……
2. …….
3. …….
4. …….
5. …….

Marks Obtained			Dated sign of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 5: Efflorescence Test

I Practical Significance:

The presence of efflorescence in damp masonry or concrete work leads to its deterioration. It may result in unhygienic conditions in usable area of the building. Therefore it is necessary to check the extent of efflorescence in such work. This practical enable to access the masonry part of a damaged or undamaged building. It helps to take decision to remove the efflorescence of building using relevant technique like brushing with strong brush, washing with pressurized water, application of diluted vinegar.

II Relevant Program Outcomes:

PO 1. Basic knowledge: *An ability to apply knowledge of basic mathematics, science and engineering to solve the engineering problems.*

PO 2. Discipline knowledge*: An ability to apply discipline - specific knowledge to solve core and/or applied engineering problems.*

PO 3. Engineering tools: *Apply relevant civil technologies and tools with an understanding of the limitations.*

PO 8. Individual and team work: *Function effectively as leader and team member in Diverse /multidisciplinary team.*

III Relevant Course Outcomes:

a. Test the structures to predict its stability.
b. Apply the relevant methods of repair for the masonry structures.

IV Practical Outcome:

Determine the extent of efflorescence in masonry/concrete for damaged/undamaged structure IS: 3495 – Part (3)-1992.

V Competency and Practical Skills:

This practical is expected to develop the following skills for the industry identified competency, ***"Maintain different types of building structures."***

1. Visual observation skill.
2. Handling tools and equipments.
3. Analyzing the problems.

VI Relevant Affective domain related:

a. Follow safety practices.
b. Practice good housekeeping.
c. Demonstrate working as a leader/ team member.
d. Follow ethical Practices.

VII Minimum Theoretical Background:

Meaning of Efflorescence: Efflorescence is a crystalline deposit of water-soluble salts on that can form when water is present in or on brick, concrete, stone, stucco or other building surfaces. It is a white or grayish tint describes the deposit of crusty white mineral salts that

appear on a masonry surface (concrete, render, brick or mortar) that have leached out from within the substrate when moisture migrates through it. When masonry contains water/moisture, cement or lime contains soluble salts and then efflorescence takes place.

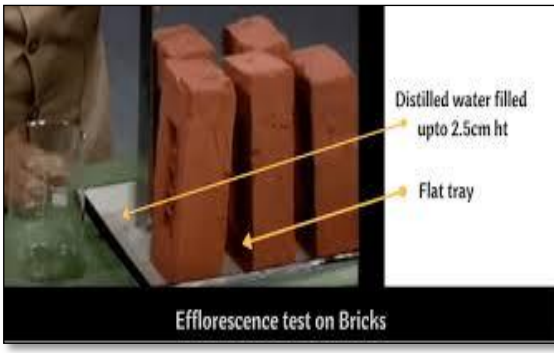
Effect of Efflorescence: Although efflorescence is unsightly and a nuisance to remove, it is not harmful to the brick masonry nor does it affect the structural integrity of the masonry. The presence of efflorescence in damp wall leads to various damages like unhygienic conditions, decay, dry rot of woodwork, disintegration of masonry, damage to furniture and internal decorations, crumbling of plaster, etc.

Degree of Efflorescence: The extent efflorescence in the masonry or concrete can be defined in terms of degree of efflorescence as given in Table 1 below.

Sr. No.	Observations of % area coverage of salts	Degree of efflorescence
1	When there is no perceptible deposit of efflorescence.	Nil
2	When thin deposit is on area less than 10 % of the exposed brick area.	Slight
3	When deposit is up to 50 % of the exposed brick without powdering.	Moderate
4	When deposit is more than 50 % of the exposed brick without powdering.	Heavy
5	When deposit is more than 50 % of the exposed brick with powdering.	Serious

IS Requirement of Efflorescence: As per IS: 3495 – Part(3)-1992,the specifications limit the efflorescence to be not more than moderate (10-50%) up to class and not more than slight (< 10 per cent) for higher classes.

VIII Experimental Set-up:



(a) Bricks in square tray

(b) Bricks in circular tray

(c) Efflorescence in concrete (d) Efflorescence observed after immersion

Figure1: Efflorescence Test on Brick

IX Resources required:

Sr. No.	Particulars	Specification	Quantity	Remark
1	Shallow flat bottom dish.	Glass, porcelain or glazed stoneware material and	2 Nos.	Per batch
2	Measuring Scale.	1 mm accuracy.	1 No.	Per batch
3	Distilled water.	--	4-5 liters approx.	Per batch
4	Bricks sample.	From damaged/undamaged part.	5 Nos.	Per batch
5	Concrete sample.	From damaged/undamaged part.	1 No.	Per batch
6	HCl acid.	Concentrated form.	200 gm/m^2	Per batch
7	Cleaning brush.	--	1 No.	Per batch
8	Sponge	--	1 No.	Per batch

X Procedure:

Efflorescence test on masonry bricks:

1. Arrange the visit to accessible building nearby and take out 5 bricks safely from damaged or undamaged part of the building.
2. Remove the plastered part of the brick taken clearly without breaking the brick as a whole and identify the type and size of brick by measuring its dimensions.
3. Maintain the warm and well ventilated room at a temperature ranging between 200C to 300C for this test.
4. Take the shallow flat bottom dish of size 180x180 mm in plan with 40mm height for square shaped and 200 mm dia. x 40 mm depth for cylindrical shaped.
5. Fill this dish with sufficient quantity of distilled water up to 25 mm depth using measuring scale required for complete saturation.

6. Keep the 5cleaned bricks in the water by immersing its header end, so that the immersed brick will absorb the water completely as per its full capacity.
7. Allow to evaporate the surplus water will evaporate and bricks will appear to be dry within minimum 48 hours or more.
8. Now again add same quantity of water in the tray containing bricks. Allow to absorb the water by bricks completely with evaporation of excess water.
9. Observe the dry surface of brick for the presence of soluble salts in the form of white or grey spots in the average % area coverage by efflorescence.
10. Define the degree of efflorescence of bricks using Table 1.

Efflorescence test on concrete element: As there is no standard test method to access the extent of efflorescence in concrete material, one can take judgment by following the procedure given below.

1. Arrange the visit to accessible building nearby and identify the doubtful concrete surface where chances of efflorescence are more.
2. Clean it properly by removing dust present on the surface if any.
3. Prepare the diluted HCl from its concentrated form so that the quantity of HCl acid would be 200 gm/m^2.
4. Apply the prepared diluted HCl on the target concrete surface using a sponge with thickness 0.5 mm uniformly.
5. Remove the concrete surface using sharp edge up to depth 0.01 mm uniformly.
6. Observe the concrete surface after end of the reaction.
7. Observe the surface of concrete thoroughly, if the concrete surface is dark, medium dark or light, then it indicates high, medium or low degree of efflorescence respectively.

XI Precautions to be followed:

1. Ensure the complete cleaning of brick should be done by removing plaster and mortar joint material if any before it's testing.
2. Check the exact depth of water in tray as per requirement for each trial.
3. Ensure that the brick should absorb the water and tray should become empty completely.
4. Keep the brick in water vertically by dipping the header only.
5. Handle the HCl acid carefully to avoid any mis-happenings while applying on concrete.

XII Actual procedure followed: *(Use blank sheet if provided space is not sufficient).*

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XIII Resources used:

	Name of Resource	Broad Specifications		Quantity	Remark
		Make	Details		
1					
2					
3					
4					

XIV Precautions followed:

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XV Observations:

a. Name of the Building: ……

b. Address of the building: ……

c. Condition of the building: ……(damaged/undamaged)

Observation table for efflorescence test in masonry brick:

Type of Brick	Size of Brick (L x B x t) mm	Observed Degree of Efflorescence in					Average Degree of Efflorescence
		Brick Sample 1	Brick Sample 2	Brick Sample 3	Brick Sample 4	Brick Sample 5	

Observation table for efflorescence test in concrete element:

Name of Building Element	Observed color of the concrete surface (Dark/Medium dark/light)	Degree of efflorescence (High/Medium/Low)

XVI Results:

1. The degree of efflorescence observed in the bricks of damaged/undamaged wall is found to be ……. (Nil/Slight/Moderate/Heavy/Serious)**.**
2. The efflorescence is …… (removable /non-removable) from the damp wall.
3. As per the observed extent of efflorescence in tests bricks, it is required to remove efflorescence of damaged part by ……..(water washing/strong brushing/vinegar spraying)
4. The effect of efflorescence in the building is mainly caused due to …….. (use of damp brick in construction/entry of moisture after construction).
5. The degree of efflorescence in tested concrete element is …….. (High/Medium/Low).

XVII Interpretation of results: *(Give meaning of the above obtained results).*

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XVIII Conclusions and Recommendations:

(Actions/decisions to be taken based on the interpretation of results).

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XIX Practical Related Questions:

Note*: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions.*

1. Enlist minimum three major causes of occurrence of efflorescence in the building.
2. Write minimum three precautions to be taken while construction of the building to minimize efflorescence.
3. How did you remove the plaster and other materials attached to the brick in this test?
4. Which work is more susceptible for efflorescence; masonry or concrete? Give reasons.
5. Write the chemical used for the efflorescence test on concrete.
6. Describe in brief, the phenomenon of formation of efflorescence.
7. State the effect of formation of efflorescence on strength of material.

8. 'The room temperature affects degree of efflorescence of brick.' Justify the statement.
9. What will happen if distilled water is not used for this test?

(Note: Each batch should attempt three questions and not to be repeated the same questions by other batches)

Space to Write Answers

XX References / Suggestions for further Reading:

Sr. No.	Title of Book/Website Links	Author	Publication
1.	Building Repair and Maintenance Management.	P.S.Gahlot, Sanjay Sharma	CBS Publishers & Distributors Pvt. Ltd., New Delhi, 2016, ISBN: 81-239-1243-9.
2.	Maintenance and Repair of Buildings.	P.K.Guha	New Central Book Agency (P) Ltd., New Delhi, 2011, ISBN: 81-7381-073-7.
3.	Building: Structural Audit, Repairs and Restoration.	Arun Kelkar	Majestic Publishing House, Thane, 2015, ISBN: 978-93-83678-93-8.
4.	Concrete Technology-Theory and Practice.	M.S.Shetty	S. Chand & Co. Pvt. Ltd., New Delhi, 2016, ISBN:978-81-219-0003-4.
5.	https://www.youtube.com/watch?v=2pu2SxAK-Q8		
6.	http://www.iitk.ac.in/ce/test/IS-codes/is.3495.1-4.1992.pdf		
7.	properties-of-concrete-by-a-m-neville.pdf		

XXI Suggested Assessment Scheme:

Performance Indicators		Weightage (%)
Process related:15 Marks		**60%**
1	Safety precautions followed	30 %
2	Visual observation and Recording of observations	30 %
Product related:10 Marks		**40%**
3	Analyzing the observations	10%
4	Answers to practical related questions.	20%
5	Submission of report in time.	10%
Total: 25 Marks		**100%**

List of Student Team Members (Roll No.)

1. ……
2. …….
3. …….
4. …….
5. …….

Marks Obtained			Dated sign of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 6: Ultrasonic Pulse Velocity Test

I Practical Significance:

When the structural element (beam, column, beam slab, wall, floors, doors-windows etc.) are having defects (cracks, plaster spalling, reinforcement corrosion etc.); then it is suggested to check its strength. If the tested strength is known; then further one can take judgment of repairs and maintenance. This practical helps to undertake the strength determination of building component in damaged or undamaged structure under consideration by using ultrasonic pulse velocity test apparatus.

II Relevant Program Outcomes:

PO 1. Basic knowledge: *An ability to apply knowledge of basic mathematics, science and engineering to solve the engineering problems.*

PO 2. Discipline knowledge*: An ability to apply discipline- specific knowledge to solve core and/or applied engineering problems.*

PO 3. Engineering tools: *Apply relevant civil technologies and tools with an understanding of the limitations.*

PO 8. Individual and team work: *Function effectively as leader and team member in Diverse / multidisciplinary team.*

III Relevant Course Outcomes:

a. Select the relevant method of maintaining different building structures.
b. Test the structures to predict its stability.

IV Practical Outcome:

Determine the strength of any two structural elements such as column, beam, slab etc. for damaged/undamaged structure using Ultrasonic Pulse Velocity Test as per IS: 13311-Part-I-1992.

V Competency and Practical Skills:

This practical is expected to develop the following skills for the industry identified competency, ***"Maintain different types of building structures."***

1. Visual observation skill.
2. Judgment of appropriate use of instrument.
3. Handling of portable instruments.
4. Interpretation skill of the obtained results.

VI Relevant Affective domain related:

a. Follow safety practices.
b. Practice good housekeeping.
c. Demonstrate working as a leader/ team member.
d. Follow ethical Practices.

VII Minimum Theoretical Background:

The non-destructive tests are the group of useful methods to evaluate the strength of construction materials without causing damage.

It is not always possible to do destructive tests for the materials of construction like concrete, block and clay bricks, etc. particularly when they are already laid. They

are independent tests sufficient to make the structural engineering decisions after establishing figurative substantiation through its application. Rebound hammer test procedure is used to examine the hardness of concrete particularly when you want to carry out repairs of RCC structure.

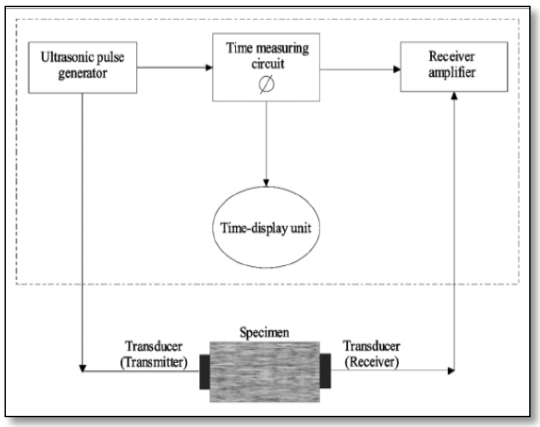
Ultrasonic Pulse Velocity Test: This test is done to assess the quality of concrete by ultrasonic pulse velocity method as per IS: 13311 (Part 1) – 1992. The underlying principle of this test is measuring the time of travel of an ultrasonic pulse passing through the concrete being tested. Comparatively higher velocity is obtained when concrete quality is good in terms of density, uniformity, homogeneity etc. as given in table 1.

Table.1: Quality of Velocity Criterion for Concrete Quality Grading.

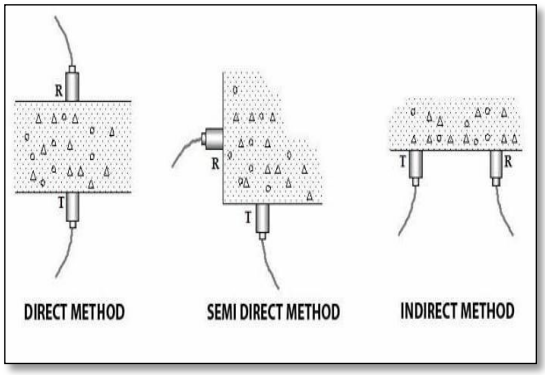
Sr. No.	Average Ultrasonic Pulse Velocity (V)	Approximate Compressive Strength(S)	Overall Quality of Concrete
1	V > 4.5 Km/s	S > 40 N/mm^2	Excellent
2	V = 3.5 – 4.5 Km/s	S = 25 -40 N/mm^2	Good
3	V = 3 – 3.5 Km/s	S = 10 - 20N/mm^2	Medium
4	V = 2 – 3 Km/s	S = 4 - 10N/mm^2	Poor
5	V < 2 Km/s	S < 4 N/mm^2	Very Poor

VIII Experimental Set-up:

(a) Ultrasonic Pulse Velocity Meter with Probes



(b) Schematic Diagram of UPVT



(c) Modes of Attaching Transducer Ends. (d) Direct Transmission Ultrasonic Pulse Velocity Test.

Figure 1: Ultrasonic Pulse Velocity Test

IX Resources required:

Sr. No.	Particulars	Specification	Quantity	Remark
1	Electrical pulse generator or Ultrasonic Pulse Velocity Meter.	Confirming IS: 13311-Part-I-1992.	1 No.	Per batch.
2	Transducer	Piezoelectric and magnetostrictive type; frequency Lange of 50 kHz to 60 kHz.	1 Pair.	Per batch.
3	Amplifier	Confirming IS:13311-Part-I-1992.	1 No.	Per batch.
4	Electronic timing device.	Accuracy of +/-1 percent over a range of 20 microseconds to 10 milliseconds.	1 No.	Per batch.
5	Acoustical coupling material.	Petroleum jelly, grease, liquid soap and kaolin glycerol paste.	Sufficient quantity.	Per batch.

X Procedure:

1. Identify the target concrete surface and clean it properly. Then define two end points of application of ultrasonic pulses.
2. Apply one of the acoustical coupling materials mentioned above to both the points of the concrete.
3. Attach the transmitter and receiver end of transducer to the identified concrete surface of building component (beam, column, slab etc.) in the one of the form given in figure 1 above.
4. Generate the ultrasonic pulses or waves of 50 to 60 kHz using electro-acoustical or ultrasonic pulse generator; so that it will pass through the transmitter end attached to concrete and will reach to receiver end depending upon homogeneity of concrete mass.
5. Note down the time of travel i.e. transit time (T) of these waves displayed on display unit of electronic timing device in seconds.

6. Calculate the ultrasonic pulse velocity (V) of transmitted waves as V = (L / T) in Km/s.
7. Repeat all above steps at other locations if defect or damage extent is more. Calculate the average ultrasonic pulse velocity of all such observations for building component under consideration.
8. Determine the overall quality of concrete based on calculated ultrasonic pulse velocity by using table 1 given above.

XI Precautions to be followed:

1. Connect the transmitter and receiver end of transducer on plain surface only to ensure complete transmission. If the surface is rough, then make it smooth leveled manner.
2. Take care of the distance between these two ends i.e. path length (L) should be 100mm for maximum nominal size of aggregate is less than 20 mm and it should be 150mm for aggregate size 20 to 40mm.
3. A minimum path length of 150 mm and 400mm is recommended for direct and indirect transmission.

XII Actual procedure followed: *(Use blank sheet if provided space is not sufficient).*

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XIII Resources used:

Sr. No.	Name of Resource	Broad Specifications		Quantity	Remark
		Make	Details		
1					
2					
3					
4					

XIV Precautions followed:

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XV Observations:

a. Location of Building: ……..

b. Number of floors in Building: …….

c. Condition of Building : ……..... (Damaged / Undamaged)

Sr. No.	Name of structural/building element *(Any Two)*	Path Length (L) in mm	Transit Time of Waves (T) in sec.	Ultrasonic Pulse Velocity (V)=(L/T) in mm/sec.	Average Ultrasonic Pulse Velocity ($V_{avg.}$) in mm/sec.	Ultrasonic Pulse Velocity (V) in Km/sec.
1	Beam					
2	Column					
3	Slab					

Calculations:

1. Average Ultrasonic Pulse Velocity for building element:
   d) For Beam, $V_{avg.}$ = …….. mm/sec.
   e) For Column, $V_{avg.}$ = …….. mm/sec.
   f) For Slab, $V_{avg.}$ = …… mm/sec.

2. Ultrasonic Pulse Velocity for building element:
   a) For Beam, V = ……..…… Km/sec.
   b) For Column, V = ……..…. Km/sec.
   c) For Slab, V = ……..…….. Km/sec.

3. The approximate compressive strength for building element: from Table 1
   a) For Beam, $V_{avg.}$ = …… N/mm^2
   b) For Column, $V_{avg.}$ = …….. N/mm^2
   c) For Slab, $V_{avg.}$ = ……..... N/mm^2

XVI Results:

1. The average ultrasonic pulse velocity obtained for Beam is found to be ……Km/sec. and its approximate compressive strength ……. N/mm^2**.**
2. The average ultrasonic pulse velocity obtained for Column is found to be ……Km/sec. and its approximate compressive strength ……. N/mm^2.

3. The average ultrasonic pulse velocity obtained for Slab is found to be ……Km/sec. and its approximate compressive strength ……. N/mm^2.

XVII Interpretation of results: *(Give meaning of the above obtained results).*

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XVIII Conclusions and Recommendations:

(Actions/decisions to be taken based on the interpretation of results).

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XIX Practical Related Questions:

***Note**: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions.*

1. Name the company and cost of the ultrasonic pulse velocity test apparatus used in this test.
2. Write minimum four factors influencing the ultrasonic pulse velocity passing through concrete.
3. State in which case, the pulse velocity will be more, (i) Direct transmission or cross probing (ii) Semi-direct transmission or lateral probing (iii) Indirect transmission or surface probing. Justify the answer.
4. State out of which type of concrete i.e. PCC or RCC of same grade, the pulse velocity will be more and justify your answer.
5. Compare the ultrasonic pulse velocity test with rebound hammer test (min. two points).
6. Write two advantages and two disadvantages of ultrasonic pulse velocity test.
7. State the approximate time required to conduct the ultrasonic pulse velocity test on one building element.
8. Do you think that the UPVT can be conducted for soil to check its stability? Justify your answer.
9. Is it possible to conduct this test on masonry? If yes, in which case the ultrasonic velocity will be more i.e. masonry or RCC.

(Note: Each batch should attempt three questions and not to be repeated the same questions by other batches)

Space for Write Answer.

XX References / Suggestions for further Reading:

Sr. No.	Title of Book/Website Links	Author	Publication
1.	Building Repair and Maintenance Management.	P.S.Gahlot, Sanjay Sharma	CBS Publishers & Distributors Pvt. Ltd., New Delhi, 2016 ISBN: 81-239-1243-9.
2.	Maintenance and Repair of Buildings.	P.K.Guha	New Central Book Agency (P) Ltd., New Delhi, 2011, ISBN: 81-7381-073-7.
3.	Building: Structural Audit, Repairs and Restoration.	Arun Kelkar	Majestic Publishing House, Thane, 2015 ISBN: 978-93-83678-93-8.
4.	Hand Book of Causes and Prevention of Cracks.	SP-25:1984	Bureau Of Indian Standards, 1985, Fourth Reprint March 1999, ISBN 81-7061-015-X.
5.	https://theconstructor.org/concrete/ultrasonic-test-on-concrete/2847/		
6.	http://www.iitk.ac.in/ce/test/IS-codes/is.13311.1.1992.pdf.		

XXI Suggested Assessment Scheme:

Performance Indicators		Weightage (%)
Process related:15 Marks		**60%**
1	Safety precautions followed	30 %
2	Conduct of test and Recording of observations	30 %
Product related:10 Marks		**40%**
3	Analyzing the recorded the observations	10%
4	Answers to practical related questions.	20%
5	Submission of report in time.	10%
Total: 25 Marks		**100%**

List of Student Team Members (Roll No.)

1. ……
2. ……
3. ……
4. ……
5. ……

Marks Obtained			Dated sign of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 7: Pull Out Test

I Practical Significance:

If the concrete possess sufficient resistance against the tensile force, it is the indication of better strength of reinforced concrete. It is necessary to ensure better bonding between embedded steel reinforcement and concrete covered. This practical is able to take the judgment about the bond strength of RCC in terms of compressive strength. It is essential to know the resistance of concrete against pull force against grip between pulled concrete mass and steel inside.

