A Laboratory Manual for

Retrofitting of Structures (3170616)

B.E. Semester 7 (Civil)

Directorate of Technical Education
Gandhinagar, Gujarat

L. E. College , Morbi

Certificate

This is to certify that Mr./Ms. ____ _________ Enrollment No. _________________ of B.E. Semester ______Civil Engineering of this Institute (GTU Code: ______) has satisfactorily completed the Practical / Tutorial work for the subject Retrofitting of Structures (3170616) for the academic year 2025-26.

Place: ___________
Date: ___________

Name and Sign of Faculty member

Head of the Department

Preface

The basic aim of laboratory/practical/field work is to enhance the required skills as well as create the ability amongst students to solve real-time problems by developing relevant competencies in the psychomotor domain. By keeping this in view, GTU has designed a competency-focused outcome-based curriculum for engineering degree programs where sufficient focus is given to practical work. It shows the importance of enhancement of skills amongst the students and pays attention to utilizing every second of time allotted for practicals amongst students, instructors, and faculty members to achieve relevant outcomes by performing the experiments rather than merely study-type experiments. It is a must for the effective implementation of a competency-focused outcome-based curriculum that every practical is keenly designed to serve as a tool to develop and enhance relevant competency required by the various industry among every student. These psychomotor skills are very difficult to develop through a traditional chalk-and-board content delivery method in the classroom. Accordingly, this lab manual is designed to focus on the industry-defined relevant outcomes, rather than the old practice of conducting practicals to prove concepts and theories.

By using this lab manual students can go through the relevant theory and procedure in advance before the actual performance which creates interest and students can have a basic idea prior to the performance. This in turn enhances pre-determined outcomes amongst students. Each experiment in this manual begins with competency, industry-relevant skills, course outcomes as well as practical outcomes (objectives). The students will also achieve safety and necessary precautions to be taken while performing practicals.

This manual also provides guidelines to faculty members to facilitate student-centric lab activities through each experiment by arranging and managing necessary resources in order that the students follow the procedures with required safety and necessary precautions to achieve the outcomes. It also gives an idea that how students will be assessed by providing rubrics.

Retrofitting of Structures is a Professional Elective Course. This subject is designed with an aim to give the students an insight into the subject of deterioration of concrete structures, investigations to be carried out for Structural assessment, to make conversant with the various repair materials and strengthening techniques to salvage the distressed stock of structures.

Utmost care has been taken while preparing this lab manual however always there are chances for improvement. Therefore, we welcome constructive suggestions for improvement and removal of errors if any.

Practical – Course Outcome matrix

Course Outcomes (COs):

CO1 - Identify and define all the terms and concepts associated with the deterioration of concrete structures.

CO2 - Carry out the damage assessment and Rapid Visual inspection of a building showing signs of deterioration and thus should be able to detect the possible cause /source of deterioration.

CO3 - Develop know-how of the Concrete repair industry equipped with a variety of repair materials and techniques.

CO4 - Describe and apply the importance of quality control in concrete construction and the significance of protection and maintenance of structures.

Sr. No.	Objective(s) of Experiment	CO1	CO2	CO3	CO4
1.	Rapid visual structural inspection of distressed buildings	√	√		
2.	Determination of loss in mass & compressive strength of concrete exposed to Accelerated deterioration	√	√		√
3.	Determine the flexural strength of repaired concrete beams	√	√	√	
4.	Assessment of concrete strength & quality of the distressed beam, slab & column for the building in Experiment No.1 using Rebound Hammer	√	√		√
5.	Assessment of Concrete Strength & Quality of distressed Beam, Slab & Column for the building in Experiment No.1 using Ultra-Sound Pulse Velocity Test	√	√		√

Industry Relevant Skills

The following industry-relevant competencies are expected to be developed in the student by undertaking the practical work of this laboratory.

1. Skill to identify the distress in reinforced concrete and masonry components of the structure.
2. Develop the thinking of accurately relating the signs of symptoms of distress with their respective causes.
3. Skill to handle the equipments and tools on site while carrying out the Structural Assessment.
4. Proper Interpretation & articulation of the test results, observations, and articulating the facts in form of a report.
5. Recommend the most relevant underlying cause of distress and suggest treatment for the same.

Guidelines for the Faculty Members

1. Teacher should provide the guideline with the demonstration of practicals to the students with all features.
2. Teacher shall explain basic concepts/theories related to the experiment to the students before starting each practical.
3. Involve all the students in the performance of each experiment.
4. Teacher is expected to share the skills and competencies to be developed in the students and ensure that the respective skills and competencies are developed in the students after the completion of the experimentation.
5. Teachers should give an opportunity to students for hands-on experience after the demonstration.
6. Teacher may provide additional knowledge and skills to the students even though not covered in the manual but are expected from the students by the concerned industry.
7. Give practical assignments and assess the performance of students based on the task assigned to check whether it is as per the instructions or not.
8. Teacher is expected to refer complete curriculum of the course and follow the guidelines for implementation.

Instructions for Students

1. Students are expected to carefully listen to all the theory classes delivered by the faculty members and understand the COs, content of the course, teaching and examination scheme, skill set to be developed, etc.
2. Students shall organize the work in the group and make a record of all observations.
3. Students shall develop maintenance skills as expected by industries.
4. Students shall attempt to develop related hands-on skills and build confidence.
5. Students shall develop the habits of evolving more ideas, innovations, skills, etc. apart from those included in the scope of the manual.
6. Students shall refer to technical magazines and data books.
7. Students should develop a habit of submitting the experimentation work as per the schedule and s/he should be well prepared for the same.

Common Safety Instructions

1. Abide by all the safety precautions mentioned in each experiment.
2. Read the notice board of the Laboratory.
3. Follow the test procedure as described.
4. Avoid any mischief when on-site for evaluation or while working in the lab.

Index
(Progressive Assessment Sheet)

Sr. No.	Objective(s) of Experiment	Page No.	Date of performance	Date of submission	Assessment Marks	Sign. of Teacher with date	Remarks
Total							

Experiment No: 1
Rapid Visual Structural Inspection of Distressed Buildings

Date:

Competency and Practical Skills:

1. Ability to identify and locate different symptoms of distress
2. Relate the Symptom and cause of damage
3. Ability to detect the probable source of distress

Relevant CO: CO1 & CO2

Objectives:
(a) To enable the understanding of the basic process of deterioration of structures during their service life.
(b) To have an insight into the location of damages in structural and non-structural components of the building
(c) To be able to relate the symptom with the underlying cause of damage

Equipment/Instruments:

Documentation Tools such as Notepad, Pen, Pencil, Marker pen,

Measuring tools such as Needle or u-pin or fine wire, 100 ft Measuring tape, Torch, High-resolution camera, magnifying glass, wire brush, crack comparator, chalk, Light-weight hammer, chisel, or knife,

Safety tools such as gloves, shoes, and helmet for protection for eyes and head against falling hazards

Theory: The basic theory underlying this process of Structural assessment is to avoid repairing the structure without determining the cause of damage. Any attempts to repair the distress without treating the cause will merely result in "repair of repairs." This can be avoided by having a thorough visual inspection of distressed structures that enables to identification and evaluate the severity of different types of defects such as cracking, spalling, level of corrosion, dimensions of cracks, construction faults, seepage, etc. The visual inspection helps to identify the prima-facie causes of damages observed and noted and also helps to gauge the requirement of carrying out a Detailed Structural inspection.

Safety and necessary Precautions:

(1) Enter the site of distressed structures with a helmet and shoes.
(2) Do not venture or explore severely distressed parts of a structure.
(3) Evaluate the buildings after seeking proper permission from the owner of the building.
(4) Carry your College-ID cards to the site during each visit

Procedure:

1. Identify the location of any distressed building in your city. The building could be residential, commercial, educational, or government but has to be an RCC structure.
2. Take all the necessary permissions for making the visit to the site.
3. Equipped with all tools mentioned above, take a complete tour of the structure to understand its structural framing. Plot a general line diagram of a structure in the Format for RVI as shown in the subsequent section.
4. Collect general information about the building in form of structural drawings, material specifications, maintenance history, geotechnical soil reports, and design calculations.
5. Verify the dimensions of the buildings from the available set of drawings, if drawings are not available or provided, then have general measurements of buildings' dimensions and components.
6. Visually inspect each component of the building i.e., columns, beams, slabs, staircase, parapet walls, cantilever components, walls (peripheral and internal), and roof slabs.
7. Look out for all the possible defects listed in Format for RVI and map the defects for each structural and non-structural component.
8. Visually survey the entire building based on all parametric descriptions mentioned in the format.
9. Record neatly all the observations in form of high-resolution photographs, sketches, and notes.
10. After having a thorough evaluation make the best judgment on the condition of the building and give the recommendation in Section 6-Part 3 of the RVI Format.