II Relevant Program Outcomes:

PO 1. Basic knowledge: *An ability to apply knowledge of basic mathematics, science and engineering to solve the engineering problems.*

PO 2. Discipline knowledge*: An ability to apply discipline- specific knowledge to solve core and/or applied engineering problems.*

PO 3. Engineering tools: *Apply relevant civil technologies and tools with an understanding of the limitations.*

PO 8. Individual and team work: *Function effectively as leader and team member in Diverse /multidisciplinary team.*

III Relevant Course Outcomes:

a. Select the relevant method of maintaining different building structures.
b. Test the structures to predict its stability.

IV Practical Outcome:

Determine the bond strength of any one structural element such as column, beam, slab etc. using pull out test.

V Competency and Practical Skills:

This practical is expected to develop the following skills for the industry identified competency, ***"Maintain different types of building structures."***

1. Visual observation skill.
2. Handling the tools and equipment.
3. Analyzing the problems.

VI Relevant Affective domain related:

a. Follow safety practices.
b. Practice good housekeeping.
c. Demonstrate working as a leader/ team member.
d. Follow ethical Practices.

VII Minimum Theoretical Background:

Principle of Pull out Test: The fundamental principle behind pull-out testing with LOK-test and CAPO- test is that test equipment designed to a specific geometry will produce results (pull-out forces) that closely correlate to the compressive strength of concrete. This

correlation is achieved by measuring the force required to pull a steel disc or ring, embedded in the concrete, against a circular counter pressure placed on the concrete

surface concentric with the disc/ring. The steel disc is only for fresh concrete. For hardened concrete, an expandable steel ring is used instead. This ring expands to fit a specially drilled hole and routed recess in the concrete.

Correlation between Pull out force and Strength of concrete: The relationship between pull out force and strength is shown here in figure 1 below.

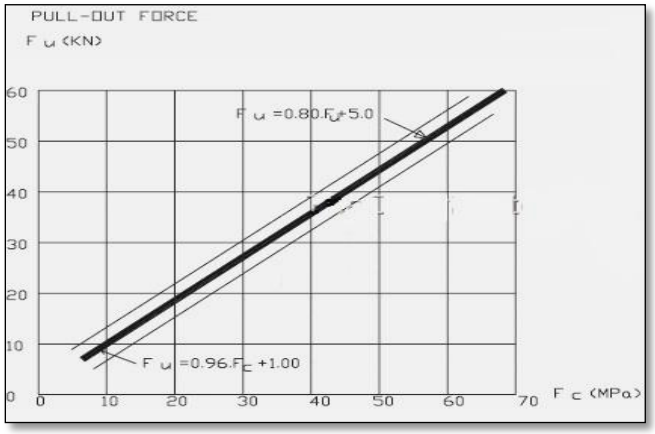
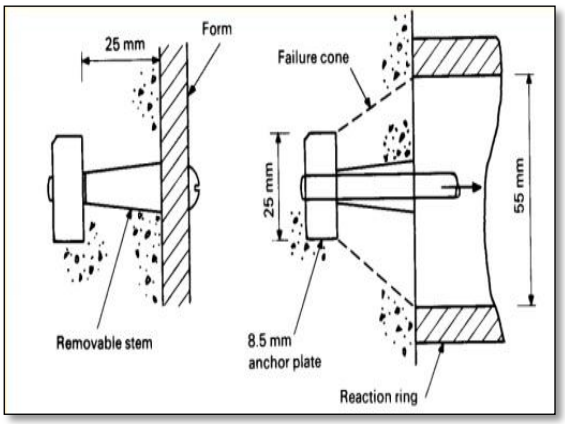


Figure 1: Pull Out Force vs. Strength.

VIII Experimental Set-up:

(a) CAPO Test Apparatus with Accessories.



(b) Details of Cut Hole.

(c) CAPO Test on Column.

(d) Conical hole cut on Column.

Figure 2: Cut and Pull Out (CAPO) Test

IX Resources required:

Sr. No.	Particulars	Specification	Quantity	Remark
1	CAPO Test ApparatusC-101 Preparation Kit.	Conforming to ASTM C900 and EN 12504-3	1 No.	Per batch
2	C-102 DSV-Kit.		1 No.	Per batch
3	C-104 pull machine kit with the 0 to 100 kN digital gauge.		1 No.	Per batch
4	C-102 CAPO-TEST DSV-Kit.		1 No.	Per batch
5	C-104 CAPO Pull Machine Kit.		1 No.	Per batch
6	C-112 CAPO expandable inserts(expandable rings).		1 No.	Per batch
7	C-111 Resizing Tool for resizing C-112 insert 2 to 3 times.		1 No.	Per batch

X Procedure:

1. Identify the nearby building for this test.
2. Check the location of reinforcement using cover meter and finalize the target test surface 50 mm away from reinforcement and 100 mm away from corners and edges.
3. Drill the central hole of 18.4 mm in diameter up to depth of 65 mm on the test surface using diamond drill machine with application of water.
4. Insert the diamond recess router in the drilled hole. Continue the recess routing until the diamond shaft hits the drill hole circumference and a hole of 25 mm diameter and 25 mm depth will form.
5. A split ring is expanded in the recess and pulled out using a pull machine reacting against a 55 mm diameter counter pressure ring.
6. The expansion unit mounted on the CAPO-test insert is inserted in the hole and expanded by means of the adjustable wrenches.
7. The counter pressure is fitted around the expansion unit and the coupling is threaded 1-2 rotations on the thread of the base pull-bolt.
8. The pull-machines telescopic handle is fully extended as shown in figure 2 above. Remaining slack between the concrete surface, the counter pressure and the instrument is removed by turning the instrument clockwise.
9. Apply the loading by turning the handle slowly with a speed of one rotation every 2 seconds.
10. Hold the piston handle located between the two cylinders with other hand. The pointer of the gauge will start to move upwards.
11. Keep on loading at the recommended speed and record the peak load. The pointer will, at the peak load of the load-displacement curve, hold its position for a short moment and then slowly fall back. Continue loading using as fast a speed of the loading handle as possible to extract the pull-out cone fully.

12. Do not twist or pull the instrument to release the cone. If there is no more travel left of the telescopic handle, turn the handle anti-clockwise 39 rotations, then turn the equipment clockwise to thread the coupling further on the base pull bolt and repeat the loading sequence. Then the cone will be fully dislodged.
13. Note down the force required to take out the conical core as pull out force (Fu) in kN.
14. Repeat above steps at two different points or locations and calculate the strength (Fc) in MPa using correlation graph given in figure no.1 above.

XI Precautions to be followed:

1. Ensure that the test surface has to be smooth and plane. If not, the surface must be ground with the diamond surface planning wheel.
2. Note: The instrument needs to be fully oil-refilled and the insert has to be correctly installed to make the cone come out in the first loading sequence.
3. Ensure the full contact of apparatus with test surface by appropriate turning.
4. Refill the excavated hole with suitable mix.
5. Keep the distance between two target points at least 200 mm.

XII Actual procedure followed: *(Use blank sheet if provided space is not sufficient).*

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XIII Resources used:

Sr. No.	Name of Resource	Broad Specifications		Quantity	Remark
		Make	Details		
1					
2					
3					
4					

XIV Precautions followed:

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XV Observations:

a. Name of the Building:……
b. Address of the building:……
c. Date and time of visit:……
d. Type of building/structure: ……
e. Year of construction: ……

Sr. No.	Name of Structural/ Building Element (Any one)	Pull out Force obtained (Fu)			Average Pull out Force (Fu) in KN	Compressive Strength (Fc) in MPa
		Test point 1	Test point 2	Test point 3		
1	Beam					
2	Column					
3	Slab					

XVI Results:

For tested ……..… (beam, column/slab), the average pull out force is ……. kN and the corresponding strength obtained is …….. MPa.

XVII Interpretation of results: *(Give meaning of the above obtained results)*

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XVIII Conclusions and Recommendations:

(Actions/decisions to be taken based on the interpretation of results).

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XIX Practical Related Questions:

Note*: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions.*

1. Write the working principle of Cut and Pull out (CAPO) test.

2. State two criteria's for fixing the target test concrete surface for CAPO test.
3. State the cost and name of company of the apparatus used by you in this test.
4. What will happen if the reinforcement is closer to drill hole in the cut and pull out test.
5. Why water is used while cutting the hole in this test?
6. Give minimum two accessories required for this test.
7. Is there any crack formation while conducting this test? If yes, give reason for it.
8. State two conditions under which this test is preferred.
9. State the approximate time and manpower required for conducting this test on one building element.

(Note: Each batch should attempt three questions and not to be repeated the same questions by other batches)

Space to Write Answers

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XX References / Suggestions for further Reading:

Sr. No.	Title of Book/Website Links	Author	Publication
1.	Building Repair and Maintenance Management.	P.S.Gahlot, Sanjay Sharma	CBS Publishers & Distributors Pvt. Ltd., New Delhi, 2016 ISBN: 81-239-1243-9.
2.	Maintenance and Repair of Buildings.	P.K.Guha	New Central Book Agency (P) Ltd., New Delhi, 2011, ISBN: 81-7381-073-7.
3.	Concrete Technology-Theory and Practice.	M.S.Shetty	S. Chand & Co. Pvt. Ltd., New Delhi, 2016, ISBN:978-81-219-0003-4.
4.	https://theconstructor.org/concrete/pullout-lok-capo-test-hardened-concrete/2861/		
5.	http://germann.org/products-by-application/category-1/capo-test.		
6.	http://www.germann.org/TestSystems/CAPO-TEST/Pull-out%20testing%20by%20LOK-test%20and%20CAPO-test.pdf.		

XXI Suggested Assessment Scheme:

Performance Indicators		Weightage (%)
Process related:15 Marks		**60%**
1	Safety precautions followed.	30 %
2	Installing the equipment and performing test.	30 %
Product related:10 Marks		**40%**
3	Analyzing the observations.	10%
4	Answers to practical related questions.	20%
5	Submission of report in time.	10%
Total: 25 Marks		**100%**

List of Student Team Members (Roll No.)

1. ……
2. …….
3. …….
4. …….
5. …….

Marks Obtained			Dated sign of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 8: Rebar Locator Test

I Practical Significance:

It is necessary to provide adequate cover to reinforcement in any reinforced concrete structure to prevent corrosion and to improve durability of structure. It is also necessary to find the number of reinforcing bars, their condition of corrosion, cover to reinforcement, and grade of concrete for evaluating actual strength of concrete structures. This practical enable to compute strength of structure when structural drawings are unavailable. Furthermore this test is significant to take decision of strengthening of the structure if any. The reinforcement details of structures permits increase in higher loads.

II Relevant Program Outcomes:

PO 1. Basic knowledge: *An ability to apply knowledge of basic mathematics, science and engineering to solve the engineering problems.*

PO 2. Discipline knowledge*: An ability to apply discipline- specific knowledge to solve core and/or applied engineering problems.*

PO 3. Engineering tools: *Apply relevant civil technologies and tools with an understanding of the limitations.*

PO 8. Individual and team work: *Function effectively as leader and team member in Diverse /multidisciplinary team.*

III Relevant Course Outcomes:

a. Select the relevant method of maintaining different building structures.
b. Test the structures to predict its stability.

IV Practical Outcome:

Determine the size, depth and location of reinforcement bar using Rebar locator of any two structural elements such as column, beam, slab etc. for damaged/undamaged structure.

V Competency and Practical Skills:

This practical is expected to develop the following skills for the industry identified competency. ***"Maintain different types of building structures."***

1. Visual observation skill.
2. Handling the tools and equipments.
3. Analyzing the problems.

VI Relevant Affective domain related:

a. Follow safety practices.
b. Practice good housekeeping.
c. Demonstrate working as a leader/ team member.
d. Follow ethical Practices.

VII Minimum Theoretical Background:

Construction of rebar locator: The detection of location of reinforcement is required as a preprocess for core cutting. The rebar locator is the instrument a small versatile instrument for detecting location, size of reinforcement and concrete cover. This is a portable and
handy instrument which is normally used to locate the reinforcement on LCD display. This instrument is available with sufficient memory to store measured data. Integrated software is loaded in the equipment for carrying out and printing statistical values.

Principle of rebar locator test: The instrument is based upon measurement of change of an electromagnetic field caused by steel embedded in the concrete. The reinforcement bar is detected by magnetizing it and inducing a circulating eddy current in it. After the end of the pulse, the eddy current dies away, creating a weaker magnetic field as an echo of the initial pulse. The strength of the induced filed is measured by a search head as it dies away and this signal is processed to give the depth measurement. The eddy current echo is determined by the depth of the bar, the size of bar and the orientation of the bar.

Factors affecting the test results: The arrangement of reinforcement, variation in the iron content of cement and use of aggregate with magnetic properties, metal ties also affects the magnetic field.

VIII Experimental Set-up:

(a) Rebar Locator. (b) Rebar Locator with accessories.

Figure 1: Rebar Locator Test

IX Resources required:

Sr. No.	Particulars	Specification	Quantity	Remark
1	Rebar Locator with accessories like spot probe, diameter probe, depth probe	LCD with backlight; Depth range 100-185 mm; Accuracy ± 2mm, ±5% for cover.	1 No.	Per batch
2	Measuring scale	Least Count 1 mm.	1 No.	Per batch
3	Marking pen/chalk	--	1 No.	Per batch

X Procedure:

1. Take the rebar locator test apparatus and calibrate it by using the test block provided with it. The depth and size of reinforced bar of test block shown by apparatus should be same to that of actual one (i.e. measured with scale).
2. Identify the test surface of beam/column/slab of the building and mark the target points in a suitable grid pattern using marking pen or chalk.
3. Erect the necessary staging, ladder or suspended platform for the application of rebar locator if required.
4. Clean the test surface and make it smooth leveled manner by removing the dust, and other unwanted projections if any.
5. Take the rebar locator connected with path measuring device and spot probes and move the same in horizontal and vertical direction.
6. Mark the location of bar when the position of the bar displayed on the screen. Note down the distance of the bar from surface shown of display.
7. Now attach the diameter probe to the rebar locator after finding the position of the bar and keep the probe parallel to located bar.
8. Observe four readings are displayed on screen and take mean value of these readings as diameter of bar.
9. Now attach the depth probe to the rebar locator and keep it exactly over identified bar location.
10. Note down the depth of concrete cover after getting an audio signal i.e. beep sound. The detected concrete cover is stored in memory.

XI Precautions to be followed:

1. Ensure that the probes should be perfectly aligning the reinforcement bar for each trial.
2. Repeat the movement gently on the test surface if the bar diameter is less and reinforcement cover is more.
3. Do not apply the rebar locator on the rough or plaster removed surface as it may result erroneous result.

XII Actual procedure followed: *(Use blank sheet if provided space is not sufficient).*

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XIII Resources used:

Sr. No.	Name of Resource	Broad Specifications		Quantity	Remark
		Make	Details		
1					
2					
3					
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XIV Precautions followed:

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XV Observations:

a. Name of the Building: ……
b. Address of the site: ……
c. Date and time of visit: ……
d. Type of building/structure: ……
e. Year of construction: ……

Sr. No.	Name of structural element (beam/column/slab)	Observed particulars						Average diameter of Steel Bar (mm)
		Location / Position of Steel Bar (mm)	Cover of Steel Bar (mm)	Diameter of Steel Bar (mm)				
1								
2								

XVI Results:

1. The details of size and location of the ……... (beam/column/slab) tested by rebar locator are as follows.
   i. Position of bar from surface = ……. mm.
   ii. Minimum cover of reinforcement bar = …….. mm.
   iii. Average diameter of reinforcement bar = …….. mm.

2. The details of size and location of the ……... (beam/column/slab) tested by rebar locator are as follows.
   i. Position of bar from surface = ……. mm.
   ii. Minimum cover of reinforcement bar = …….. mm.
   iii. Average diameter of reinforcement bar = …….. mm.

XVII Interpretation of results: *(Give meaning of the above obtained results).*

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XVIII Conclusions and Recommendations:
(Actions/decisions to be taken based on the interpretation of results).

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XIX Practical Related Questions:

Note*: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions.*

1. List out various types of probes along with their applicability required in this test.
2. Write the name and cost of company of test apparatus used by you in this test.
3. State the accuracy of rebar locator used by you.
4. State two advantages of rebar locator test.
5. Is it possible to detect the status of reinforcement corrosion with this rebar locator? If not, give the name of alternative equipment to be used for the same.
6. Write the principle of rebar locator test.
7. List out three factors affecting the accuracy and results of rebar locator test.
8. State any four applications of the rebar locator test.
9. State the time and manpower required to perform the rebar locator test on one building element.

(Note: Each batch should attempt three questions and not to be repeated the same questions by other batches)

Space to Write Answers

XX References / Suggestions for further Reading:

Sr. No.	Title of Book/Website Links	Author	Publication
1.	Building Repair and Maintenance Management.	P.S.Gahlot, Sanjay Sharma	CBS Publishers & Distributors Pvt. Ltd., New Delhi, 2016 ISBN: 81-239-1243-9.
2.	Maintenance and Repair of Buildings.	P.K.Guha	New Central Book Agency (P) Ltd., New Delhi, 2011, ISBN: 81-7381-073-7.
3.	Building: Structural Audit, Repairs and Restoration.	Arun Kelkar	Majestic Publishing House, Thane, 2015 ISBN: 978-93-83678-93-8.
4.	https://theconstructor.org/practical-guide/profometer-test-evaluate-rcc-structure-strength/8738/		
5.	https://www.slideshare.net/mustafahasan33633/rebar-detector-test-of-nondestructive-test.		

XXI Suggested Assessment Scheme:

Performance Indicators		Weightage (%)
Process related:15 Marks		**60%**
1	Safety precautions followed.	30 %
2	Installing the equipment and performing test.	30 %
Product related:10 Marks		**40%**
3	Analyzing the observations.	10%
4	Answers to practical related questions.	20%
5	Submission of report in time.	10%
Total: 25 Marks		**100%**

List of Student Team Members (Roll No.)

1. ……
2. …….
3. …….
4. …….
5. …….

Marks Obtained			Dated sign of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 9: Rapid Chloride Test

I Practical Significance:

The ingress of chloride ions in concrete i.e. chloride attack destroys that protective oxide layer and corrosion starts. It results in subsequent reduction of strength, serviceability, and aesthetics of the structure. This practical enable to determine the chloride content using chemicals. It is essential to check the same for minimizing the risk of corrosion under the impact of chlorides in concrete as well as for ensuring the future stability of structure.

II Relevant Program Outcomes:

PO 1. Basic knowledge: *An ability to apply knowledge of basic mathematics, science and engineering to solve the engineering problems.*

PO 2. Discipline knowledge*: An ability to apply discipline- specific knowledge to solve core and/or applied engineering problems.*

PO 3. Engineering tools: *Apply relevant civil technologies and tools with an understanding of the limitations.*

PO 8. Individual and team work: *Function effectively as leader and team member in Diverse /multidisciplinary team.*

III Relevant Course Outcomes:

a. Select the relevant method of maintaining different building structures.
b. Test the structures to predict its stability.

IV Practical Outcome:

Determine Maximum Chloride content in concrete in percent by weight of cement using Rapid Chloride Test of any one structural elements such as column, beam, slab etc.. forum damaged structure as per IS:14959 Part (2)-2001.

V Competency and Practical Skills:

This practical is expected to develop the following skills for the industry identified Competency, ***"Maintain different types of building structures."***

1. Visual observation skill.
2. Handling the equipment's scientifically.
3. Analyzing the problems.

VI Relevant Affective domain related:

a. Follow safety practices.
b. Practice good housekeeping.
c. Demonstrate working as a leader/ team member.
d. Follow ethical Practices.

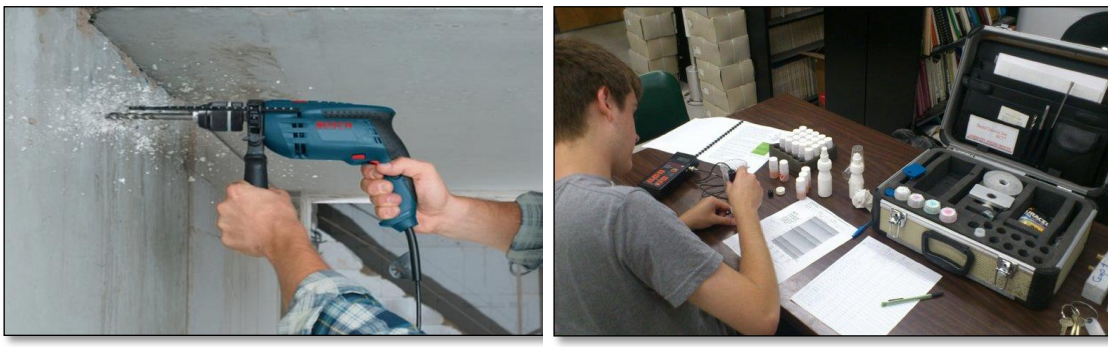
VII Minimum Theoretical Background:

Rapid Chloride Test (RCT): This is quick method to estimate of total soluble chloride (fixed as well as free chloride) contents is essential from corrosion risks point of view. For water soluble chlorides standard titration is carried out and expressed by weight of concrete

or cement. The water soluble chloride testing gives the average chloride content in the concrete cover region. Further, a level of chloride across the cover thickness will be a more useful measurement. This can permit to make a preliminary estimate of chloride diffusion rate. The accuracy of the RTC method is equivalent to standard laboratory titration and has been accepted as such. All chlorides in concrete do not contribute to corrosion process of the reinforcement steel. It is estimated that between 50 and 75% of the total chloride content in the concrete will be water soluble and will impact the corrosion process.

Permissible limits of chloride content in concrete: The maximum permissible chlorides concentration are in the range of 0.05 to 0.1% by weight of concrete, which is about 1.1 to 2.4 Kg/m3.The maximum permissible chloride limits are also expressed on the basis of the weight of cement, and these are approximately 0.4 to 0.8% when the cement in concrete is about 300 Kg/m^3.