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Observations: All the observations are to be recorded in the RVI format shown overleaf.

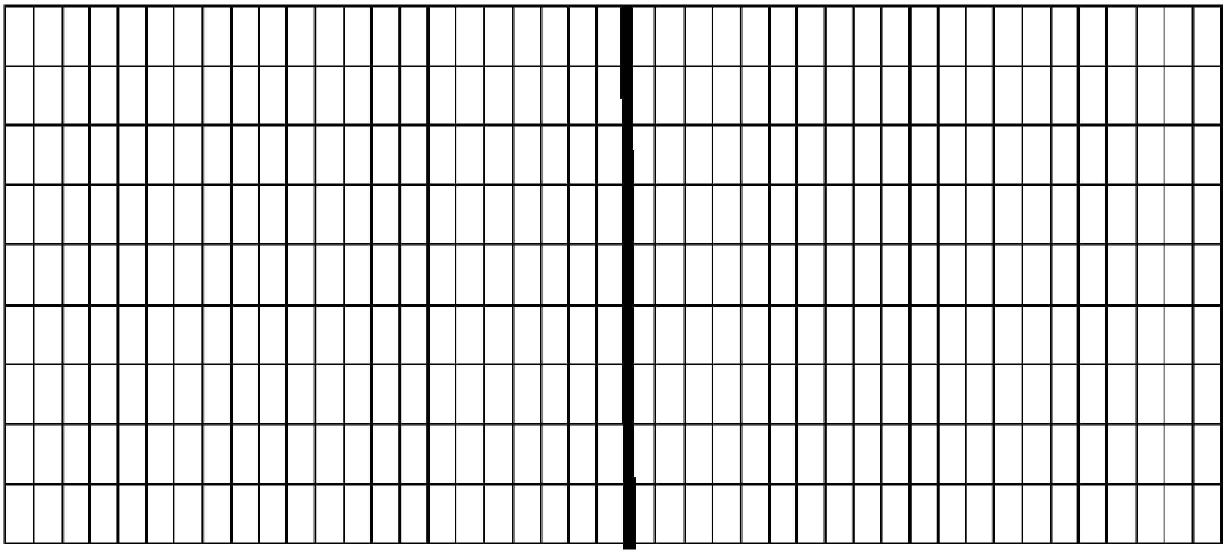
RAPID VISUAL INSPECTION FORMAT

Sr. No.	Description	Details	
PART 1 GENERAL INFORMATION OF THE BUILDING			
1	Name and address of the building, Year of the construction		
2	TYPE OF BUILDINGS Load bearing/partly load bearing and partly RCC/RCC frame		
3	Number of storey in each block of the building		
4	Description of the main usage of the building: Residential/educational/office/ hostel/ workshop/hospital/any other specify		
5	TYPE OF FLOOR and ROOF RCC/Wooden/Steel		
6	Year of construction, Maintenance history of the building if known to be mentioned		
PART 2 STRUCTURAL SYSTEM OF THE BUILDING			
1	Description of the structural forms, systems and materials used in different parts of the building, e.g., RCC, prestressed concrete, steel, etc.		
2	Description of soil condition and foundation system, if known		
3	Identification of critical structures (e.g. slender columns, floating columns, cantilever structures, long span structures, etc.)		
4	Description of any area not covered in visual inspections. State the reasons for the same.		
5	State, if the existing usage and loading condition is compatible with the intended purpose of structure		
6	State the misuse, abuse or deviation has given rise to excessive loading		
7	State, if there was any addition/alteration works done to the building structure		
PART 3 SURVEY OF SIGNS OF DISTRESS, DEFORMATION OR DETERIORATION IN BUILDING STRUCTURE (CONDITION ASSESSMENT)			
		YES	NO
1	LEANING OF BUILDING	☐	☐
2	SETTLEMENTS (a) Floor settlement (b) Settlement of load bearing wall (c) Settlement of RCC foundation	 ☐ ☐ ☐	 ☐ ☐ ☐