VIII Experimental Set-up:



(a) Drilling of concrete element (b) Chloride content test

Figure: Rapid Chloride Test

IX Resources required:

Sr. No.	Particulars	Specification	Quantity	Remark
1	Drilling equipment	sufficient to drill the concrete surface	1 No.	Per batch
2	Whatman filter paper No.1	--	4-5 Nos.	Per batch
3	Beaker	250mlcapacity	1 No.	Per batch
4	Conical flask.	250mlcapacity	1 No.	Per batch
5	Nitric acid.	6 N concentration	20-25 ml	Per batch
6	Silver nitrate.	0.2 N concentration	75-80 ml	Per batch
7	Ferric alum.	---	4-5 ml	Per batch
8	Nitrobenzene	----	15-20 ml	Per batch
9	Ammonium thiocyanate.	0.2 N concentration	As required	Per batch

X Procedure:

1. Take out the powder sample of target concrete surface by drilling it at 5mm depth using suitable drilling equipment.
2. Weigh 1000 ± 5 gm of the pulverized mortar or concrete sample in a 2 litre capacity beaker.
3. Add 1000 ml of distilled water (chloride free) to the pulverized or powdered form of concrete. Stir the mixture vigorously and warm gently for 15 min.
4. Allow the mixture to stand in a room temperature for24 hours for settling.
5. Pour this about 200 ml of the supernatant solution into a clean dry250mlcapacity beaker.
6. Filter the solution through Whatman filter paper No. 1 immediately and collect the filtrate.
7. Pipette 50 ml of filtrate in a 250 ml capacity conical flask.
8. Add 5 ml of 6 N nitric acid in filtrate. Also add a known volume (X) preferably 25 ml of 0.2 N silver nitrate solution in filtrate.
9. Add 1mlferric alum and 5ml of nitrobenzene.
10. Shake vigorously to coagulate the precipitate.
11. Titrate excess silver nitrate with 0.2N ammonium thiocyanate solution until a permanent faint reddish brown color appears.
12. Note down the volume (Y) of ammonium thiocyanate used to obtain the above mentioned color.
13. Calculate the percentage of chloride (acid soluble/ water soluble) by mass of mortar or concrete as Chloride, percent =0.00142(X- Y) where x = volume of silver nitrate added, in ml; and Y = volume of 0.02 N ammonium thiocyanate consumed in ml.

XI Precautions to be followed:

1. Unless otherwise specified, pure chemicals of analytical reagent grade and distilled water (see IS: 1070) shall be used in the test.
2. Interference of silver chloride particles (which are generated in-situ) in titration by reacting with thiocyanate can be avoided by the addition of nitrobenzene which forms a film on silver chloride particles.
3. Normally concrete shall be 14days old before the specimens are removed.
4. Specimens that show abnormal defects or that have been damaged in removal shall not be used.
5. Handle the chemicals carefully to avoid the certain mis-happenings.

XII Actual procedure followed: *(Use blank sheet if provided space is not sufficient).*

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XIII Resources used:

Sr. No.	Name of Resource	Broad Specifications		Quantity	Remark
		Make	Details		
1					
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XIV Precautions followed:

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XV Observations:

a. Name of the Building: ……

b. Address of the building: …….

Name of building element	Trial No.	Color observed after titration	Volume of silver nitrate added (X) in ml	Volume of ammonium thiocyanate (Y) in ml	Chloride Content= 0.00142(X- Y) %	Average Chloride Content in %
	1					
	2					
	3					

Calculations:

For trial no. ……,

The percentage of chloride for the ……. building element is

Chloride percent = 0.00142(X- Y)

= ……..

= …….. %.

Average Chloride percent = ……..

= …….. %.

XVI Results:

The average chloride content in percentage in tested …… (beam/column/slab) is found to be …….. %.

XVII Interpretation of results: *(Give meaning of the above obtained results).*

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XVIII Conclusions and Recommendations:

(Actions/decisions to be taken based on the interpretation of results).

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XIX Practical Related Questions:

***Note**: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions.*

1. State the effect of chloride content on various properties of concrete.
2. State any four factors affecting the chloride content of concrete.
3. Write the tool used by you for drilling the concrete element.
4. State any four causes of chloride attack on concrete structures.
5. State the alternative method to determine chloride content in concrete.
6. State the permissible limit of maximum chloride content for (i) pre-stressed concrete structures (ii) non-prestressed concrete structures.
7. Give two practical situations where this test is preferred.
8. Give two precautions to be taken to reduce the occurrence of chloride content in concrete.
9. Enlist five degrees of chloride permeability identified using RCPT i.e. Rapid Chloride Permeability Test as per AASHTO T277 and ASTM C1202.

(Note: Each batch should attempt three questions and not to be repeated the same questions by other batches)

Space to Write Answers

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XX References / Suggestions for further Reading:

Sr. No.	Title of Book/Website Links	Author	Publication
1.	Building Repair and Maintenance Management.	P.S.Gahlot Sanjay Sharma	CBS Publishers & Distributors Pvt. Ltd., New Delhi, 2016, ISBN: 81-239-1243-9.
2.	Maintenance and Repair of Buildings.	P.K.Guha	New Central Book Agency (P) Ltd., New Delhi, 2011, ISBN: 81-7381-073-7.
3.	Building: Structural Audit, Repairs and Restoration.	Arun Kelkar	Majestic Publishing House, Thane, 2015, ISBN: 978-93-83678-93-8.
4.	Concrete Technology-Theory and Practice.	M.S.Shetty	S. Chand & Co. Pvt. Ltd., New Delhi, 2016, ISBN:978-81-219-0003-4.
5.	https://ia803002.us.archive.org/27/items/gov.in.is.14959.2.2001/is.14959.2.2001.pdf		
6.	https://gharpedia.com/blog/chloride-content-test-for-concrete-structure-durability/		
7.	https://theconstructor.org/concrete/chloride-attack-concrete-structures-cause-prevention/7802/		
8.	https://theconstructor.org/concrete/chemical-tests-on-concrete-structures/2953/		

XXI Suggested Assessment Scheme:

Performance Indicators		Weightage (%)
Process related:15 Marks		**60%**
1	Safety precautions followed.	30 %
2	Installing the equipment and performing test.	30 %
Product related:10 Marks		**40%**
3	Analyzing the observations.	10%
4	Answers to practical related questions.	20%
5	Submission of report in time.	10%
Total: 25 Marks		**100%**

List of Student Team Members (Roll No.).

1. ……
2. ……
3. ……
4. ……
5. ……

Marks Obtained			Dated sign of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 10: Carbonation Test

I Practical Significance:

The significance of carbonation is that usual protection of the reinforcing steel generally present in concrete due to the alkaline conditions caused by hydrated cement paste is neutralized by carbonation. Thus, if the entire concrete cover over the reinforcing steel is carbonated, corrosion of the steel would occur if moisture and oxygen could reach the steel. This practical enable to know the extent of carbonation of concrete and hence it becomes significant in deciding the further measures against corrosion of concrete element.

II Relevant Program Outcomes:

PO 1. Basic knowledge: *An ability to apply knowledge of basic mathematics, science and engineering to solve the engineering problems.*

PO 2. Discipline knowledge*: An ability to apply discipline- specific knowledge to solve core and/or applied engineering problems.*

PO 3. Engineering tools: *Apply relevant civil technologies and tools with an understanding of the limitations.*

PO 8. Individual and team work: *Function effectively as leader and team member in Diverse /multidisciplinary team.*

III Relevant Course Outcomes:

a. Select the relevant method of maintaining different building structures.
b. Test the structures to predict its stability.

IV Practical Outcome:

Determine the depth of carbonation of concrete using phenolphthalein indicator of any two structural elements such as column, beam, slab etc. for undamaged structure.

V Competency and Practical Skills:

This practical is expected to develop the following skills for the industry identifiedcompetency, ***"Maintain different types of building structures."***

1. Visual observation skill.
2. Handling the equipments.
3. Analyzing the problems.

VI Relevant Affective domain related:

a. Follow safety practices.
b. Practice good housekeeping.
c. Demonstrate working as a leader/ team member.
d. Follow ethical Practices.

VII Minimum Theoretical Background:

Phenomenon of Carbonation of Concrete: Concrete Carbonation occurs when the atmospheric carbon dioxide (CO_2) reacts with hydrated cement minerals ($CaOH_2$). CO_2 react in the presence of moisture with $CaOH_2$ and produce carbonates ($CaCO_3$).

Carbonates slowly penetrate below the exposed surface of the concrete. Thus the carbonation affects the concrete cover over the reinforcing steel. Hence steel corrosion

occurs due to the process of concrete carbonation. The concrete loses its durability, and finally, it cracks due to the expansion of film over the bar. At the same time, the rate of steel corrosion is at the highest level. The concrete carbonation process is also called Concrete de-passivation.

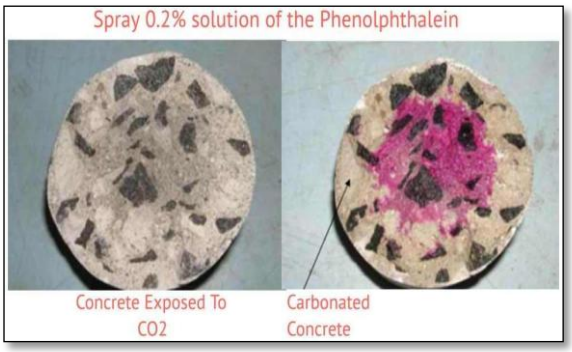
Measurement of pH: Phenolphthalein solution indicates the change of pH level in the concrete.

- If the indicator turns purple, the pH is above 8.6.
- In practice, a pH of 8.6 may only give a faintly discernible slightly pink color.
- When the solution remains colorless, the pH of the concrete is below 8.6, suggesting carbonation.
- A fully-carbonated paste has a pH of about 8.4.
- A strong, immediate, color change to purple suggests a pH that is rather higher, perhaps pH 9 or 10.
- Normal concrete pore solution is saturated with calcium hydroxide and also contains sodium and potassium hydroxide; the pH is typically 13-14.
- Concrete with a pore solution of pH 10-12 is less alkaline than sound concrete but would still produce a strong color change with phenolphthalein indicator.

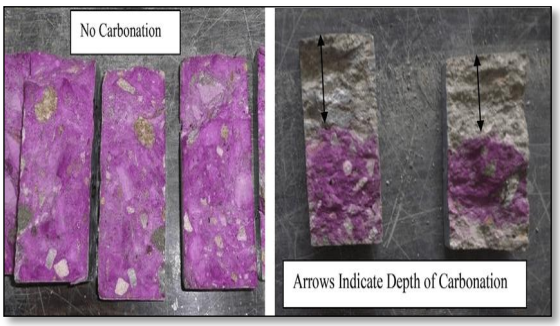
Alternative method of estimating depth of carbonation: The carbonation depth is approximately proportional to the square root of time. For example, if the carbonation depth is 1mm in a one-year-old concrete, it will be about 3mm after 9 years, 5mm after 25 years and 10mm after 100 years.

VIII Experimental Set-up:

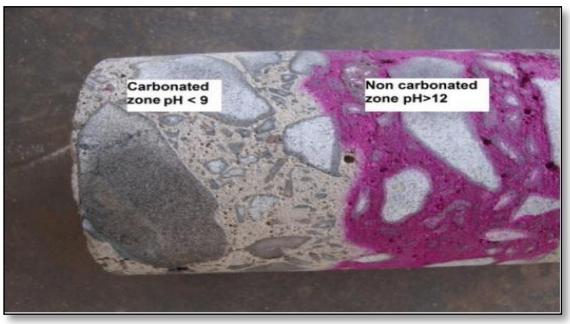
(a) Phenolphthalein solution as indicator.



(b) Concrete core before and after carbonation test.



(c) Measurement of depth of carbonation.



(d) Zones of carbonation.

Figure 1: Carbonation Test

IX Resources required:

Sr. No.	Particulars	Specification	Quantity	Remark
1	Phenolphthalein solution	0.2% concentration	300 ml approx.	Per batch
2	Measuring scale.	--	1 No.	Per batch
3	Physician's injection syringe or needle.	5 cc	1 No.	Per batch
4	Core sampler or drilling machine.	--	1 No. as per availability.	Per batch

X Procedure: The carbonation test on the concrete of existing building can be done by two methods described below.

Method by taking concrete core:

1. Identify the target concrete surface of undamaged building such as beam/column/slab/footing so that it will be sufficiently away from reinforcement bar.
2. Extract the concrete core (square/circular) from the identified element i.e. beam/colum/slab by removing the plastered surface if any.
3. Phenolphthalein is dissolved in a suitable solvent such as isopropyl alcohol (isopropanol) in a 1% solution. OR The 1% phenolthalein solution is made by dissolving 1gm of phenolthalein in 90 cc of ethanol. The solution is then made up to 100 cc by adding distilled water.
4. Spray 0.2% solution of the prepared phenolphthalein solution with physician's injection syringe or needle on such fresh concrete core at all cross-sectional surface.
5. Observe the change in normal grey colour of concrete in to purple or pink shades. If the concrete changes its grey colour to pink, it means that the concrete is in good condition. When there is no change in colour of concrete, it means that the area is affected by carbonation.
6. Measure the depth of uncoloured layer (carbonated layer) in millimeter using measuring scale from the external surface at 4 to 8 positions.
7. Calculate the mean value of all measurements as average depth of carbonation of tested concrete.

Method by drilling hole in concrete:

1. Identify the target concrete surface of undamaged building such as beam/column/slab/footing so that it will be sufficiently away from reinforcement bar.

   Remove the dust from the hole by brush and blow the air to clean the hole.
3. Flush out the drilled hole with de-ionized water immediately after the drilling to avoid contamination.
4. Inject the 0.2% solution of the phenolphthalein with physician's injection syringe or needle on such freshly drilled/broken concrete at different or number of possible depths.

5. Observe the change in normal grey colour of concrete in to purple or pink shades. If the concrete changes its grey colour to pink, it means that the concrete is in good condition. When there is no change in colour of concrete, it means that the area is affected by carbonation.
6. Measure the depth of uncoloured layer (carbonated layer) in millimeters using measuring scale from the external surface at 4 to 8 positions.
7. Calculate the mean value of all measurements as average depth of carbonations of tested concrete.

XI Precautions to be followed:

1. Ensure that the test surface is getting wet completely for effective reaction.
2. Handle both phenolphthalein and isopropyl alcohol carefully, as it is harmful and flammable.
3. Avoid the ingestion or contact of solution with skin or eyes, as it may cause difficulty in breathing, kidney damage and cancer.

XII Actual procedure followed: *(Use blank sheet if provided space is not sufficient).*

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XIII Resources used:

Sr. No.	Name of Resource	Broad Specifications		Quantity	Remark
		Make	Details		
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2					
3					
4					

XIV Precautions followed:

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XV Observations:

a. Name of the Building: ……..
b. Address of the building: ……
c. Date and time of visit: ……...

d. Type of building/structure: ……...
e. Year of construction: ……

Sr. No.	Name of Structural/Building element	Average depth of carbonation (mm)	Observed changed colour of concrete	pH of concrete
1				
2				

XVI Results:

1. The average depth of carbonation observed for …….. (beam/column/slab) is found to be …….. mm and the change in colour observed in the tested concrete surface is found ……. (unchanged grey / purple shade / pink shade).
2. The average depth of carbonation observed for …….. (beam/column/slab) is found to be …….. mm and the change in colour observed in the tested concrete surface is found ……. (unchanged grey / purple shade / pink shade).

XVII Interpretation of results: *(Give meaning of the above obtained results).*

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XVIII Conclusions and Recommendations:

(Actions/decisions to be taken based on the interpretation of results).

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XIX Practical Related Questions:

Note*: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions.*

1. State the effect of carbonation on strength of concrete.
2. Write any two limitations of the carbonation test.
3. Which method of carbonation test is followed by you and why?
4. State the chemical reaction due to which carbonation of concrete takes place.
5. Enlist two factors affecting the carbonation process in concrete.
6. State the alternative method to determine the depth of carbonation in concrete.

7. Write the relationship between depth of carbonation and time/age of structure.
8. State the typical values of depth of carbonation for M20 and M40 grade concrete after 2,5,10 and 50 years.
9. Write two precautionary/preventive measures to avoid the carbonation of concrete.

(Note: Each batch should attempt three questions and not to be repeated the same questions by other batches)

Space to Write Answers

XX References / Suggestions for further Reading:

Sr. No.	Title of Book/Website Links	Author	Publication
1.	Building Repair and Maintenance Management.	P.S.Gahlot, Sanjay Sharma	CBS Publishers & Distributors Pvt. Ltd., New Delhi, 2016, ISBN: 81-239-1243-9.
2.	Maintenance and Repair of Buildings.	P.K.Guha	New Central Book Agency (P) Ltd., New Delhi, 2011, ISBN: 81-7381-073-7.
3.	Building: Structural Audit, Repairs and Restoration.	Arun Kelkar	Majestic Publishing House, Thane, 2015, ISBN: 978-93-83678-93-8.
4.	Concrete Technology-Theory and Practice.	M.S.Shetty	S. Chand & Co. Pvt. Ltd., New Delhi, 2016, ISBN:978-81-219-0003-4.
5.	http://civil-online2010.blogspot.com/2010/09/carbonation-depth-measurement-test.html		
6.	https://gharpedia.com/concrete-carbonation-test/		
7.	https://www.understanding-cement.com/carbonation.html		

XXI Suggested Assessment Scheme:

Performance Indicators		Weightage (%)
Process related:15 Marks		**60%**
1	Safety precautions followed	30 %
2	Installing the equipment and performing test	30 %
Product related:10 Marks		**40%**
3	Analyzing the observations	10%
4	Answers to practical related questions.	20%
5	Submission of report in time.	10%
Total: 25 Marks		**100%**

List of Student Team Members (Roll No.)

1. ……
2. ……
3. ……
4. ……
5. ……

Marks Obtained			Dated sign of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 11: Moisture Content Test

I Practical Significance:

Concrete is a construction material that is widely used in many different structures including houses, commercial buildings, roadways, underground structures, and waterfront structures. These structures are dynamic systems subjected to continuous changes in moisture content. More importantly, parts of these structures are exposed to extreme environmental conditions such as with bridge piers, dams, and waterfront structures. They experience variations in the tidal zone, hence continuous changes in the moisture content. Concrete modulus of elasticity is related to concrete compressive strength in both temperature and moisture variation. Concrete strength and modulus of elasticity are inversely related to temperature as well as moisture content in the concrete. This practical is able to measure moisture content of the damp structure, strength can be predicted and method of repair or re-strengthening can be decided.

II Relevant Program Outcomes:

PO 1. Basic knowledge: *An ability to apply knowledge of basic mathematics, science and engineering to solve the engineering problems.*

PO 2. Discipline knowledge*: An ability to apply discipline- specific knowledge to solve core and/or applied engineering problems.*

PO 3. Experiments and practice: *An ability to plan and perform experiments and practices and to use the results to solve engineering problems.*

PO 14. Engineering tools: *Apply relevant civil technologies and tools with an understanding of the limitations.*

PO 8. Individual and Team Work: *Function effectively as leader and team member in Diverse /multidisciplinary team.*

III Relevant Course Outcomes:

a. Select the relevant method of maintaining different building structures.
b. Test the structures to predict its stability.

IV Practical Outcome:

Determine the moisture content using Moisture Meter of any two structural elements such as column, beam, slab etc. for damaged or undamaged structure.

V Competency and Practical Skills:

This practical is expected to develop the following skills for the industry identified competency. ***"Maintain different types of building structures."***

1. Handling of instruments.
2. Correlate the mechanical properties of concrete to moisture content for the given building component.

VI Relevant Affective domain related:

a. Follow safety practices.
b. Practice good housekeeping.
c. Demonstrate working as a leader/a team member.
d. Maintain tools and equipment.
e. Follow ethical Practices.

VII Minimum Theoretical Background:

There are three primary mechanisms that control the transport of fluids through concrete. They are permeation (saturated fluid flow under a pressure head), diffusion (fluid flow under a concentration gradient), and capillary suction (fluid flow due to capillary pressures in an unsaturated element).

Degree of saturation is calculated as

$$S_r = \frac{M_a}{M_s} \times 100$$

Where,

Sr is the saturation ratio of specimen (%),

Ma is the moisture content at different soaking period in minutes;

Ms is the moisture content at the full saturation period (5days).

Table: Saturation ratio of specimens prepared for mechanical tests.

Soaking time	0 min	30 min	90 min	200 min	5 days
Saturation ratio	0%	52%	87%	92%	100%

With decreasing degree of saturation, increase surface tension and compressive stress is found. It should be noted that as only physically absorbed water affects surface tension. At higher moisture content, water starts to fill capillary pores in the concrete, which is outside the range of surface tension.

The increase in concrete strength with decreasing saturation in the range of higher saturation ratio (52-92%) is assumed to come from the capillary suction effect leading to an almost isotropic compression of solid skeleton. As a result, the material behaves like a pre-stressed concrete of higher strength. At nearly saturated condition (92-100%), an increase in compressive strength can be found. This could probably due to the pore pressure developed in the concrete.

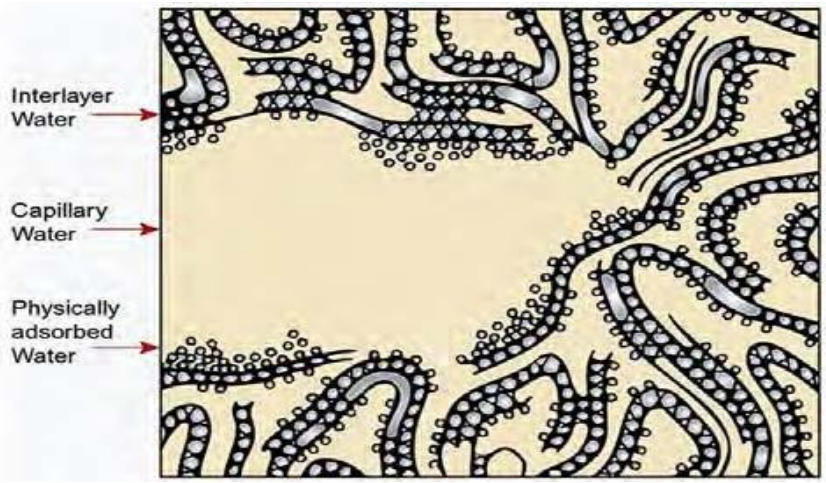

Figure 1: Flow of water through concrete

VIII Experimental Set-up:

Figure 2: Moisture meter test apparatus

IX Resources required:

Sr. No.	Particulars	Specification	Quantity	Remark
1	Concrete Moisture Meter.	Moisture meter should be capable of in-situ moisture measurement up to depth of 300mm with the help of probe and should be operated on batteries.	1No.	Per batch
2	Compression testing machine.	Compression testing machine of 2000KN capacity.	1No.	-----
3	Curing tank.	Water tank of sufficient size.	1NO.	-----
4	Measuring scale.	15 or 30 cm in length.	1 No.	Per batch
5	Thermostatically controlled Oven.	Temperature range 105-110^0C.	1 No.	Per batch

X Procedure:

1. Measure the sides of five concrete cubes available in the laboratory.
2. Keep the same cubes in oven for drying for 24 hours.
3. Keep concrete cube in a tray for soaking such as 0 minutes (i.e. dry),30minutes,90minutes,200minutes,5days (full saturation).
4. Take out the each cube from water at different soaking period. After wiping off excess water from the surface of the cube, measure the moisture content using moisture meter.
5. Calculate the saturation ratio (Sr) for five samples using Sr = (moisture content at particular soaking time / moisture content at full saturation) x 100
6. Crush each cube samples by applying crushing load using compression testing machine.

7. Correlate the moisture content to compressive strength for different saturation ratios.
8. Draw the graph of saturation ratio (Sr) v/s compressive strength (σ) on regular graph paper.

XI Precautions to be followed:

1. Ensure that the cubes are totally immersed in water.
2. While measuring strength of cubes all surface water should be wiped off completely.
3. Rate of loading of CTM should be proper.

XII Actual procedure followed: *(Use blank sheet if provided space is not sufficient).*

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XIII Resources used:

Sr. No.	Name of Resource	Broad Specifications		Quantity	Remark
		Make	Details		
1					
2					
3					
4					

XIV Precautions followed:

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XV Observations:

Sr. No.	Particulars	Observation No.				
	Sample No.	1	2	3	4	5
	Soaking time in minutes	0	30	90	200	5 days
1	Moisture content at different saturation period (Ma).					
2	Moisture content of cube at full saturation					

	period (5 days) (Ms).					
3	Saturation ratio (Sr) in percentage.					
	Compressive strength Determination.					
5	Actual cube size.					
6	Cross sectional area.					
7	Compressive load in Newton.					
8	Compressive strength in N/mm^2.					

Sample Calculation:

Saturation ratio (Sr) $= \frac{Ma}{Ms} \times 100$

For observation no. ……

Sr = ……..%

Compressive strength = $\frac{Crushing \quad load}{Cross \quad \text{sec} \quad tional \quad area}$ in N/mm^2

σ =…….. N/mm^2

XVI Results:

1. The Compressive strength of given concrete cube for Sr (0%) is ……..
2. The Compressive strength of given concrete cube for Sr(….%) is ……..
3. The Compressive strength of given concrete cube for Sr (…%) is ……
4. The Compressive strength of given concrete cube for Sr (….%) is ……...
5. The Compressive strength of given concrete cube for Sr (100%) is ……..

XVII Interpretation of results :*(Give meaning of the above obtained results).*

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XVIII Conclusions and Recommendations:

(Actions/decisions to be taken based on the interpretation of results).

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XIX Practical Related Questions:

***Note**: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions.*

1. How porosity affects the moisture content?
2. State the effect of W/C ratio with respect to moisture content.
3. State the effect of moisture content on strength of the concrete.
4. How the density of cube affects the moisture content?
5. State the cost of moisture meter you have used and the name of supplier.
6. State the grade of concrete you have used for this practical.
7. State the depth up to which moisture meter you have used will be effective.
8. State the method to determine the moisture content of cube without using moisture meter.
9. Write the conclusion from the graph drawn between Saturation ratio (Sr) and Compressive strength.

(Note: Each batch should attempt three questions and not to be repeated the same questions by other batches)

Space to Write Answers

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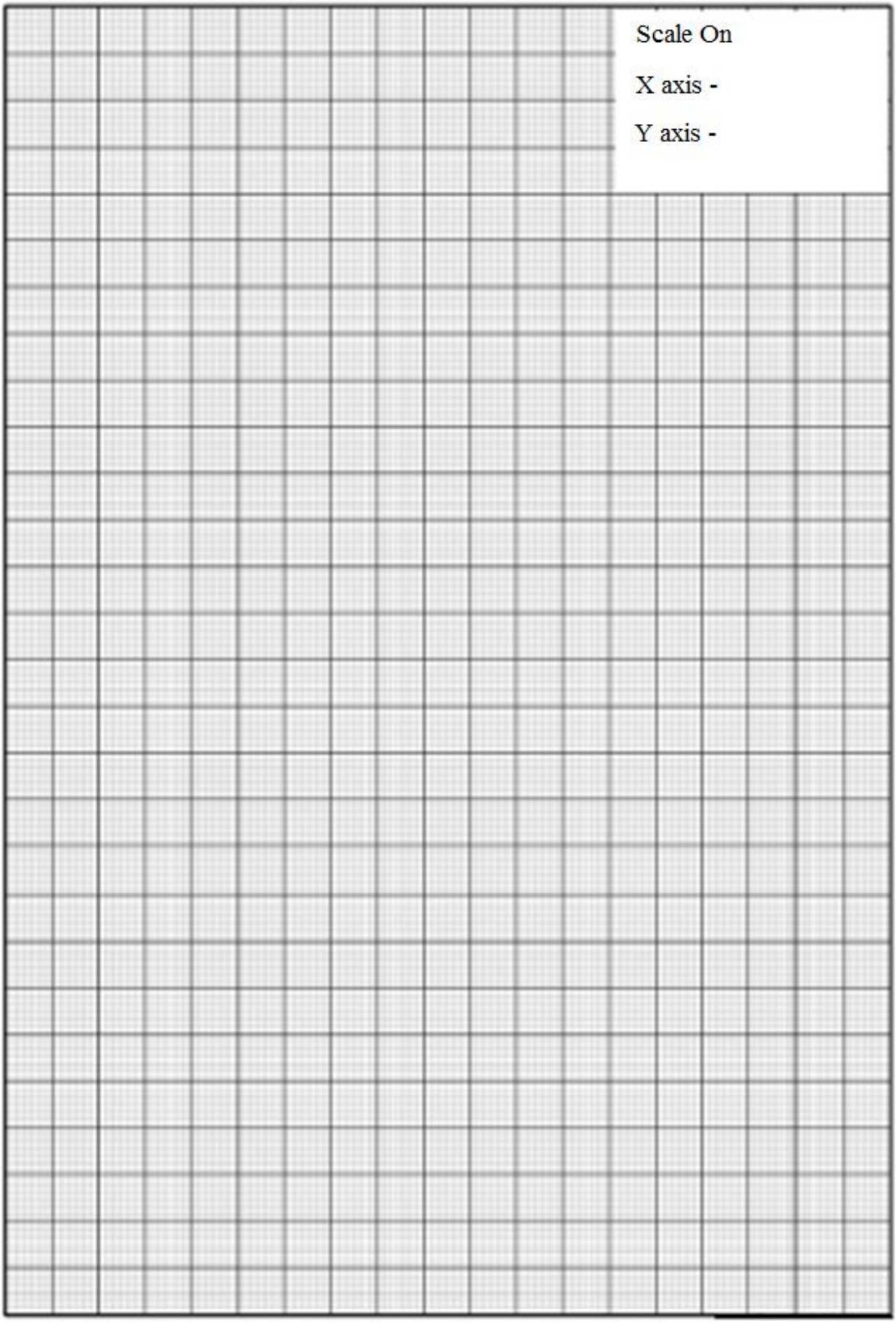
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XX References / Suggestions for further Reading:

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3.	Building: Structural Audit, Repairs and Restoration.	Arun Kelkar	Majestic Publishing House, Thane, 2015 ISBN: 978-93-83678-93-8.
4.	Concrete Technology-Theory and Practice.	M.S.Shetty	S. Chand &Co. Pvt. Ltd., New Delhi, 2016, ISBN:978-81-219-0003-4.

XXI Suggested Assessment Scheme:

Performance Indicators		Weightage (%)
Process related:15 Marks		**60%**
1	Measurement of mass of soil samples.	30 %
2	Recording of observations.	30 %
Product related:10 Marks		**40%**
3	Calculations and analysis of result.	10%
4	Answers to practical related questions.	20%
5	Submission of report in time.	10%
Total: 25 Marks		**100%**

List of Student Team Members (Roll No.)

1. ……
2. …….
3. …….
4. ……
5. ……

Marks Obtained			Dated sign of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 12: Reinforcement Corrosion Test

I Practical Significance:

The risk of corrosion of reinforcement steel is determined by this test. Half-cell measurement is considered to be a zonal measurement. It will take an average potential measurement of the surroundings It is a sort of an average over a certain distance and where the actual location of corroded bar can be challenging to distinguish, even with corrosion potential mapping. It can be very useful in doing a quick assessment and identifying the regions where there might be a relatively higher corrosion activity. It remains that the corrosion potential technique's output is qualitative as it provides information only on the chance of corrosion activity, not quantitative information such as the rate at which the rebar is corroding. This practical is able to define probability of corrosion which can be beneficial in deciding the type of repair or remedial measure.

II Relevant Program Outcomes:

PO 1. Basic knowledge: *An ability to apply knowledge of basic mathematics, science and engineering to solve the engineering problems.*

PO 2. Discipline knowledge*: An ability to apply discipline- specific knowledge to solve core and/or applied engineering problems.*

PO 3. Experiments and practice: *An ability to plan and perform experiments and practices and to use the results to solve engineering problems.*

Po 4. Engineering tools: *Apply relevant civil technologies and tools with an understanding of the limitations.*

PO 8. Individual and Team Work: *Function effectively as leader and team member in Diverse /multidisciplinary team.*

III Relevant Course Outcomes:

a. Select the relevant method of maintaining different building structures.
b. Test the structures to predict its stability.

IV Practical Outcome:

Determine the moisture content using Moisture Meter of any two structural elements such as column, beam, slab etc. for damaged/undamaged structure.

V Competency and Practical Skills:

This practical is expected to develop the following skills for the industry identified competency. ***"Maintain different types of building structures."***

1. Handling of instruments.
2. Predictability skill by test analysis.

VI Relevant Affective domain related:

a. Follow safety practices.
b. Practice good housekeeping.
c. Demonstrate working as a leader/a team member.
d. Maintain tools and equipment.
e. Follow ethical Practices.

VII Minimum Theoretical Background:

In reinforced concrete structures, there is a natural protective film that forms on the surface and prevents the bar from corroding. With time, chlorides (from de-icing salts or marine exposure) and/or CO2 penetrate the concrete and breakdown that protective layer. Chlorides destabilize the passive film leading to its localized breakdown, while CO2 lowers the pH of the concrete below the level of stability of passive film. In the presence of oxygen and water, an electrochemical reaction initiates the process of corrosion. Corrosion can be illustrated as shown in Figure 1, where the metal (rebar) reacts in the solution (available in the concrete pores) and gives away electrons from the anode (where oxidization occurs) to the cathode (where reduction occurs). The positive ions formed at the surface of the anode will react and create corrosion by-products. This electrochemical reaction creates a potential difference, and consequently a corrosion current, between the anodic and cathodic areas at the surface of the steel reinforcement. This current, or the potential distribution on the reinforcement surface, is what is of interest when measuring half-cell potential.

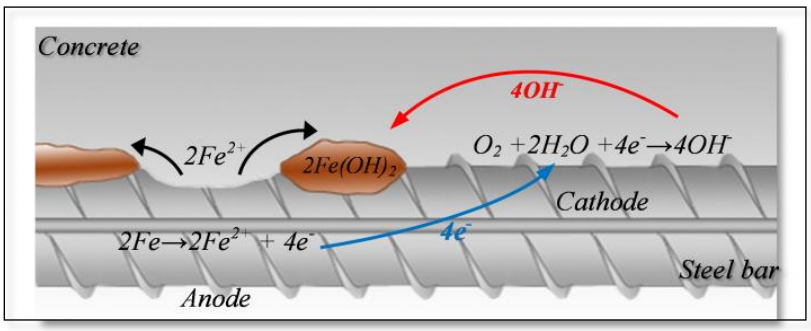

Figure 1: Reinforced concrete corrosion reaction

Relationship between the potential values and corrosion probability as below.

Measured Potential (mV CSE)	Probability of steel corrosion activity
mV>-200	Less than 10%
mV-200 to -350	50% (Uncertain)
mV>-350	More than 90%

Typical ranges of half-cell potentials of rebar in concrete

Conditions	Potential values (mV/CSE*)
Humid, chloride free concrete	-200 to +100
Chloride contaminated wet concrete	-600 to -400
Water saturated concrete without oxygen	-1000 to -900
Humid carbonated concrete	-400 to +100
Dry, carbonated concrete	0 to +200
Dry concrete	0 to +200

VIII Experimental Set-up:

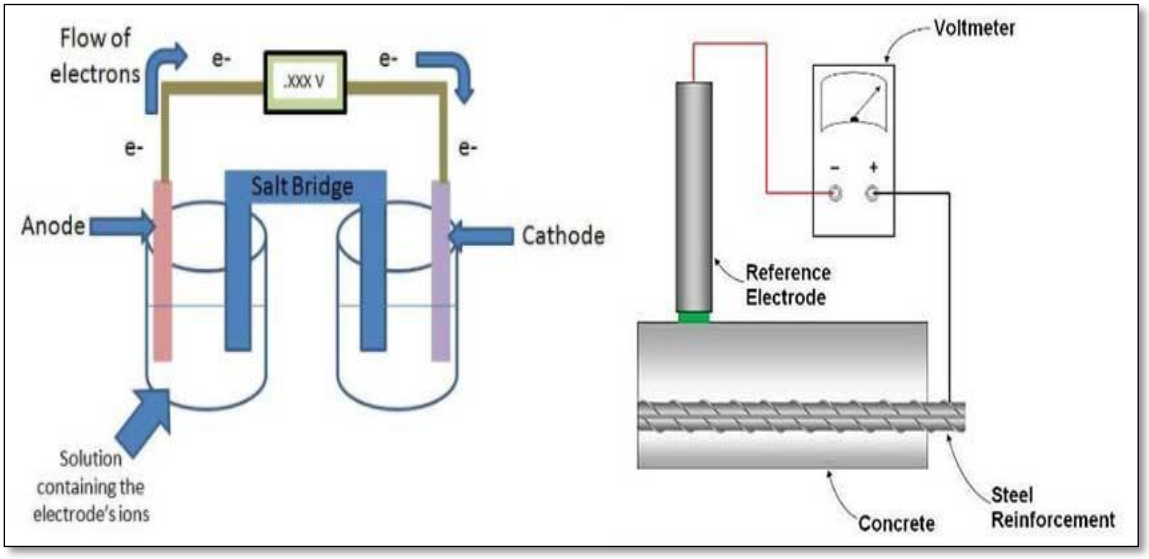

Figure 2: Measurement process of Half-Cell Potentiometer

IX Resources required:

Sr. No.	Particulars	Specification		Quantity	Remark
01	Half-cell potentiometer.	Brand:	Avantech.	1No.	Per batch
		Voltage:	220 V		
		Power Source:	Electric		
		Frequency:	50 Hz		
02	Rebar corrosion tester or Locate manually	Bosch Rebar Locator, D-Tech 150.		1No.	Per batch
03	Measuring scale	15 cm or 30 cm.		1No.	Per batch

X Procedure:

1. Identify rebar location.
2. Make a connection with the reinforcement (more than one connection can be required if there is a discontinuity between reinforcements).
3. Prepare concrete surface through wetting.
4. Measure the potential difference at regular intervals on different points along the length of the bar.
5. Divide the batch in to four groups and measure the potential difference at regular intervals on different points along the length of one bar.
6. Draw the graph of potential v/s location for each group.
7. The graph itself gives the idea of corrosion and its location also.

XI Precautions to be followed:

1. Measurements must be quick as potential values only take a few seconds to stabilize before the next measurement can be taken.

2. The effect of concrete condition (dry or wet), presence of chloride, absence of oxygen at the rebar surface (due to saturation), cover thickness, concrete resistivity, and temperature are all factors that can influence the results by shifting their potential reading towards a more positive or negative value .

XII Actual procedure followed: *(Use blank sheet if provided space is not sufficient).*

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XIII Resources used:

	Name of Resource	Broad Specifications		Quantity	Remark
		Make	Details		
1					
2					
3					
4					

XIV Precautions followed:

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XV Observations:

Sr. No.	Distance from origin	Half-cell potential (mv)	Grade range (mv)	Probability of corrosion

Sample Calculation:

For different locations from origin point, evaluate the range of corrosion and find the location of corrosion.

XVI Results:

1. The corrosion at ……. distance from origin is …….

XVII Interpretation of results: *(Give meaning of the above obtained results).*

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XVIII Conclusions and Recommendations:

(Actions/decisions to be taken based on the interpretation of results).

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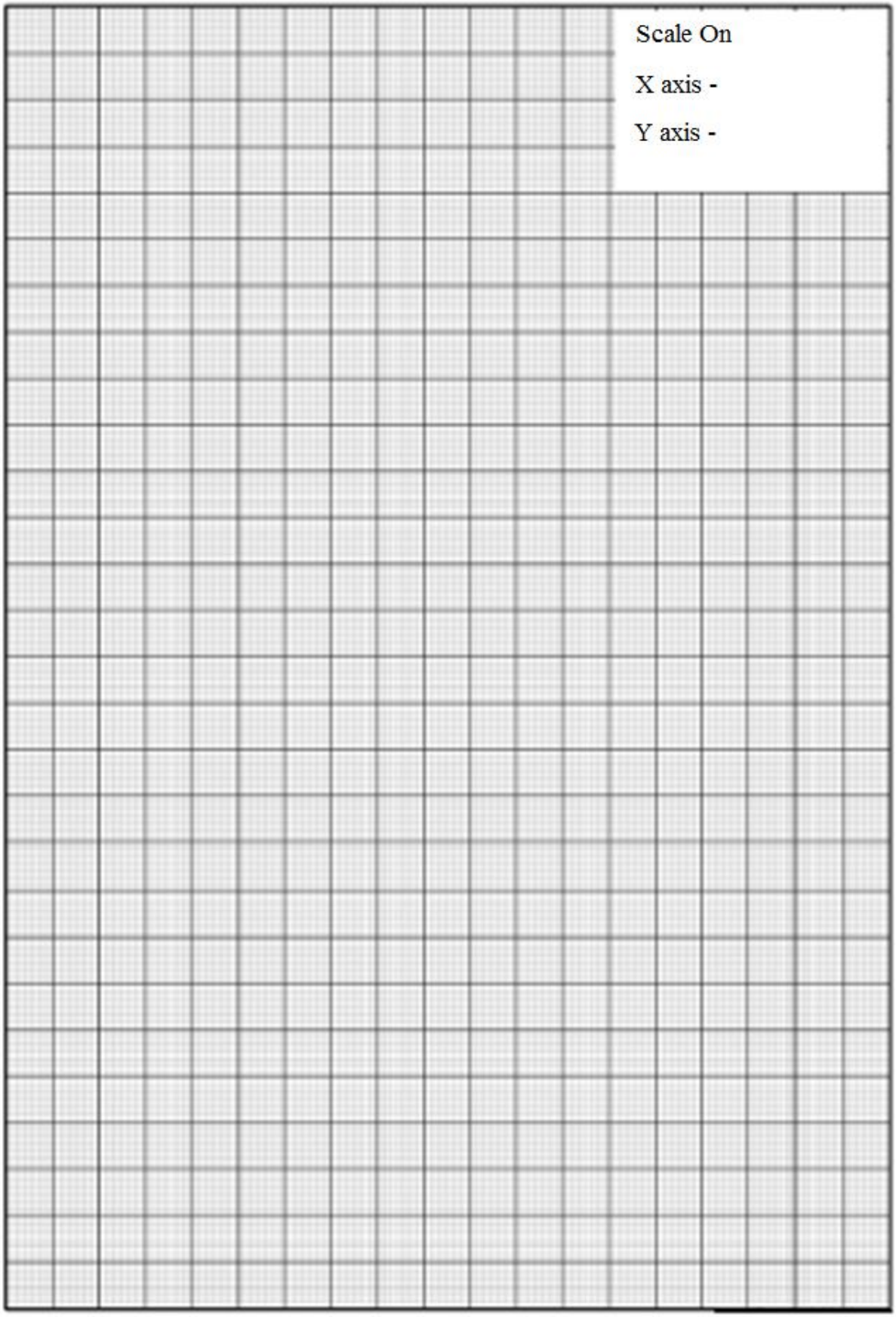
XIX Practical Related Questions:

Note*: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions.*

1. Illustrate the corrosion process of reinforcing bar.
2. State the surface condition of slab which affects the working of half-cell potential.
3. How the depth of section affects the half-cell potential.
4. How to locate the discontinuity of a bar using the potentiometer.
5. State two advantages of Rebar corrosion locator apparatus.
6. Comment on Nature of graph between potential and location.
7. State a reason, why it is necessary to prepare the wet surface before the start of test.
8. State three disadvantages of corrosion of reinforcement.
9. Can we identify the rupture of protective anticorrosive paint in case of reinforcement using potentiometer?

(Note: Each batch should attempt three questions and not to be repeated the same questions by other batches)

Space to Write Answers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4.	Concrete Technology-Theory and Practice.	M. S. Shetty	S. Chand & Co. Pvt. Ltd., New Delhi, 2016, ISBN: 978-81-219-0003-4.

XXI Suggested Assessment Scheme:

Performance Indicators		Weightage (%)
Process related:15 Marks		**60%**
1	Measurement of voltage	30 %
2	Recording of observations	30 %
Product related:10 Marks		**40%**
3	Calculations of result	10%
4	Answers to practical related questions.	20%
5	Submission of report in time.	10%
Total: 25 Marks		**100%**

List of Student Team Members (Roll No.)

1. ……
2. ……
3. ……
4. ……
5. ……

Marks Obtained			Dated sign of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 13: Compressive Strength of Extracted Core

I Practical Significance:

To ascertain the quality of concrete at site without disturbing its properties then it is essential to extract core from existing RCC construction. Further, required test can be performed in order to know functioning status of concrete. The examination and compression testing of cores cut from hardened concrete is a well–established method, enabling visual inspection of the interior regions of a member to be coupled with strength estimation. This practical is able to determine compressive strength by extracting into concrete core.

II Relevant Program Outcomes:

PO 1. Basic knowledge: *An ability to apply knowledge of basic mathematics, science and engineering to solve the engineering problems.*

PO 2. Discipline knowledge*: An ability to apply discipline- specific knowledge to solve core and/or applied engineering problems.*

PO 3. Experiments and practice: *An ability to plan and perform experiments and practices and to use the results to solve engineering problems.*

PO 4. Engineering tools: *Apply relevant civil technologies and tools with an understanding of the limitations.*

PO 8. Individual and Team Work: *Function effectively as leader and team member in Diverse /multidisciplinary team.*

III Relevant Course Outcomes:

a. Select the relevant method of maintaining different building structures.
b. Test the structures to predict its stability.
d. Apply the relevant methods of repair for the masonry structures.

IV Practical Outcome:

Determine the compressive strength of extractor core using Compression Testing Machine of any one structural element such as column, beam, slab etc. for damaged or undamaged structure.

V Competency and Practical Skills:

This practical is expected to develop the following skills for the industry identified competency. ***"Maintain different types of building structures."***

1. Handling of instruments and extraction of core.
2. Correlate the compressive strength to the safety of given building components.

VI Relevant Affective domain related:

a. Follow safety practices.
b. Practice good housekeeping.
c. Demonstrate working as a leader/a team member.
d. Maintain tools and equipment.
e. Follow ethical Practices.

VII Minimum Theoretical Background:

IS: 456-2000 specified that the points from which cores are to be taken and numbers of cores required are at the discretion of engineer-in-charge and shall be representative of

the whole concrete concerned. In no case, however, shall fewer than three cores be tested. Core shall be prepared and tested as described in IS: 516.Concrete in the member represented by a core test shall be considered acceptable, if the average equivalent cube strength of the cores is equal to at least 85 percent of the cube strength of concrete grade specified for the corresponding age and no individual core has strength less than 75 percent. In case the core test results do not satisfy these requirements, or where such tests have not been done, load test may be resorted to.

The Core strength can be determined as

$$\text{Core strength} = \frac{Ultimate \quad Load}{Core \quad cross \quad \text{sec} \; tion \quad area}$$

The core strength is to be corrected as per the dimensions of the core cylinder as follows.

Core Strength Correction factor:-

L/D Ratio	As per IS: 516
2.00	1.00
1.75	0.97
1.50	0.95
1.25	0.92
1.00	0.89

VIII Experimental Set-up:

(a) Core extractor **(b) Compression test on core**

Figure 1:- Extracted core compression test.

IX Resources required:

Sr. No.	Particulars	Specification	Quantity	Remark
1	Concrete core cutter	Suitable to Cut / Drill cores of concrete, rocks, stones. The machine is suitable for core samples of size up to 150 mm diameters (with the help of thin walled Diamond Bits). The machine may have sturdy base with pillar support in which rack and pinion is provided for	1No.	Per batch

		adjustment in height and penetration assembly. The leveling screws are provided at the base. For gripping, the sample kept in position with suitable grips. A suitable electric motor is fitted in the machine with cooling arrangement of water. The base frame may fit with wheels for ease of transportation. **Suitably with following dimensions.** Height : 1300 mm Base : 600 x 1200 mm, Head travel on rack : 350 mm, Drill Speeds : 900 RPM for hard samples and 350 rpm for soft samples Water Swivel: Built in the machines. Suitable for 230 volts AC, single phase.		
2	Compression testing machine.	Compression testing machine of 2000KN capacity.	1No.	-----
3	Measuring scale.	15 or 30 cm in length.	1 No.	Per batch
4	Weighing balance.	With accuracy 0.01 gm.	1 No.	Per batch
5	Grinder	--	1 No.	Per batch

X Procedure:

1. **Core drilling**: A core is usually cut by means of a rotary cutting tool with diamond bits. The concrete core drilling machine is portable, but it is heavy and must be firmly supported and braced against the concrete to prevent relative movement which will result in a distorted or broken core, and a water supply is also necessary to lubricate the cutter. Hand-held equipment is available for cores up to 75 mm diameter. The ratio of diameter to the maximum aggregate size shall be not less than 3.

2. **Capping:** unless their ends are prepared by grinding, cores should be capped with high alumina cement mortar or sulfur-sand mixture to provide parallel end surfaces normal to the axis of the core. Caps should be kept as thin as possible preferably 1.5 to 3 mm, but if the core is hand trimmed then they may be up to about the maximum aggregate size at the thickest point. The capping material must be no weaker than the concrete in specimen.

3. **Measurement of Core:** Before testing, measure the average length of capped or ground specimen and use this length to compute L/D ratio. Determine the average diameter by averaging two measurements taken at right angles to each other at the mid-height of specimen.

4. **Testing of Core:** The core shall be placed in water at a temperature 24^{o} to 30^{o}C for 48 hours before testing. Centre the core carefully on the lower platen of the machine without shock apply and increase the load continuously at constant rate within range of 0.2 N/(mm^2/s) to 0.4N/(mm^2/s) until no greater load can be sustained. Note any unusual failures and appearance of the concrete. Calculate the compressive strength of each core by dividing the maximum load with cross-sectional area, calculated from the average diameter. Express the results to the nearest 0.5 N/mm^2.

5. One core for each batch is tested separately and the observation table is to be completed for the class by using observations of each batch instead of taking three cores for each batch.

XI Precautions to be followed:

1. Core should be taken to avoid reinforcements therefore cover meter can be used to locate the bars. It is usual to find rebar in the core samples. These are usually on one or the other side. The part of the core beyond rebar is cut off and only the concrete portion is taken for the test.
2. It is preferred the concrete should have 28 days old for drilling cores.

XII Actual procedure followed: *(Use blank sheet if provided space is not sufficient).*

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XIII Resources used:

Sr. No.	Name of Resource	Broad Specifications		Quantity	Remark
		Make	Details		
1					
2					
3					
4					

XIV Precautions followed:

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.....
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XV Observations:

1. Location = ……
2. Nominal maximum size of coarse aggregate =……
3. Type and grade of cement =……
4. Grade of concrete =……
5. Date of casting of structural member =……
6. Date of core drilling =……
7. Date of core testing =……

Table 1:-

Sr. No.	Id core	Core dia. (mm)	Core length after grinding (mm)	Core length after capping (mm)	Weight (N)	Density (N/m^3)	L/D Ratio
1.							
2.							
3.							

Table 2:-

Sr. No.	Core area (mm^2)	Ultimate Load (kN)	Core strength (N/mm^2)	Correction factor	Corrected core strength (N/mm^2)	Equ. Cube strength = Core Strength x 1.25 (N/mm^2)	Remarks
1.							
2.							
3.							

Sample Calculation:

For observation no. …….

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XVI Results:

1. The Core strength of sample No.1 = ……N/mm^2
2. The Core strength of sample No.2 = ……N/mm^2
3. The Core strength of sample No.3 = ……N/mm^2

XVII Interpretation of results: *(Give meaning of the above obtained results).*

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XVIII Conclusions and Recommendations:

(Actions/decisions to be taken based on the interpretation of results).

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XIX Practical Related Questions:

Note*: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions.*

1. If reinforcement is present in the core write the corrections to be applied for crushing strength.
2. State three other properties which can be determined by direct and indirect visual observations of the core.
3. State the relation between the compressive strength of cube of concrete and compressive strength of core of concrete.
4. Explain the effect of Shape, Size, Direction of Coring Placing of Concrete, H/D Ratio affects the core strength.
5. State the significance of extracting core.
6. State the name of machine used by you for extracting core along with its cost and supplier.
7. List four precautions to be observed while taking core of concrete.
8. State minimum two effects if the core having uneven surface is tested.
9. If the L/D ratio of core is greater than 12. Comment on the probable result of the test.

(Note: Each batch should attempt three questions and not to be repeated the same questions by other batches)

Space to Write Answers

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XX References / Suggestions for further Reading:

Sr. No.	Title of Book	Author	Publication
1.	Building Repair and Maintenance Management.	P.S.Gahlot, Sanjay Sharma	CBS Publishers & Distributors Pvt. Ltd., New Delhi, 2016 ISBN: 81-239-1243-9.
2.	Maintenance and Repair of Buildings.	P.K.Guha	New Central Book Agency (P) Ltd., New Delhi, 2011, ISBN: 81-7381-073-7.
3.	Concrete Technology-Theory and Practice.	M.S.Shetty	S. Chand & Co. Pvt. Ltd., New Delhi, 2016, ISBN:978-81-219-0003-4.
4.	IS 516 1959.	BIS	BIS

XXI Suggested Assessment Scheme:

Performance Indicators		Weightage (%)
Process related:15 Marks		**60%**
1	Measurement of voltage.	30 %
2	Sampling & Testing the core.	30 %
Product related:10 Marks		**40%**
3	Calculations & analysis of test results.	10%
4	Answers to practical related questions.	20%
5	Submission of report in time.	10%
Total: 25 Marks		**100%**

List of Student Team Members (Roll No.)

1. ……
2. ……
3. ……
4. …….
5. …….

Marks Obtained			Dated sign of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 14: Check List of Material Requirements and Repair Methods of Wall Cracks

I Practical Significance:

Repair of cracks are one of the common problems in building in particular wall which requires high degree of skill. If the cracking is primarily due to drying shrinkage, then it is likely to stabilize. However if the cracks are due to other structural changes then they will continue to grow, hence it is need to apply appropriate repair methods. Further, it is also have equal importance to prepare the materials which is to be planned by preparing check list in a systematic way.

II Relevant Program Outcomes:

PO 1. Basic knowledge: *An ability to apply knowledge of basic mathematics, science and engineering to solve the engineering problems.*

PO 2. Discipline knowledge*: An ability to apply discipline- specific knowledge to solve core and/or applied engineering problems.*

PO 3. Experiments and practice: *An ability to plan and perform experiments and practices and to use the results to solve engineering problems.*

PO 8. Individual and Team Work: *Function effectively as leader and team member in Diverse/multidisciplinary team.*

III Relevant Course Outcomes:

C. Select the relevant materials for repair of structures.

d. Apply the relevant methods of repair for the masonry structures.

IV Practical Outcome:

Prepare a list of material requirements and check list for repair of wall cracks as per the damages found.

V Competency and Practical Skills:

This practical is expected to develop the following skills for the industry identified competency. ***"Maintain different types of building structures."***

1. Select appropriate repair material according to the type of crack.
2. Apply suitable repair method as per the type of crack.

VI Relevant Affective domain related:

a. Follow safety practices.

b. Demonstrate working as a leader/a team member.

c. Maintain tools and equipment.

VII Minimum Theoretical Background:

Cracks in walls are signs of distress in structural or nonstructural members caused by separation of joints, development of fissures, shearing, member separation, built with different materials in masonry building in the form of wide, medium, narrow or hairline etc. Cracks may be at different nature such as vertical, horizontal or inclined and having probable locations separation at roof level just below the roof at the junction, in parapet, at

corners of openings, junctions of RCC columns and masonry wall, at the outlet of waste water pipes, over arch openings etc.

A) Examples of Probable cracks

Type1. Horizontal Crack at the Junction of Roof Slab and Masonry Wall Support:

1) Provision of L-beam with nominal reinforcement, integrated with the slab would provide rigidity against deflection.

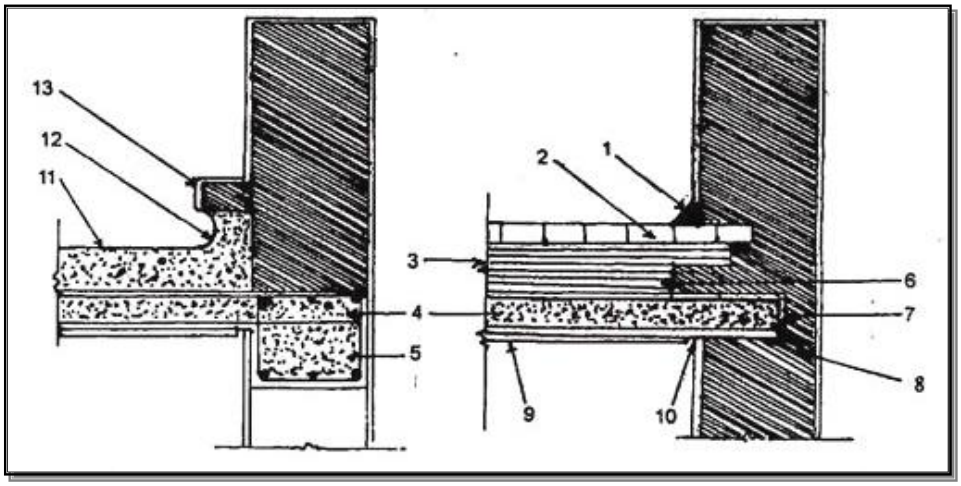


Figure 1: Horizontal crack at the junction of roof slab and masonry wall support

1. Concrete fillet, 2. One course of brick tiles chased into parapet, 3. Protective cover, 4. R.C.C. slab, 5. L-beam, 6. First course of masonry is thicker than the wall by ½ brick, 7. 12mm gap between slab and masonry, ¾ filled with mastic compound, 8. Slip joint at support of R.C.C. slab, 9. Celing plaster, 10. 12mm wide groove in plaster, 11. Lime terracing minimum 100mm thick, 12. Cove (ghoondi), 13.Brickwork projection as cover over cove.

2) In case of framed structure roof slab, beams, and columns move jointly, causing diagonal cracks in walls which are generally parallel to the movement and horizontal cracks are located below the beams. Extent of movement in a framed structure is comparatively less as columns on account of their stiffness and ability to withstand bending stresses is able to resist and contain the movement to some extent. Both in load-bearing and framed structures, provision of adequate or protective cover on the roof are very important in order to avoid cracks in walls.

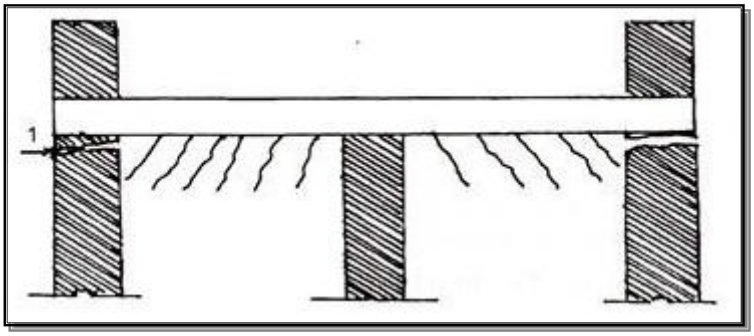


Figure 2: Crack in non-load bearing wall
1. Crack

Type2. Vertical Cracks at Junction of R.C.C. Column and Wall Masonry:
The cracks occur a few months after construction not only due to differential strain between R.C.C. and masonry but also due to elastic deformation, shrinkage and creep in R.C.C. column acted upon. As a preventive measure butterfly ties may be provided at the junctions.

Type3. Extension of existing Building:

When extension of existing building is desired, new construction should not be bonded with the old. Two parts should be separated by a step or expansion joint right from the foundation to top. Care should be taken while excavating below the foundation of existing building. When the existing structure is 20 – 25 m long, the old and new work should be separated by an expansion joint with a gap of about 25 to 40 mm to allow room for unhindered expansion or impact of the two portions.

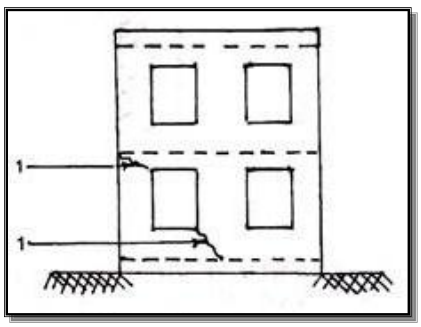


Figure 3: Crack at the corner of building due to foundation settlement.
1. Crack

In case of extension of framed structure, twin columns should be provided with combined footing. Combined footing shall be provided during original construction

Type 4. Cracking of Compound Wall:
Plants take root and begin to grow in fissures of walls. When soil under the foundation of a building happens to be shrinkable clay, cracking in walls and floors of the building may occur. This happens due to dehydrating action of growing roots on the soil which may shrink and cause foundation settlement or due to upward thrust on

portion of the building. When old trees are cut off the soil that has been dehydrated by roots, swell up getting moisture from some source, such as rain. This may cause crack in the foundation. The cracks are wider at top and narrower downward. The cracks pass through DPC and extend up to foundation.

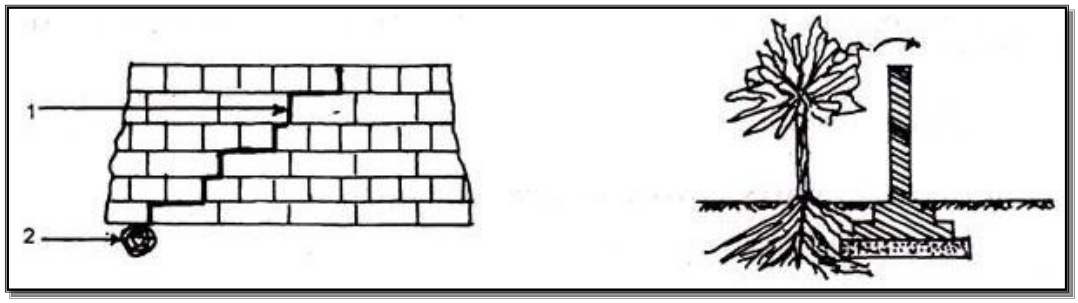


Figure 4: Cracking of compound wall due to growing roots under the foundation.

1. Crack, 2. Root

Type 5. Horizontal Cracks in the Topmost Story:

Horizontal cracks in the topmost story of building at corner cause up-liftment of the slab corners due to deflection of slab in both directions. As a preventive measure, proper corner reinforcement in two layers should be provided to resist lifting of the corners.

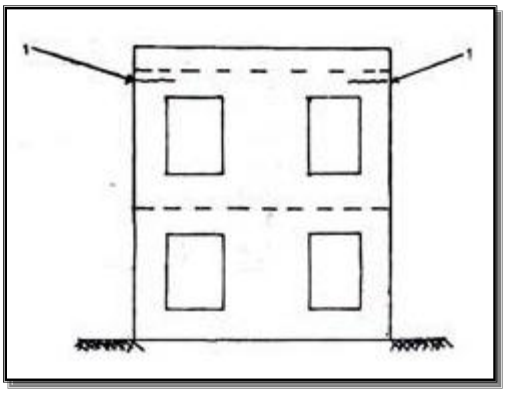


Figure 5: Horizontal cracks in topmost storey.

1. Crack

Type 6. Cracks in external and internal walls of load-bearing structures:

i. Vertical cracks in walls built with concrete blocks or sand lime bricks. Cracks generally occur at weak sections, i.e., at midpoints or at regular intervals in long stretches. The cracks may be straight or toothed.

ii. Vertical cracks at the junctions of an old portion of building and new extension. The cracks should be repaired by filling with weak mortar when they are dormant or by providing a vertical groove in the plaster at the junction.

iii. Horizontal cracks in mortar joints appearing two to three years after construction. These are generally due to sulphate attack.

iv. Ripping cracks occurring at the ceiling level in cross walls as shown in Fig. 3.9. The cracks are due to relative movement between R.C.C. roof slab and cross wall. Movement of R.C.C. roof slab is caused due to thermal expansion and contraction because of inadequate thermal insulation or protective cover on the roof slab.

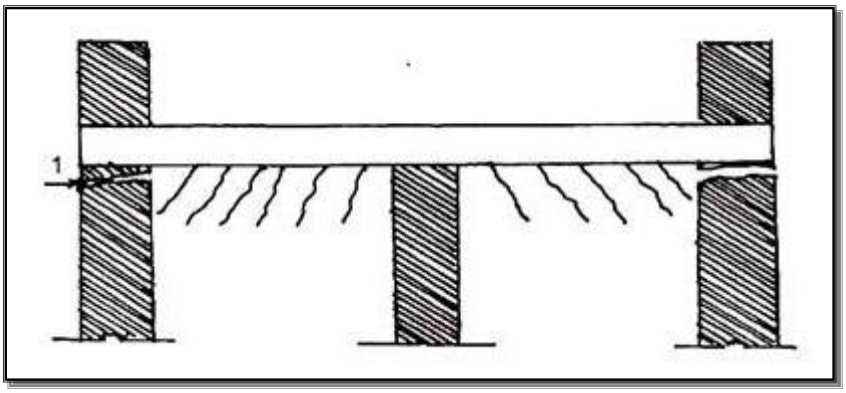


Figure 6: Crack in non-load bearing wall.

1. Crack

v. Diagonal cracks accompanied by outward tilting of external walls. Internal walls undergo random cracking and floors crack up and become uneven. The cracks develop due to moisture movement of shrinkable soil such as black cotton soil, when the foundation is shallow.

vi. Diagonal cracks over R.C.C. lintels spanning large openings. The cracks are due to drying shrinkage of concrete.
The cracks could be avoided by using low-shrink- able and low slump concrete.

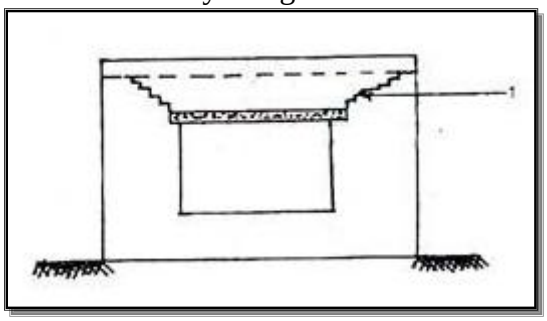


Figure 7: Diagonal cracks over R.C.C. lintel.

1. Crack

Type 7. Random Cracks in All Directions Involving both External and Internal Walls:

These cracks are generally formed either due to foundation settlement or sulphate action in the foundation concrete and masonry in foundation and plinth. The cracks may be thin, medium or wide.

Type 8. Partition Walls in Load-Bearing Structures:

i. Partition walls supported on R.C.C. slab or beam. Cracks may occur due to excessive deflection of support. As a preventive measure horizontal expansion joint 10 mm on top of the wall need be provided.

ii. Partition walls built of concrete blocks or sand lime bricks.
The cracks generally occur due to drying shrinkage of masonry units.
If the masonry is built with concrete blocks, the concrete blocks should be of dense and light weight concrete. In case of bricks, those should be well-burnt. Strong mortars should not be used in joining and plastering.

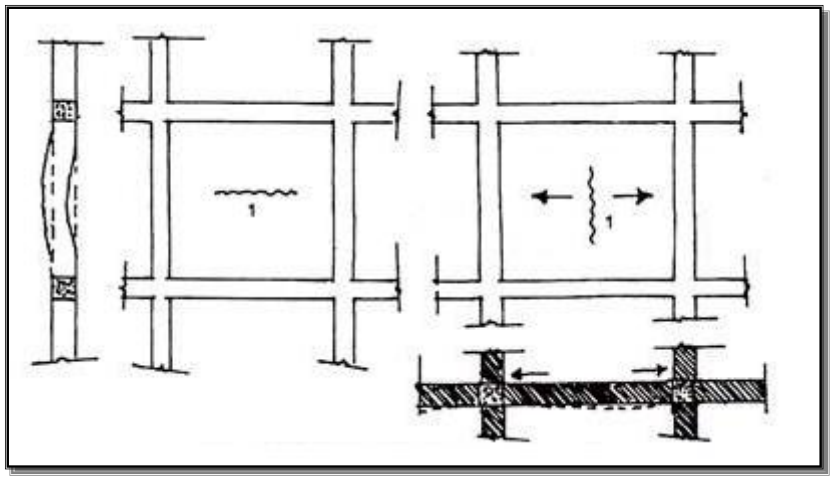


Figure 8: Horizontal cracks in panel-walls.

1. Crack

Horizontal cracks in panel-walls of R.C.C. framed structures occur, if the panels are built too tightly between the beams of the frame.

B) Common repair materials

Following are the some of common repair materials used for repair or rehabilitation or strengthening of the concrete structures

1. Unmodified Portland Cement Mortar or Grout:

Portland cement mortar or grout is the most common repair materials used for repairing damages to concrete structures. It is selected because it is readily available and has a low cost. This material consists of ordinary Portland cement and suitable aggregate. Cement mortar is generally used for small repair works and cement concrete are commonly selected where a large area is to be repaired.

2. Latex Modified Portland Cement Mortar or Concrete

This repair material is used to prevent chloride attack on concrete structures due to the use of low water-cement ratio. This is the same as ordinary Portland cement mortar or grout with the addition of a latex emulsion. The strength of this material is same as ordinary mortar or grout. Ingress can be reduced due to lower water-cement ratio. The addition of latex modifier influences the strength and durability of cement. The use of this material should be based on the service conditions of the structure. Latex modifier concrete recommended for sections up to 30mm deep, should have 1:3-3.5 as the ratio of cement and fine aggregates. Water ratio should be 0.3 with latex solid cement ratio of 0.1 to 0.2 by weight. Latex modifier concrete recommended for sections deeper than 30mm should have proportions of 1 part of cement to 2.5-3 parts fine aggregate to 1.5-2 parts coarse aggregate.

3. Quick Setting Non-shrink Mortar

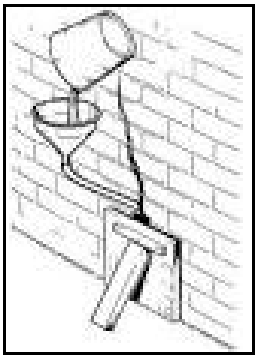
Cracks on concrete surface due to shrinkage of concrete are repaired by this material. It develops a good bond with old concrete. The use of suitable admixtures combined with this repair material also increases strength and improve bond and workability while reducing curing time. Polymer Concrete Most popular polymer concrete used is an epoxy concrete system with curing agents or methyl methacrylate monomer with an inhibitor and promoter. Epoxy system is widely available in formulated repairing materials. This repair material can be customized as per the requirement for use in repair of different types of concrete damages.

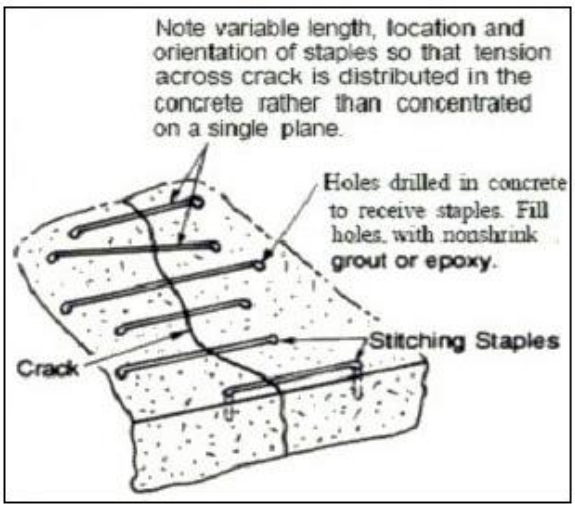
C) Common repair methods are tabulated as below.

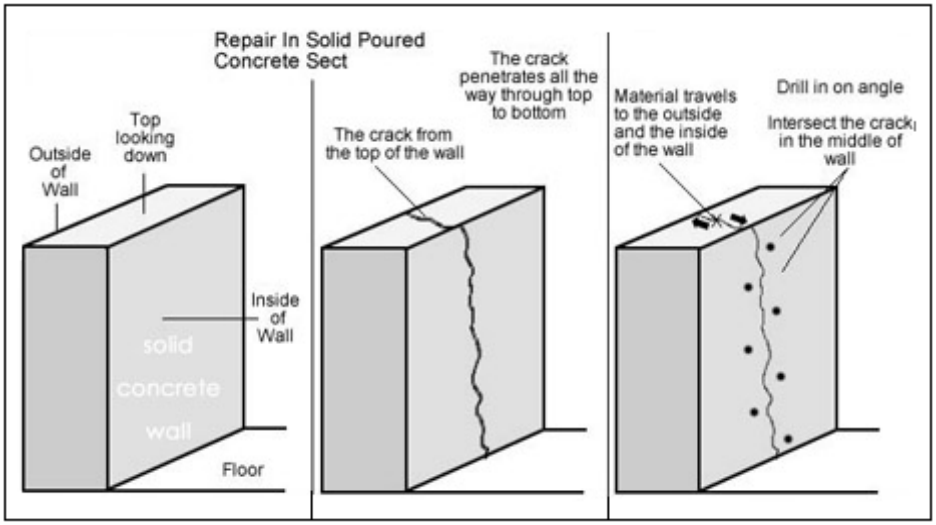
Sr. No.	Method	Applicability	Observations
1	Raking and Re-pointing.	Usually applied to cracks localized in the mortar joints. Effective for cosmetic reasons only. Requires a skilled bricklayer and correct specification of a compatible mortar	Difficulty to completely fill the joint. Long term shrinkage of fresh mortar can cause cracking to re-appear at the same interface. The use of a polymer modified cement mortar can allow better penetration and bonding characteristics. Special care should be taken with facing brick masonry, in order to preserve aesthetics.
2	Re-Construction of Selected Areas	Usually applied to restore structural integrity, including demolition and re-building of the damaged area. Also requires skilled tradesmen and the correct specification of materials.	Difficult to guarantee bond between new and old masonry unless a control joint is provided. The use of a new reinforced coating, when possible, is recommendable.
3	Resin injection	Usually applied to cracks in masonry units and to mortar joints. Requires specialized equipment and personnel.	Epoxy infection, despite the extra cost compared with conventional methods, provides mostly full penetration and effective bond. The resin must have compatible stiffness to the repaired material, to avoid local stress concentrations under future movements. Exposed resin must be resilient.
4	Insertion of mild steel U shaped dowels	Stitching of brickwork along the sides of crack.	M.S. U shaped hooks /dowels are made of m. s. bars of diameter. Chase holes and drills are made for insertion of the

			dowels with legs inside ensuring that the top of the U is at least 20mm below the brick surface. The chase is then filled with cement concert in the ratio 1:1.5:3 with 6mm down stone chips. The surface is then plastered.

VIII Experimental Set-up: (Few experimental repair methods)







IX Resources required:

Sr. No.	Particulars	Specification	Quantity	Remark
1	Microscope	Highly précised capable of magnifying crack width	01	Per batch
2	Measuring scale	15 or 30 cm in length	1 No.	Per batch
3	Cleaning brush	Cleaning surface of the crack.	1No.	Per batch

X Procedure:

1. Identify the type and nature of defects in wall cracks.
2. Clean crack surface by brush properly.
3. Measure the crack width and depth with the help of microscope or available magnifying device.
4. Suggest suitable materials and prepare the check list based on extent of cracks.
5. Suggest suitable method for repair and prepare the check list.

XI Precautions to be followed:

1. Select appropriate crack location and classify it as structural or non-structural, live or dormant crack accurately.
2. Ensure the complete cleaning of crack surface.

XII Actual procedure followed: *(Use blank sheet if provided space is not sufficient).*

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XIII Resources used:

Sr. No.	Name of Resource	Broad Specifications		Quantity	Remark
		Make	Details		
1					
2					
3					
4					

XIV Precautions followed:

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XV Observations: preparation of check list for material requirement.

Sr. No.	Crack location	Crack nature	Material required	Repair method
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3				
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5				

XVI Results:

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XVII Interpretation of results: *(Give meaning of the above obtained results).*

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XVIII Conclusions and Recommendations:

(Actions/decisions to be taken based on the interpretation of results).

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XIX Practical Related Questions:

***Note**: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions. Each batch should write any three following questions separately.*

1. Illustrate with sketches the structural and non-structural cracks
2. Illustrate with sketches the live and dormant cracks.
3. State any two differentiation points between surface and structural cracks.
4. Write any four influencing factors while material selection.
5. Explain importance of repair materials with original construction.
6. State any three important characteristics of repair materials.
7. State commercial trade names of following repair materials.
   a. Rebar primer, b. Epoxy based adhesive, c. Shot-Crete admixture,
   d. Protective coatings, e. Curing compounds.
8. Write any five groups repair materials those are broadly categorized.
9. State any four causes of structural crack formation.

(Note: Each batch should attempt three questions and not to be repeated the same questions by other batches)

Space to Write Answers

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XX References / Suggestions for further Reading:

Sr. No.	Title of Book	Author	Publication
1.	Building Repair and Maintenance Management	P.S.Gahlot, Sanjay Sharma	CBS Publishers & Distributors Pvt. Ltd., New Delhi, 2016 ISBN: 81-239-1243-9
2.	Maintenance and Repair of Buildings	P.K.Guha	New Central Book Agency (P) Ltd., New Delhi, 2011, ISBN: 81-7381-073-7
3.	Building: Structural Audit, Repairs and Restoration	Arun Kelkar	Majestic Publishing House, Thane, 2015 ISBN: 978-93-83678-93-8
4.	Concrete Technology-Theory and Practice	M.S.Shetty	S. Chand & Co. Pvt. Ltd., New Delhi, 2016, ISBN:978-81-219-0003-4

XXI Suggested Assessment Scheme:

Performance Indicators		Weightage (%)
Process related:15 Marks		**60%**
1	Measurement of voltage	30 %
2	Recording of observations	30 %
Product related:10 Marks		**40%**
3	Preparing checklist properly.	10%
4	Answers to practical related questions.	20%
5	Submission of report in time.	10%
Total: 25 Marks		**100%**

List of Student Team Members (Roll No.)

1. ……
2. ……
3. ……
4. ……
5. ……

Marks Obtained			Dated sign of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 15: Damage Assessment Report of Non-residential Structures

I. Practical Significance:

Ensuring the integrity of structures is not only a matter of public safety, but also critical to prevent major damages and extend the lifespan. Visual inspection of non-residential building components is the first action to identify the defects and quantify the extent and severity of defects. Visual inspection is normally conducted on a routine basis at regular interval and defects are marked and recorded. Based on extent of deterioration, an engineer can recommend for additional testing and suggestions. The maintenance plan should be implemented at the very beginning of repair process. A maintenance plan includes both the routine and comprehensive inspections along with exhaustive report. When symptoms of damage mechanism are observed during the routine and comprehensive inspections, an immediate and in-depth or detail inspection (damage inspection) is scheduled in order to further evaluate the source, amount, effect, and future potential of damage mechanism. The significance of damaged report enables to take the decision about the action to be given either re-strengthening or new construction.

II Relevant Program Outcomes:

PO 1. Basic knowledge: *An ability to apply knowledge of basic mathematics, science and engineering to solve the engineering problems.*

PO 2. Discipline knowledge*: An ability to apply discipline- specific knowledge to solve core and/or applied engineering problems.*

PO 8. Individual and Team Work: *Function effectively as leader and team member in Diverse /multidisciplinary team.*

III Relevant Course Outcomes:

c. Select the relevant materials for repair of structures.
d. Apply the relevant methods of repair for the masonry structures.

IV Practical Outcome:

Prepare a report on damage assessment of non-residential structures such as dams, bridges, industrial buildings etc.

V Competency and Practical Skills:

This practical is expected to develop the following skills for the industry identified competency. ***"Maintain different types of building structures"***

1. Enables to assess damages in the non-residential structures.
2. Co-relate the rate of damages and repairs to be undertaken.

VI Relevant Affective domain related:

a. Follow safety practices.
b. Demonstrate working as a leader/a team member.

VII Minimum theoretical Background:

Common defects in bridge structures

Defects in Superstructure: Several deterioration mechanisms can impact the integrity of superstructure part of bridge (mainly bridge decks). Depending on the material used in the construction of the bridge, different deterioration mechanisms can develop over time.

Deterioration of Concrete: the defect that has occurred over a period of time referred as deterioration and different defects can be involved in the deterioration of concrete. The following review provides a brief summary on the most commonly observed defects in the existing structures. Normally, one or number of these defects can be seen in structures; therefore, it is necessary to identify them properly. One needs to understand these different defects properly in order to get more realistic evaluation of the structure.

1. Scaling: Scaling is referred to the loss of the surface portion of concrete (or mortar) as a result of freezing and thawing (OSIM, 2008). It is a physical action that usually leaves the aggregates clearly exposed. Scaling happens when the hydraulic pressure from water freezing within concrete exceeds the tensile strength of concrete. This type of damage i.e. scaling is more common in non-air-entrained concrete, but can also occur in air-entrained concrete in the fully saturated condition.

2. Disintegration: Disintegration is the physical deterioration (such as scaling) or breaking down of concrete into small fragments or particles and it is usually starts in the form of scaling. It may be also caused by de-icing chemicals, sulphates, chlorides or by frost action.

3. Erosion: Erosion is the deterioration of concrete surface as a result of particles in moving water scrubbing the surface and shows an indicator of poor durability of concrete for that specific exposure. When concrete surface is exposed to the water-borne sand and gravel, the surface gets deteriorated by particles scrubbing against the surfaces. Similarly, flowing ice particles can also cause the problem

4. Reinforcement corrosion: Corrosion is the deterioration of steel reinforcement in concrete and may be induced by chloride or carbonation. The corrosion can result in cracking of concrete cover, delamination in concrete decks, etc. When the concentration of chloride ions above the surface of reinforcement reaches the threshold limit (which is the amount required to break down the passive film) then corrosion begins. The volume of resulting material (rust) is 6-7 times, which increases the stress around the rebar leads to fracture and cracking. A crack extends to the surface of concrete over time that is, when we can visually inspect the sign of rust over the surface of concrete.

Figure 1 : Delaminated Surface

5. Delamination: "Delamination is defined as a discontinuity of the surface concrete which is substantially separated but not completely detached from concrete below or above it" (OSIM, 2008). Delamination is often identified by the hollow sound by tapping or chain
dragging of concrete surface. The corrosion of reinforcement and subsequent cracking of cover can cause delamination. When the rebar have small spacing, cracking extends in the plane of reinforcement parallel to the exterior surface of concrete.

6. Spalling: Spalling can be considered an extended process of delamination. In fact, when the delamination continues, the concrete fragments detach from a larger concrete mass. If delamination is not repaired on time, the progress of damages as a result of external loads, corrosion, freezing and thawing can break off the delaminated pieces.

7. Alkali-aggregate reactions: It is the internal cracking of concrete mass as a result of a chemical reaction between alkali in cement and silica in aggregates. The AAR/ASR (Alkali Aggregates Reaction and Alkali Silica Reaction) cracking are very famous for their crack patterns. The alkalis in the cement can react with the active silica in the aggregates to form a swelling gel. When this gel absorbs water, it expands and applies pressure to surrounding environment which makes the concrete crack.

8. Cracking of concrete: A crack is a linear fracture in concrete which extends partly or completely through the member. Cracking of concrete can happen in different stages: It can happen before hardening of concrete and/ or can occur in an old concrete structure.

IX Resources required:

Sr. No.	Particulars	Specification	Quantity	Remark
1	Microscope	Highly précised capable of magnifying crack width	1 No.	Per batch
2	Measuring scale	15 or 30 cm in length	1 No.	Per batch
3	Cleaning brush	Cleaning surface of the crack.	1 No.	Per batch

X Procedure:

1. Visit in group a nearby nonresidential building structure such as culvert, concrete road, bridge, Industrial construction, water tank GSR/ESR, jetty, spillways, KT weir, canal etc.
2. Carry out a visual inspection of identified structure.
3. Record the common damages observed as per the sample format provided in the observations.
4. Suggest suitable method for repair and prepare the check list.
5. Suggest detailed investigation and NDT if any those are essential.

XI Precautions to be followed:

1. While taking observations of damages all safety precautions to be followed on site.
2. Observations should be done in batches and then ampile together with photographs if possible.

XII Actual procedure followed: *(Use blank sheet if provided space is not sufficient).*

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XIII Resources used:

	Name of Resource	Broad Specifications		Quantity	Remark
		Make	Details		
1					
2					
3					
4					

XIV Precautions followed:

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XV Observations:

Follow the format as given below and record the visual observation made during the visit. The format and theoretical background are mentioned herewith for the bridge structure. In Similar, the a group 20 students can visit and collect information and formats for other nonresidential structures such as steel bridge, RCC ESR, industrial shades etc. can be prepared and according to visit of any one of the structure the visual inspection can be done.

Sr. No.	Activities	Description
01	Date of visit	
02	Name of Structure	
03	Year of construction	
04	Damage location	
05	Source of damages	
06	Nature of damages	
07	Rate of damage loss	

08	Observations	
	Aging	
	Construction deficiency	
	Poor maintenance	
	Planning and designing deficiencies	
09	Damage	
	Complete destruction	
	Type of degradation mechanism (Refer table as below)	
	Partly	
	Any other	
10	Repair materials	
11	Liable to repair or obsolete	
12	Past maintenance date	
13	Task force	
14	Repairing techniques	
15	Duration for repair	
16	Approximate expenses for repair	

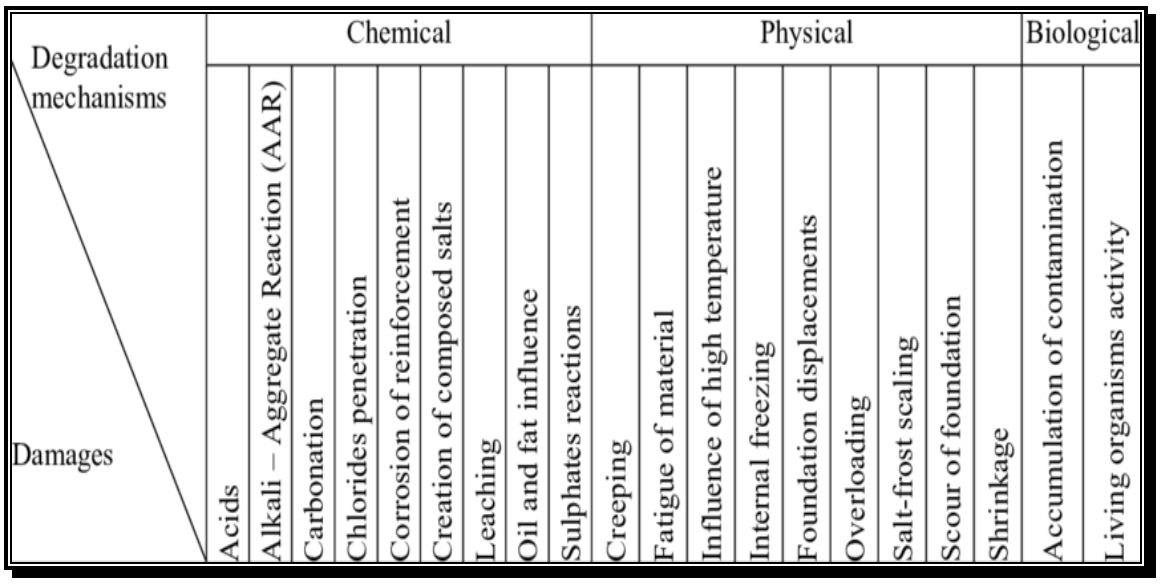

Figure 2 : Degradation Mechanisms

XVI Results: The damages observed during the visit of non-residential building structure are

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XVII Interpretation of results :*(Give meaning of the above obtained results)*

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XVIII Conclusions and Recommendations:

(Actions/decisions to be taken based on the interpretation of results).

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XIX Practical Related Questions:

Note*: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions. Each batch should write any three following questions separately.*

1. State four differences between residential and non-residential structures w.r.t. functional point of view.
2. State four differences between residential and non residential structures w.r.t. loading point of view.
3. State four differences between residential and non residential structures w.r.t. structural point of view.
4. State four differences between residential and non residential structures w.r.t. causes of damages.

5. Justify can we repair the non residential structures with the same methods used for residential structures.
6. Give in brief the agencies which you will come across from identification of repair up to the completion of repair.
7. Comment on effect of hydrostatic pressure in case of repairs of cracks in water tanks.
8. Comment the effect of vibration load while repairing joints in case of bridges.
9. List four commercial trade names of repair materials used for non residential structures.

(Note: Each batch should attempt three questions and not to be repeated the same questions by other batches)

Space to Write Answers

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XX References / Suggestions for further Reading:

Sr. No.	Title of Book	Author	Publication
1	Building Repair and maintenance management	Gahlot, P. S., Sharma, Sanjay	CBS Publishers & Distributors Pvt. Ltd. New Delhi, *ISBN*: 81-239-1243-9
2	Maintenance Engineering for civil Engineers	Nayak B. S.	Khanna Publication, New Delhi ISBN: 978-81-7409-051-7
3	Maintenance and Repairs of Buildings	Guha,P. K.	New Central book Agencies, New Delhi, ISBN 10: 8173810737 ISBN: 9788173810732
4	Maintenance and Repairs of Buildings	Hutchin Son, BD	Newnes-Butterworth, London (UK) ISBN : 0408001917

XXI Suggested Assessment Scheme:

Performance Indicators		Weightage (%)
Process related:15 Marks		**60%**
1	Identification of damages.	30 %
2	Recording of observations	30 %
Product related:10 Marks		**40%**
3	Suggestion of further investigations	10%
4	Suggestions to the repair of damages.	20%
5	Submission of report in time.	10%
Total: 25 Marks		**100%**

List of Student Team Members (Roll No.)

1. ……
2. …….
3. …….
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Marks Obtained			Dated sign of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 16: Check List for Repair and Materials for Flooring Damages

I Practical Significance:

In spite of the concrete finisher's efforts, sometimes the finished product has significant imperfections. Even when carpet lay on a pad or vinyl flooring, the same cannot be expected to cover-up every flaw, so repairing a flooring slab is the builder or homeowner's choice for correcting the problem. Before patching, concrete should be structurally sound and sometimes surface defects give a clue that there is a bigger problem at hand. This practical us able to make checklist of repairing materials for damages in floors.

II Relevant Program Outcomes:

PO 1. Basic knowledge: *An ability to apply knowledge of basic mathematics, science and engineering to solve the engineering problems.*

PO 2. Discipline knowledge*: An ability to apply discipline - specific knowledge to solve core and/or applied engineering problems.*

PO 3. Experiments and practice: *An ability to plan and perform experiments and practices and to use the results to solve engineering problems.*

PO 4. Engineering tools: *Apply relevant civil technologies and tools with an understanding of the limitations.*

PO 8. Individual and Team Work: *Function effectively as leader and team member in Diverse /multidisciplinary team*

III Relevant Course Outcomes:

c. Select the relevant materials for repair of structures.
d. Apply the relevant methods of repair for the masonry structures.

IV Practical Outcome:

Prepare a check list for repair and material requirement for flooring of given structure.

V Competency and Practical Skills:

This practical is expected to develop the following skills for the industry identified competency. ***"Maintain different types of building structures."***

1. Select appropriate repairing materials/tiles as per flooring damages.
2. Apply suitable repair method based on the flooring damages.

VI Relevant Affective domain related:

a. Follow safety practices.
b. Demonstrate working as a leader/a team member.
c. Maintain tools and equipment to good workable.

VII Minimum Theoretical Background:

Flooring may be of various types such as timber flooring, Indian patent stone flooring, terrazzo flooring, mosaic flooring, etc. The method of repair would be different according to the cause of damage and type of flooring system.

Common defects in concrete floors:

The problems such as random cracking, scaling, pop outs and slab settlement can be controlled by good construction. Followings are the different types of floors and their common damages.

Floor and Tile Repairs:

1) **Stone flooring repairs:** Tile and grout sealing could be natural stone sealing or artificial stone sealing to the floors. Tile grout removal, repairs to the cracked grout where the tile has moved over time or adhesive has failed should be done. The adhesive cavity fills, incorrectly fitted tiles be filled with large adhesive voids without removal of the tiles.

2) **Hardwood Floor repairs:** Dustless floor sanding worn and damaged areas of the tiled portion be completely transformed and should look as good as new. Hardwood floor sealing, adding a protective layer often ensures hardwood looking and feeling great. Replacing damaged floor sections ensures a safe area to live in preventing trips and removing sharp edges. Repairing chips and dents in flooring, invisible repairs are possible and avoid further damage to the flooring form water and grit etc.

3) **Veneers and laminate floor repairs:** Chips and dents over the time laminate and veneer floors can become chipped and dented from accidentally dropping items on the flooring and such types of damages can be carried out. The scratches are filled and colored to look like a natural piece of grain; sometimes it is possible to lightly sand repair veneer and laminate surface scratches.

4) **Repairs to ceramic tiles:** Ceramic tiles are brittle and easily damaged and also they are susceptible to heat which damage from the rapid expansion when cold. Further, chipped tiles need to be replaced.

VIII Resources required:

Sr. No.	Particulars	Specification	Quantity	Remark
1	Microscope	Highly précised capable of magnifying crack width	1No.	Per batch
2	Repairing tools	Locally available	1 No.	Per batch
3	Measuring scale	15 or 30 cm in length	1 No.	Per batch
4	Cleaning brush	Cleaning surface of the crack.	1No.	Per batch

IX Procedure:

1. Identify the type of damage you have seen and its nature for the flooring area.
2. Measure the dimensions of damages observed.

3. Find the probable causes of damages with proper discussion.
4. Suggest suitable materials and prepare the check list.
5. Suggest suitable method for repair and prepare the check list.

X Precautions to be followed:

1. Classify the damages as structural or non-structural, live or dormant damages accurately.
2. Keep safely aids and first aid kit while observing sleeper floor.

XI Actual procedure followed: *(Use blank sheet if provided space is not sufficient).*

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XII Resources used:

Sr. No.	Name of Resource	Broad Specifications		Quantity	Remark
		Make	Details		
1					
2					
3					
4					

XIII Precautions followed:

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XIV Observations:

Preparation of check list for damages and materials and method of repairs.

Sr. No.	Type of floor	Damages observed	Probable causes of damages	Material required for repairs	Method of repair
1					
2					

3					
4					
5					

XV Results:

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XVI Interpretation of results: *(Give meaning of the above obtained results).*

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XVII Conclusions and Recommendations:

(Actions/decisions to be taken based on the interpretation of results).

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XVIII Practical Related Questions:

***Note**: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions. Each batch should write any three following questions separately.*

1. Enlist five types of tiles commonly used.
2. Give four precautions to be observed while placing tiles to avoid the damages.
3. State the situations when it is better to replace the tiles as compared to repair.
4. State weather can we replace hard wood flooring by vinyl flooring.
5. State whether we can replace mosaic tiles flooring with wooden flooring or to overlay the mosaic tile flooring with wooden flooring.
6. Suggest two types of flooring to be provided in case of residential buildings, industrial buildings and public buildings.

7. State whether we can replace ceramic tiles flooring with vitrified flooring or to overlay the ceramic tile flooring with vitrified flooring.
8. State any three causes of cracks in industrial flooring.
9. State commercial trade names of any three types of tiles.

(Note: Each batch should attempt three questions and not to be repeated the same questions by other batches)

Space to Write Answers

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XIX References / Suggestions for further Reading:

Sr. No.	Title of Book	Author	Publication
1.	Building Repair and Maintenance Management	P.S.Gahlot, Sanjay Sharma	CBS Publishers & Distributors Pvt. Ltd., New Delhi, 2016 ISBN: 81-239-1243-9
2.	Maintenance and Repair of Buildings	P.K.Guha	New Central Book Agency (P) Ltd., New Delhi, 2011, ISBN: 81-7381-073-7
3.	Building: Structural Audit, Repairs and Restoration	Arun Kelkar	Majestic Publishing House, Thane, 2015 ISBN: 978-93-83678-93-8
4.	Concrete Technology-Theory and Practice	M.S.Shetty	S. Chand & Co. Pvt. Ltd., New Delhi, 2016, ISBN:978-81-219-0003-4

XX Suggested Assessment Scheme:

Performance Indicators		Weightage (%)
Process related:15 Marks		**60%**
1	Measurement of voltage	30 %
2	Recording of observations	30 %
Product related:10 Marks		**40%**
3	Calculations and analysis of result	10%
4	Answers to practical related questions.	20%
5	Submission of report in time.	10%
Total: 25 Marks		**100%**

List of Student Team Members (Roll No.)

1. ……
2. …….
3. …….
4. …….
5. …….

Marks Obtained			Dated sign of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 17: Check List for Materials and Resources for Repair of Sanitary Unit

I Practical Significance:

The history of water supply and sanitation is one of a logistical challenge to provide clean water and sanitation systems since the dawn of civilization. Further, where water resources, infrastructure in particular sanitation systems were not enough then diseases get spread and people fell sick or died prematurely. A very common and regular damage likely to occur in the sanitary unit which does not taken care as result it may complete damage or partly damage that produces unhygienic climate. Maintenance of sanitary unit consists of mainly, removal or prevention of stoppages, cleaning of sewers, pipes and repair works. Maintenance becomes costly when they are laid on flat gradients and tree roots which have been clogged due to deposition of silt, grease and oily materials.

II Relevant Program Outcomes:

PO 1. Basic knowledge: *An ability to apply knowledge of basic mathematics, science and engineering to solve the engineering problems.*

PO 2. Discipline knowledge*: An ability to apply discipline- specific knowledge to solve core and/or applied engineering problems.*

PO 8. Individual and Team Work: *Function effectively as leader and team member in Diverse /multidisciplinary team*

III Relevant Course Outcomes:

c. Select the relevant materials for repair of structures.
d. Apply the relevant methods of repair for the masonry structures.

IV Practical Outcome:

Prepare a list for materials required and resources for repair of sanitary unit of the building.

V Competency and Practical Skills:

This practical is expected to develop the following skills for the industry identified competency. ***"Maintain different types of building structures."***

1. List an appropriate repair materials and resources as per the maintenance of sanitary unit.
2. Apply suitable repair method for maintenance.

VI Relevant Affective domain related:

a. Follow safety practices.

b. Demonstrate working as a leader/a team member.
c. Maintain the tools and equipment's.

VII Minimum Theoretical Background:

Cracks around the sanitary unit reflect the signs of distress in structural or nonstructural members due to separation of joints, pipe leakage, member separation, deficiency in planning and designing, construction deficiency, crack formation etc. Most of the leakages that originate from a toilet are caused by a leak between the toilet and waste pipe because every time your toilet is flushed and water will leak. When comparing a repair to a

replacement, there are clear advantages to bathroom repairs as opposed to having the damage item or unit replaced. Things to consider when making this choice is time, money, how much damage it will do to the environment and is it really necessary to have an item replaced due to a minor amount of damage. Common damages repaired on site include chips, scratches and cracks which are often created by loose falling debris, such as tiles, building materials and hand tools.

Common repairs in sanitary unit:

Bathroom leakage and seepage:

Leak could be caused by a leak in upstairs toilet which is usually a result of some sort of defect in the seal of wax ring that adjoins the bathroom or toilet to the floor. You may not be realized it, but every time when flushed toilet, you did not felt water to penetrate through the bathroom floor but that penetration goes on continue and find the water leakage. A ceiling leak can also be caused by leaks to which substantive material lines that attach to the toilet or to the sink trap. The leak may come from water seeping out at the point where the drain lines join together, or maybe the drainpipes' connector joints are not joined tightly enough. The most common cause of a leaking toilet tank is when the flapper fails to seat properly and form a tight seal against the valve seat then water leak from the tank into the bowl which may be caused by the flapper being out of position. Bathroom repairs are completed relatively quick but time scale depend on rate of damage and volume of the bathroom repairs that need to be made.

Leaking Drains

Commodes, Tubs and Showers drains are connected to the P-traps and these traps can leak. Water can also seep past strainers (JALII) that does not properly connected to the drain and in some cases, there may have small cracks or brakes in the bottom of the fixture itself. When water leaks from any of these sources, it will usually become apparent on the bathroom ceiling or in the room roof. Water does not always originate from the drain but it may also come from loose or crack drain line connections. The most of plumbing leaks originate near plumbing fixtures like bath tubs, shower enclosures, sinks and toilets. It's a good idea to check the seal around your shower from time to time as this is somewhere then undetected leak can lead to a more serious plumbing problem.

Bathroom Surface Repairs

One can repair all amounts to sanitary ware-fixtures that are commonly found in bathrooms, shower rooms and toilets including tiles, toilets, toilet seats, shower trays,

vanity units, bathroom units, sinks and vinyl flooring. Repair and Restore can do by using large amount of fiberglass pod work that are shells which are purposely built to fit bathrooms would get on a ship as are becoming more popular with hotels. These pods are GRP fiberglass based and can damage very easily if a large amount of pressure exerted on to a point, it often shatters the fiberglass material, leaving the glass fibers exposed.

Hand Basin Repairs

Hand basin serves us as a hygienic aid when washed and shaved in daily and may also house various furnishings and cleaning items. Many cracked and chipped hand basins are fully restored to factory condition by our company. All members are fully equipped and

offer an exceptional service when colour matching damaged sinks and creating an invisible repair. Sinks made from various materials often come in a range of designs having with its own feature.

Shower Pan:

Shower Tray Repair, Shower Pan Restoration Service Majority of damaged shower trays are repaired in little time and with relative ease. Restoring the surface of a damaged shower tray can save a vast amount of time and money in comparison to a replacement. This becomes clear when factoring in the cost not only a new pan but also the cost of labour involved in the replacement process. The other shower tray repairs also include full shower tray resurfacing, this is common to both plastic gel coated fiberglass, enamel, porcelain and stone shower trays. Full restoration of a shower tray surface can also be carried out to damage created by harsh chemicals used in both the domestic and commercial sectors. The following process shall be carried out to repairs as

- Remove damaged sections ready for a repair.
- Fill the void in the shower tray.
- Profile the filled area to correct shape.
- Etch the area if required.
- Prime
- Resurface with the correct specialist coating (tinting the coating to the correct colour).
- Leave for the proper amount of time to dry.

Figure 1 –Shower pan

Both **ABS** and **PVC** are used in pipes because they are non-toxic and resistant to abrasion. Moreover, ABS pipes are easier to install compared to PVC pipes, but also more likely to deform when exposed to the sun. ABS stands for acrylonitrile butadiene styrene and PVC stands for polyvinyl chloride while PVC pipes are generally white or cream-colored and ABS is in black plastic. The PVC pipes and joint fittings are typically glued together with PVC solvent glue. These connections are quick and permanent, as the plastic parts are chemically fused together with solvent cement. It is very difficult when you get a leak in a

PVC joint or pipe, you cannot separate the joints to replace the leaky parts. A permanent repair usually requires cutting back the pipe and installing new couplings and replacement parts, or re-plumbing an entire section of piping. But if you have a leak in a PVC drain pipe, often you can repair it temporarily until there is time for a permanent fix.

Common repair techniques:

Rubber wrap: Rubber is a thick, heavy-duty tape that sticks to it rather than the part you are fixing. It is stretchy and a little gummy so it can be stretched and stuck to itself to increase the compression of the tape wraps. Wrap the tape very tightly around the leaky PVC joint or pipe; extending the wraps well beyond the repair area, however, it can be difficult to apply in tight spaces.

Repair epoxies: designed to bond to PVC and other plastics commonly come in putty and liquid (syringe) forms. Both can be used to repair PVC joint and pipe leaks.
Dry the area and apply the epoxy as directed by the manufacturer. Most types set in about 25 minutes but may take an hour or more to reach full strength. Liquid epoxy is thinner than putty and may be better for leaks in tight spaces, such as where drain pipes run through holes in studs or other framing members.

Fiberglass wrap is a fiberglass cloth coated with water-activated resin. To use it, wet the cloth in water and wrap it around the leaky PVC pipe or joint, and allow the resin to hardens for 10 or 15 minutes. Follow the manufacturer's application tips for the best results, and try to extend the wrap at least 2 inches on each side of the leaking area.

Rubber and Hose Clamps: A thick piece of rubber and a couple of hose clamps makes for a down-and-dirty temporary repair that you can apply without having to go to the store for supplies. If the leak is isolated to one area and not split down the length of a joint or a piece of pipe, then you can usually get a piece of rubber around it. Open the hose clamps all the way so you can separate them and get them around the pipe. Wrap the rubber around the leaking part, and then tighten a hose clamp at both ends of the rubber, compressing the rubber piece around the leak. This will usually stop or at least greatly slow down the leak and buy you some time for a permanent repair.

Common repair materials

Common materials for sanitary unit are types of plumbing materials used in piping for waste lines; water supply pipes, natural gas supply in the form of Flange, Caps, Gaskets, Valves, Tube-to-Tube Fittings, and Sanitary Fittings etc. are as follow-

- Cast iron for plumbing waste lines.
- PVC (Poly Vinyl Chloride) for plumbing waste lines.
- Chromed brass for plumbing waste lines.
- Chromed copper for water supply lines.
- Galvanized iron for water supply lines.

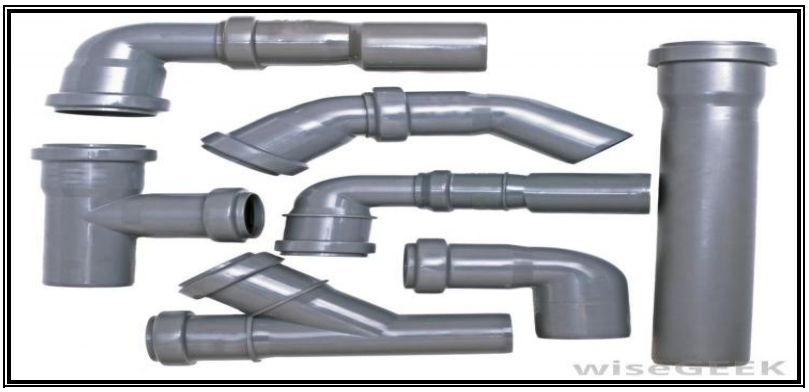

Figure 2: PVC Pipe & Joints

Basic tools and test equipment to get the job done are as below -

- Basic hand **tools** (multipurpose screwdriver, commonly used standard wrenches, adjustable wrench, commonly used Allen screw wrenches).
- Various pliers (e.g., needle nose pliers, lineman's pliers, pump pliers).
- Wire strippers.
- Spare test leads for your DMM.

General maintenance and repair workers get supplies and parts from the distributors or storerooms to complete the task. They use common hand and power tools, such as screwdrivers, saws, drills, wrenches, hoes (farm type, carbon steel blade), shovels, pick axes and hammers to fix, replace, or repair equipment and parts of buildings. Further, the most commonly used materials for drinking-water supply piping are galvanized steel or iron, copper, polybutylene, unplasticized polyvinylchloride (PVC), chlorinated polyvinylchloride (CPVC) and polyethylene (PE) etc.

Figure 3: Repairing Equipments

Man-power:

A plumber's along with required unskilled labours to complete the *task which consists of installation,* repair, maintenance *and servicing of* plumbing *fittings and fixtures.*

VIII Resources required:

Sr. No.	Particulars	Specification	Quantity	Remark
1	Tools and equipment's	As per local available	01	Per batch
2	Sanitary Fittings	As per local available	01	Per batch
3	Repairing materials	As per local available	01	Per batch
3	Cleaning brush	Cleaning surface of the crack.	01	Per batch

IX Procedure:

1. Identify the damage location of repair crack and its nature.
2. Clean the damaged location by brush.
3. Select the suitable materials and prepare the check list.
4. Suggest suitable method for repair and prepare the check list.
5. Suggest appropriate method/tools for repair and prepare the check list.

X Precautions to be followed:

1. Select appropriate damage location and categories the same for the diagnosis.
2. Ensure the complete cleaning of damaged surface.
3. Ensure the materials and methodology as applicable.

XI Actual procedure followed: *(Use blank sheet if provided space is not sufficient).*

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XII Resources used:

Sr. No.	Name of Resource	Broad Specifications		Quantity	Remark
		Make	Details		
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3					
4					

XIII Precautions followed:

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XIV Observations: preparation of check list for materials and Tools/Equipment's required

A. Source and place of damages:

Sr. No.	Damage place	Material required	Tools/Equipments required
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Sample Calculation:

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XV Results:

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XVI Interpretation of results: (*Give meaning of the above obtained results).*

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XVII Conclusions and Recommendations:

(Actions/decisions to be taken based on the interpretation of results).

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XVIII Practical Related Questions:

***Note**: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions. Each batch should write any three following questions separately.*

1. State two differences between rubber-wrap and fiber-glass wrap used for crack repairs.
2. List three materials which are used for construction of pipes.
3. List four tools which are applicable to repairs of sanitary concern.
4. State two situations when it is better to replace than to repair.
5. List two common trade names of rubber-wrap and fiber-glass wrap.
6. List two common trade names of Chromed brass for plumbing waste lines.
7. List two common trade names of Chromed copper for water supply lines.
8. List two common trade names of Galvanized iron for water supply lines.
9. List two common trade names of repairing equipments.

(Note: Each batch should attempt three questions and not to be repeated the same questions by other batches)

Space to Write Answers

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XIX References / Suggestions for further Reading:

Sr. No.	Title of Book	Author	Publication
1.	Building Repair and Maintenance Management	P.S.Gahlot, Sanjay Sharma	CBS Publishers & Distributors Pvt. Ltd., New Delhi, 2016 ISBN: 81-239-1243-9
2.	Maintenance and Repair of Buildings	P.K.Guha	New Central Book Agency (P) Ltd., New Delhi, 2011, ISBN: 81-7381-073-7
3.	Building: Structural Audit, Repairs and Restoration	Arun Kelkar	Majestic Publishing House, Thane, 2015 ISBN: 978-93-83678-93-8
4.	Concrete Technology-Theory and Practice	M.S.Shetty	S. Chand & Co. Pvt. Ltd., New Delhi, 2016, ISBN:978-81-219-0003-4

XX Suggested Assessment Scheme:

Performance Indicators		Weightage (%)
Process related:15 Marks		**60%**
1	Measurement of voltage	30 %
2	Recording of observations	30 %
Product related:10 Marks		**40%**
3	Calculations of result	10%
4	Answers to practical related questions.	20%
5	Submission of report in time.	10%
Total: 25 Marks		**100%**

List of Student Team Members (Roll No.)

1. ……
2. …….
3. …….
4. …….
5. …….

Marks Obtained			Dated sign of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 18: Cracks Repair of Damaged Plane Concrete Beam

I Practical Significance:

It is need to improve the ability of an existing building to withstand against weathering action, chemical attack, embedded metals, alkali-aggregate reaction, fire, overstress, seismic impact etc. that reflect usually from the damage evidences and poor performance. These structures may be deteriorated with use and time and might have passed their design life and require repair and rehabilitation. The old buildings such as ancient temples, monuments, heritage buildings and some residential buildings need some maintenance of repair due to which the regain of strength, durability and stability of those buildings can be retained. Moreover, plane cement concrete beam has very less resistance to tensile cracks therefore it necessary to repair the cracks as early as possible.

II Relevant Program Outcomes:

PO 1. Basic knowledge: *An ability to apply knowledge of basic mathematics, science and engineering to solve the engineering problems.*

PO 2. Discipline knowledge*: An ability to apply discipline- specific knowledge to solve core and/or applied engineering problems.*

PO 3. Experiments and practice: *An ability to plan and perform experiments and practices and to use the results to solve engineering problems.*

PO 8. Individual and Team Work: *Function effectively as leader and team member in Diverse /multidisciplinary team.*

III Relevant Course Outcomes:

d. Apply the relevant methods of repair for the masonry structures.
e. Restore the damages of building structural elements using suitable method of repair.

IV Practical Outcome:

Repair the cracks for a damaged plain concrete member of size of 100x100x500 mm or 150x150x750 mm.

V Competency and Practical Skills:

This practical is expected to develop the following skills for the industry identified competency. ***"Maintain different types of building structures."***

1. Handling of tools and instruments.
2. Carry out retrofitting work of a flexural member.

VI Relevant Affective domain related:

a. Follow safety practices.
b. Practice good housekeeping.
c. Demonstrate working as a leader/a team member.
d. Maintain tools and equipment.

VII Minimum Theoretical Background:

Cracks can occur due to various reasons such as chemical reactions in construction materials, foundation movements, settling of buildings, changes in temperature, environmental stresses like the nearby movement of trains, earthquakes etc. The flexural shear failure occurs in a beam through three main stages: At first, the crack

begins to form at the bottom of the beam due to flexural tensile stress. In second, the crack bends in a diagonal direction as it travels towards the upper end of the beam along with continuation to propagate in length and widen in breadth. And, finally, when the diagonal tensile stress exceeds the tensile strength of the concrete, the concrete fails by crushing or by shear. Finally, flexural shear failure begins as a flexural crack and ends in the shear failure of concrete. And, the failure occurs at the locations of the beams where both the shear force and bending moment are higher in magnitude. There are several methods of concrete crack repair such as epoxy injection, routing and sealing, grouting, stitching, drilling and plugging, gravity filling of cracks in concrete.

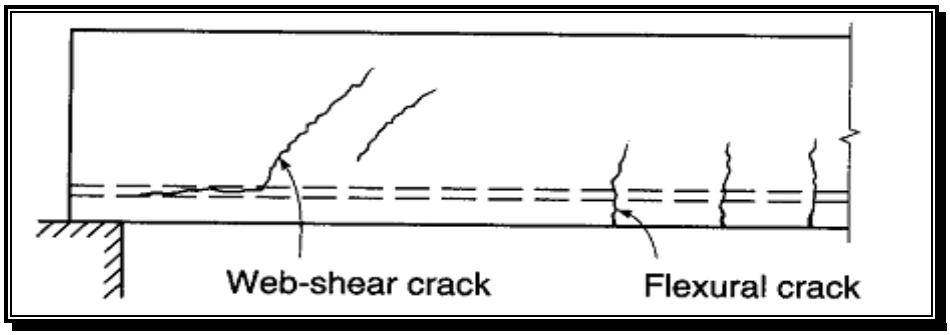


Figure 1: Types of Cracks on Beam

1) Method for jacketing

In the method of jacketing, steel elements are placed on the exterior of damaged concrete members. New reinforcement may be encased with concrete and mortar or other material or it may be left exposed and protected from corrosion with a protective coating. The reinforcement may be in the form of deformed bar, welded wire fabric, steel plates, steel rolled section, steel strapping and specially fabricated brackets. Epoxy and other chemical adhesive along with Portland cement concrete may be used to bond the new reinforcement or it may be mechanically fastened to the existing reinforcement by welding. Steel plates may be attached to resisting girder using bolts and structural adhesive requires adequate surface preparation for both steel and concrete. With appropriate adhesive to have proper bond between steel to concrete, beams, girders, columns and walls can be re-strengthened by placing longitudinal steel bars and stirrups or ties around the members and then encasing the members with concrete or cast in place concrete.

2) Method of stitching

Stitching is a rehabilitation technique used at cracks to maintain aggregate interlock and provide added reinforcement to minimize the relative movement of concrete slabs at the cracks. It is also used at the longitudinal joints to keep the slabs from separating. The process of stitching involves drilling holes on both sides of the crack and grouting in U-shaped metal units with short legs (staples or stitching dogs) that span the crack. Stitching

may be used when tensile strength must be re-established across major cracks. The stitching procedure consists of drilling holes on both sides of the crack, cleaning the holes, and anchoring the legs of the staples in the holes, with either a non-shrink grout or an epoxy resin-based bonding system. In order to resist shear cracks, it is necessary to use diagonal stitching. Moreover the stitching dogs should be of variable length,

orientate and so located that the tension transmitted across the crack does not devolve on a single plane of the section but is spread over an area. Strengthening of the adjacent sections of concrete may consist of external reinforcement embedded in a suitable overlay material.

3) Shear crack repairs

When the shear stress on an object exceeds the maximum permissible shear stress, then object undergoes a failure known as shear failure. Shear failure can be defined as a failure that takes place due to insufficiency of shear resistance available between the materials. Main cause of 45 degree crack is diagonal tension as a result of shear stresses induced and this crack is more likely to be seen near the supports because the maximum shear force due to all loads practically is likely to occur at supports.

Figure 2: Shear Crack on Beam

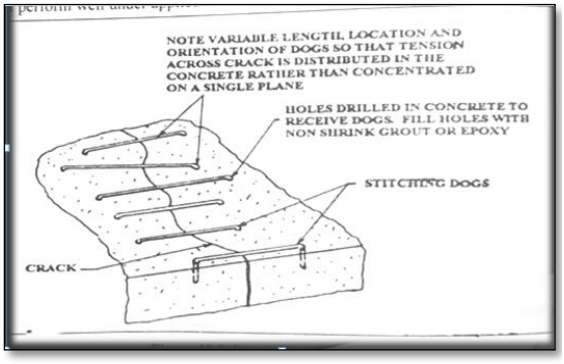
Shear failure occurs in a beam through three main stages such as at first, the crack begins to form at the bottom of the beam due to flexural tensile stress. In second, the crack bends in a diagonal direction as it travels towards the upper end of the beam along with continuation to propagate in length and widen in breadth. And, finally, when the diagonal tensile stress exceeds the tensile strength of the concrete, the concrete fails by crushing or by shear. Flexural cracks form at the locations of beams where the bending moment maximum. For example, in a beam with uniformly distributed load, the flexural cracks are observed at the mid-span. Similarly, web shear cracks form at the locations of the beam where the shear force maximum.

4) Epoxy injection:

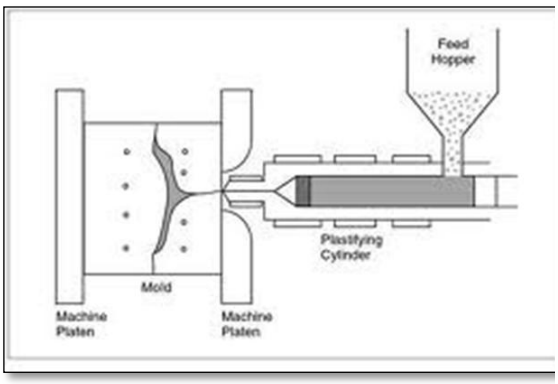
The first step is to clean the cracks that have been contaminated to the extent this is possible and practical. Then surface cracks should be sealed to keep the epoxy from leaking out before it has gelled. Where the crack face cannot be reached, but where there is backfill, or where a slab-on-grade is being repaired, the backfill material or sub base material is sometimes an adequate seal. A surface can be sealed by applying an epoxy, polyester, or other appropriate sealing material to the surface of the crack and allowing it to harden. If a permanent glossy appearance along the crack is objectionable and if high injection pressure is not required, a strippable plastic surface sealer may be applied along the face of the crack. When the job is completed, the surface sealer can be stripped away to expose the gloss-free surface. The cementitious seals can also be used where appearance of the completed work is important.

VIII Experimental Set-up:

(a) Jacketing Method



(b) Stitching method



(c) Epoxy injection

(d) Shear failure

Figure 3. Repairing method of flexural failured beam.

IX Resources required:

Sr. No.	Particulars	Specification	Quantity	Remark
1	Plain concrete cracked beam or Casted and damaged beam	100x100x500 mm 150x150x750 mm	1No.	Per batch
2	Drilling machine	Drill hole of 6mm dia. aside to the crack	1No.	Per batch
3	Steel plate (300x100x6mm) with minimum four holes at corners of plate with 6mm dia. nut bolts.	Used for jacketing plate	2 Nos.	Per beam, Per batch
4	Epoxy	Standard quality	1 No.	Per batch
5	Measuring scale	50 cm in length	1 No.	Per batch

X Procedure:

The procedure involved herewith is for jacketing method of repairing and other repair method can be applied to repair the plain beam.

Jacketing Method

- Take a cracked concrete beam of 100mmx100mmx500mm size or available in Lab.
- Drill the holes of about 6mm diameter on both sides of cracks to place the jacketing plate and based on dimensions of the beam, depth of holes shall be decided.
- Suitably apply epoxy material in cracked part of the beam and join the two separated parts of the cracked beam and allow hardening the epoxy material.
- Steel plate of size 300x100x4 mm is used as jacket which has holes at each corner.
- The nut bolts of size 6mm diameters with sufficient depth are used to fix the jacket plate to the beam.
- While fixing the jacket plate with nut bolts, epoxy material is applied on holes for more grips.
- The damaged beam is thus repaired and can be used as beam.

(Note: This repaired beam should be used for its flexural strength while performing the practical No. 20)

XI Precautions to be followed:

a. Careful consideration must be exercised when using structural adhesives especially epoxy, due to their softening and losses of strength at elevated temperature. Where required, appropriate fire protection must also be provided to such repaired elements.
b. The lengths of bolts are just sufficient to cater the additional stresses.
c. The drilling of holes is sufficiently away from the cracks.

XII Actual procedure followed: *(Use blank sheet if provided space is not sufficient).*

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XIII Resources used:

	Name of Resource	Broad Specifications		Quantity	Remark
		Make	Details		
1					
2					

3					
4					

XIV Precautions followed:

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XV Observations:

- Beam section: ……
- Repair method used: …….

Sr. No.	Sectional area (mm^2)	Magnitude of load and its position (mm)	Flexural load (N)	Flexural strength (N/mm^2)
1.				
2.				
3.				
4.				

Sample Calculation:

For observation no.1

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XVI Results:

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XVII Interpretation of results: *(Give meaning of the above obtained results).*

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XVIII Conclusions and Recommendations:

(Actions/decisions to be taken based on the interpretation of results).

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XIX Practical Related Questions:

***Note**: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions.*

1. State the significance of performing flexural strength on PCC beam.
2. List two other methods available for repair of concrete beam other than mentioned in this practical.
3. State any two differentiation between one point load and two point load method with respect to the flexural strength of beam
4. Mention a suitable method applicable to repair the cracks of the following structural building elements: slab, beam, column, water retaining wall and shear wall.
5. Discriminate the method of jacketing from method of stitching used for crack repair.
6. Can we use the specimen size other than mentioned in this practical, write the answer with justification.
7. Draw a sketch showing crack types and its nature of a cracked beam before repairing.
8. State minimum diameter of pin and pin length across the crack used while stitching.
9. State whether method of stitching is applicable to brick masonry construction with justification

(Note: Each batch should attempt three questions and not to be repeated the same questions by other batches)

Space to Write Answers

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XX References / Suggestions for further Reading:

Sr. No.	Title of Book	Author	Publication
1.	Building Repair and Maintenance Management	P.S.Gahlot Sanjay Sharma	CBS Publishers & Distributors Pvt. Ltd., New Delhi, 2016 ISBN: 81-239-1243-9
2.	Maintenance and Repair of Buildings	P.K.Guha	New Central Book Agency (P) Ltd., New Delhi, 2011, ISBN: 81-7381-073-7
3.	Building: Structural Audit, Repairs and Restoration	Arun Kelkar	Majestic Publishing House, Thane, 2015 ISBN: 978-93-83678-93-8
4.	Concrete Technology-Theory and Practice	M.S.Shetty	S. Chand & Co. Pvt. Ltd., New Delhi, 2016, ISBN:978-81-219-0003-4

XXI Suggested Assessment Scheme:

Performance Indicators		Weightage (%)
Process related:15 Marks		**60%**
1	Measurement of voltage	30 %
2	Recording of observations	30 %
Product related:10 Marks		**40%**
3	Calculations of result	10%
4	Answers to practical related questions.	20%
5	Submission of report in time.	10%
Total: 25 Marks		**100%**

List of Student Team Members (Roll No.)

1. ……
2. …….
3. …….
4. …….
5. …….

Marks Obtained			Dated sign of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 19: Budget Estimation for Repair of Damaged Structure

I Practical Significance:

Almost everyone wants to know how much it costs before they are willing to start the construction therefore estimates is one of tool to narrow down a choice to a contractor. The estimate is prepared for planning of a particular construction so as to get an idea how much the construction will cost. The objective of budget estimation as (1) to segregate the money required for different materials, procedures and labours, (2) to manage the cash flows evenly, properly as per time and requirements, (3) to check the financial feasibility of a particular construction and (4) to arrange finance time to time. The basic purpose of cost-estimating is to provide information to about construction with respect to material estimate, task force, equipment's, time, and costs. A Budget is the total amount of authorized financial resources allocated to a particular purpose for a specific period of time. It is the primary financial document that constitutes the necessary of funds for implementation of construction work.

II Relevant Program Outcomes:

PO 1. Basic knowledge: *An ability to apply knowledge of basic mathematics, science and engineering to solve the engineering problems.*

PO 2. Discipline knowledge*: An ability to apply discipline - specific knowledge to solve core and/or applied engineering problems.*

PO7. Ethics: *Apply ethical principles for commitment to professional ethics, responsibilities and norms of the practice in the field of civil engineering.*

PO 8. Individual and Team Work: *Function effectively as leader and team member in Diverse /multidisciplinary team.*

III Relevant Course Outcomes:

a. Select the relevant materials for repair of structures.
f. Prepare the structural audit and budget for the maintenance of structures.

IV Practical Outcome:

Prepare a budget estimation considering materials, task force, equipment's and methodology for the given damaged structure.

V Competency and Practical Skills:

This practical is expected to develop the following skills for the industry identified Competency. ***"Maintain different types of building structures."***

1. List an appropriate materials and equipment's for budget estimation of damaged structures.
2. Prepare estimate for the materials and equipment's for repairs of construction.

VI Relevant Affective domain related:

a. Follow safety practices.
b. Demonstrate working as a leader/a team member.
c. Prepare the budget estimation of structures as per provisions.

VII Minimum Theoretical Background:

A budget is a financial plan for a defined period generally for one year which include revenues, resource quantities, costs and expenses, assets, liabilities and cash flow. The

budge estimation shall be carried for the purpose to provide forecasting of revenues and expenditures likely to be incurred during project. A budget is the sum of money allocated for a particular purpose and summary of intended expenditures along with actions for how to meet. In general there are three types of government budget such as operating or current budget, capital or investment budget, and cash or cash flow budget.

Budget estimation for repair materials:
Material budgeting refers to the procedure of preparing material or budget materials and its purchase is the quantity and money value of materials to be procured in a specified time period. Not only it helps in estimating the material prices over a period of time but also analyses the material requirements. The materials budget calculates the materials that are to be purchased by time period in order to fulfill the requirements of production budget. It is typically presented either monthly or quarterly format during different phase of construction. This format filled within one week of site construction started by contractor and no approved materials should be allowed to be taken outside without written permission of consultant.

Budget estimation for task force:
A construction worker is a tradesperson, labour, or professional employed in the physical construction of the built environment and its infrastructure. The construction worker does is physical labour on construction sites whereas general laborer may also run equipment's, scaffoldings and other temporary construction activities. Labours works usually have a 50% ratio between labour and materials. An average residential house construction will tend to have the usual 30% labour versus 70% material costs within construction, some tasks will have more % of labour than others. To prepare the labor budget, the total budget shall be calculated by multiply the number of units to be completed by a labor time preferably in an hour then multiply that result by the average labor cost per hour.

Budget estimation of equipments:
The equipment is categorized as "special purpose" or "general purpose". The special purpose equipment is usually considered to be under items that only can be used in research whereas general purpose equipment has utility that is not limited to research. Care must be taken to include the items of cost associated with the transportation and installation costs in proposal. The budget estimation for equipment's depends on whether equipment's are utilized on hire basis or by purchasing new equipments. As many contractors and owners are utilizing the equipments on hire basis therefore estimation process has been undertaken herewith.

VIII Resources required:

Sr. No.	Particulars	Specification	Quantity	Remark
1	District Schedule Rates (DSR)	Item rates	01	Per batch
2	Brochure of construction equipments	Construction equipments	Required	Per batch
3	labour charges and acts	GR about labour charges	Required	Per batch
3	Data base of materials	Standard materials	Required	Per batch

IX Procedure:

1. Identify the location of damage for repairs and its nature.
2. Select the suitable materials and prepare check list.
3. Suggest suitable technique for repair and prepare check list.
4. Suggest appropriate equipments and tools for repair and prepare check list.

X Precautions to be followed:

1. Select appropriate damage location and categories the same for the diagnosis.
2. Ensure the complete cleaning of damaged surface.
3. Ensure the materials and methodology as applicable.

XI Actual procedure followed: *(Use blank sheet if provided space is not sufficient).*

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XII Resources used:

Sr. No.	Name of Resource	Broad Specifications		Quantity	Remark
		Make	Details		
1					
2					
3					
4					

XIII Precautions followed:

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XIV Observations:

A. Checklist for budget estimation of repair materials:

- Site Name : .....
- Name of contractor (if employed): .....
- Location of site : .....
- Date of visit : .....

Sr. No.	Repair Materials	Stock at Site with Quantity	To be Purchased quantity	Cost per Quantity unit	Total Cost
1					
2					
3					
4					
5					

B. Checklist for budget estimation of task force:

- Site Name : …….
- Name of contractor (if employed): …….
- Location of site : …….
- Date of visit : …….

Sr. No.	Labour category	No. of units completed by one labour per hour	Charges per unit of work	labour cost per hour	No. of working hours	Total labour cost
1	Male					
2	Female					

C. Checklist for budget estimation of equipment's:

- Site Name : …….
- Name of contractor (if employed): …….
- Location of site : …….
- Date of visit : …….

Sr. No.	Name of Equipments	Rent of equipment per hour (Rs./hr)	No. of hours employed	Total cost (In Rs.)
1				
2				
3				
4				
5				

Note: Add additional pages, if required.

XV Results:

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XVI Interpretation of results: *(Give meaning of the above obtained results)*

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XVII Conclusions and Recommendations:

(Actions/decisions to be taken based on the interpretation of results).

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XVIII Practical Related Questions:

***Note**: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions. Each batch should write any three following questions separately.*

1. Define the term budget and estimation used in process of construction.
2. Write any four objectives of budget estimation for damaged structures.
3. State any four advantages of budget estimation in civil work construction.
4. When and where, it is necessary to purchase equipments rather than hire (any two points).
5. Write any four influencing factors while budget estimation of a given structure.
6. Sate any three safety factors are to be considered while budget estimation of a damaged structures.
7. Write any three limitations when construction work is carried out without budget estimation.
8. Prepare the checklist for construction of septic tank to be used for residential 2BHK building.
9. State any four rules and regulations of structural budget estimation as recommended by Public Work Department.

(Note: Each batch should attempt three questions and not to be repeated the same questions by other batches)

Space to Write Answers

XIX References / Suggestions for further Reading:

Sr. No.	Title of Book	Author	Publication
1.	Building Repair and Maintenance Management	P.S.Gahlot, Sanjay Sharma	CBS Publishers & Distributors Pvt. Ltd., New Delhi, 2016 ISBN: 81-239-1243-9
2.	Maintenance and Repair of Buildings	P.K.Guha	New Central Book Agency (P) Ltd., New Delhi, 2011, ISBN: 81-7381-073-7
3.	Building: Structural Audit, Repairs and Restoration	Arun Kelkar	Majestic Publishing House, Thane, 2015 ISBN: 978-93-83678-93-8
4.	Concrete Technology-Theory and Practice	M.S.Shetty	S.Chand&Co. Pvt.Ltd., New Delhi, 2016, ISBN:978-81-219-0003-4

XX Suggested Assessment Scheme:

Performance Indicators		Weightage (%)
Process related:15 Marks		**60%**
1	Measurement of voltage	30 %
2	Recording of observations	30 %
Product related:10 Marks		**40%**
3	Analysis of result	10%
4	Answers to practical related questions.	20%
5	Submission of report in time.	10%
Total: 25 Marks		**100%**

List of Student Team Members (Roll No.)

1. ……
2. …….
3. …….
4. …….
5. …….

Marks Obtained			Dated sign of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	

Practical No. 20: Flexural Strength of Repaired Concrete Beam

I Practical Significance:

Flexural strength is one of the measures for tensile strength of concrete due to bending. This practical enables to know the flexural strength of repaired concrete beam after re-strengthening. This test plays significant role in flexural members such as deck slab, RC beam etc. The beam specimen repaired from the experiment No.18 is to be tested for its re-gaining strength in flexure during this experiment.

II Relevant Program Outcomes:

PO 1. Basic knowledge: *An ability to apply knowledge of basic mathematics, science and engineering to solve the engineering problems.*

PO 2. Discipline knowledge*: An ability to apply discipline- specific knowledge to solve core and/or applied engineering problems.*

PO 3. Experiments and practice: *An ability to plan and perform experiments and practices and to use the results to solve engineering problems.*

PO 4. Engineering tools: *Apply relevant civil technologies and tools with an understanding of the limitations.*

PO 8. Individual and Team Work: *Function effectively as leader and team member in Diverse /multidisciplinary team.*

III Relevant Course Outcomes:

a. Test the construction materials to predict the stability of structures.
e. Restore the damages of building structural elements using suitable method of repair.

IV Practical Outcome:

Determine the flexural strength of repaired beam from practical No. 18.

V Competency and Practical Skills:

This practical is expected to develop the following skills for the industry identified competency. ***"Maintain different types of building structures."***

1. Handling of instruments.
2. Procedure to know the flexural strength of a beam.

VI Relevant Affective domain related:

a. Follow safety practices.
b. Demonstrate working as a leader/a team member.
c. Use of appropriate equipments.
d. Follow ethical Practices.

VII Minimum Theoretical Background:

The Flexural Strength or modulus of rupture (f_b) is given by

$f_b = \frac{pl}{bd^2}$ (when a> 20 cm for 15 cm specimen or > 13 cm for 10cm specimen).

OR

$f_b = \frac{3\,pa}{bd^2}$ (when a< 20 cm but > 17 cm for 15cm size specimen or < 13.3 cm but > 11cm for 10 cm size of specimen.).

Where,

a = the distance between the line of fracture and nearer support, measured on the center line of the tensile side of the specimen (cm).

b = width of specimen (cm).

d = beam depth at failure point in (cm).

l = supported length (cm).

p = maximum load (kg).

VIII Experimental Set-up:

(a) Schematic diagram (b) Actual Testing of beam

Figure 1: Flexural Strength Test of Repaired Concrete Beam

IX Resources required:

Sr. No.	Particulars	Specification	Quantity	Remark
1	Plain concrete repaired beam	100 x100 x500 mm size or 150 x150 x750 mm size	1No.	Per batch
2	Universal Testing Machine	flexural attachment	1 No.	Per batch
3	Measuring scale	50 cm in length	1 No.	Per batch

X Procedure:

1. Clean the bearing surfaces of supporting and loading rollers and remove any loose sand or other material from the surfaces of specimen where they are to make contact with the rollers.
2. Circular rollers manufactured from steel having cross section with diameter 38 mm will be used for providing support and loading points to the specimens.
3. The length of rollers shall be at least 10 mm more than the width of test specimen.
4. The test specimen by placing the specimen in machine jaws correctly centered with the longitudinal axis of specimen at right angles to the rollers.
5. The load shall be applied at a rate of loading of 400 kg/min for the 15 cm size of specimens and at a rate of 180 kg/min for the 10 cm size of specimens.

XI Precautions to be followed:

1. The jacketed side of beam should be on the tensile side while testing.
2. The rate of loading should be proper.
3. Specimen should be placed perfectly horizontal.

XII Actual procedure followed: *(Use blank sheet if provided space is not sufficient).*

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XIII Resources used:

Sr. No.	Name of Resource	Broad Specifications		Quantity	Remark
		Make	Details		
1					
2					
3					
4					

XIV Precautions followed:

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XV Observations:

1. L= span of beam (cm) =…….
2. a = the distance between the line of fracture and the nearer support, measured on the
   center line of the tensile side of the specimen (cm) =……
3. b = width of specimen (cm) =……..
4. d = beam depth at failure point (cm) =……..
5. l = supported length (cm) =……
6. p = maximum load (kg.) = …….

Sample Calculation:

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XVI Results:

1. The flexural strength of the repaired beam is …….Kg/Cm^2

XVII Interpretation of results: *(Give meaning of the above obtained results)*

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XVIII Conclusions and Recommendations:

(Actions/decisions to be taken based on the interpretation of results).

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XIX Practical Related Questions:

***Note**: Below given are few sample questions for reference. Teachers must design more such questions so as to ensure the achievement of identified CO. Write answers of minimum three questions.*

1. State the clear span length and effective span of repaired specimen used by in this test.
2. Draw SFD and BMD for the beam tested during in this practical.
3. Write two purposes of conducting flexural strength on repaired concrete beam.
4. Out of square or rectangular beam (d>b) having same cross sectional area , in which case the flexural strength will be more justify your answer.
5. State the nature of failure occurred in this test.
6. If the stitching is done away from center of beam, locate the position of failure of beam. Why?
7. State two factors affecting the flexural strength of repaired beam.
8. Can we conduct the flexural strength test for the beam having circular cross section, justify your answer?

9. In case of existing structure, if the cost of repair of a beam is more than its replacement but still repairing of beam is preferred, comment.

(Note: Each batch should attempt three questions and not to be repeated the same questions by other batches)

Space to Write Answers

XX References / Suggestions for further Reading:

Sr. No.	Title of Book	Author	Publication
1.	Building Repair and Maintenance Management	P.S.Gahlot, Sanjay Sharma	CBS Publishers & Distributors Pvt. Ltd., New Delhi, 2016 ISBN: 81-239-1243-9
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4.	Concrete Technology-Theory and Practice	M.S.Shetty	S. Chand & Co. Pvt. Ltd., New Delhi, 2016, ISBN:978-81-219-0003-4

XXI Suggested Assessment Scheme:

Performance Indicators		Weightage (%)
Process related:15 Marks		**60%**
1	Measurement of voltage	30 %
2	Recording of observations	30 %
Product related:10 Marks		**40%**
3	Calculations and analysis of result	10%
4	Answers to practical related questions.	20%
5	Submission of report in time.	10%
Total: 25 Marks		**100%**

List of Student Team Members (Roll No.)

1. ……
2. ……
3. ……
4. ……
5. ……

Marks Obtained			Dated sign of Teacher
Process Related (15)	**Product Related (10)**	**Total (25)**	