3	DEFECTS (Extent of defect)`	Insignificant	Slight	Moderate	Severe	Very severe
A	Cracking Plastic shrinkage/settlement Thermal cracking Structural Crazing Honey combing Cracking in load bearing walls Cracking in RCC component (Attach separate sheets for crack details, if required)	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
B	Water seepage Pop-outs Spalling Rust staining	☐ ☐ ☐ ☐	☐ ☐ ☐ ☐	☐ ☐ ☐ ☐	☐ ☐ ☐ ☐	☐ ☐ ☐ ☐
C	Extent of corrosion (a) Corrosion in longitudinal bars (b) Corrosion in lateral ties/rings (c) Debonding of surface due to corrosion (d) Deflection in beams/slabs (Attach separate sheets for details preferably with photographs)	☐ ☐ ☐ ☐	☐ ☐ ☐ ☐	☐ ☐ ☐ ☐	☐ ☐ ☐ ☐	☐ ☐ ☐ ☐
4	State of the existing repairs (if any carried out in structure) (a) Delamination/debonding (b) Cracking Others (specify)	☐ ☐	☐ ☐	☐ ☐	☐ ☐	☐ ☐
5	OVERALL STRUCTURAL CONDITION ASSESSMENT (Based on initial design and construction and present structural condition assessments)	Unsafe ☐ Potentially hazardous ☐ Severe ☐ Moderate ☐ Minor ☐ Good condition ☐				
6	RECOMMENDATIONS (a) No further action required (b) Repair/strengthening works necessary (c) Detailed assessment required (d) Barricade/non-use needed (e) Reconstruction or any other suggestions					

PART 4: DETAILED SKETCHES OF THE FLOOR PLAN & STRUCTURAL FRAME OF THE BUILDING
PART 5: PHOTOGRAPHS
PART 6: ADDITIONAL COMMENTS, IF ANY
PART 7: STANDARD CERTIFICATE BY THE STRUCTURAL INSPECTOR & TEAM

Plan Elevation



Conclusion: (Students are required to write here the conclusion based on the overall assessment of distressed structure in terms of types of defects majorly seen, based on the types of defects identify the need for detailed investigation, group of damage)

Quiz:

1. Identify at least 3 damages along with their causes from the inspection carried out.
2. How many components were found to be having Non-structural cracks? Mention the reason for this type of cracking based on your evaluation.
3. Were there any signs of dampness/leakage in the evaluated structure? If yes locate and cite the reason for the same.

Suggested Reference:

1. Handbook on Repair and Rehabilitation of RCC buildings published by Director General (Works), Central Public Works Department, Government of India, Nirman Bhavan.
2. Poonam I. Modi; Chirag N. Patel, Repair and Rehabilitation of Concrete Structures, PHI Publication
3. Peter H. Emmons, Concrete Repair and Maintenance Illustrated, Kingston: 1994, R.S. Means Company, Inc.
4. P.C. Varghese, Maintenance Repair & Rehabilitation & Minor Works of Buildings, PHI Learning, 2014.

References used by the students: (Duly mention all the references and literature used for the activity below)

Rubric-wise marks obtained:

Performance Indicators	Selection of the relevant Site for Inspection	Quality of the filled Format of RVI inclusive of additional information	Quality of the report	Active engagement and cooperation with team members	**Total**
Marks	5	10	10	5	**30**

Experiment No: 2
Determination of loss in mass & Compressive Strength of Concrete exposed to Accelerated deterioration

Date:

Competency and Practical Skills:

1. Ability to cast concrete specimens.
2. Interpretation and articulation ability for the observations and results.
3. Ability to comprehend the severe consequences of deterioration based on test results.

Relevant CO: CO1, CO2 & CO4

Objectives: (a) To understand the mechanism of cracking in structural members.
(b) To get conversant with the application of NDT test procedures.
(c) To be able to quantify the difference in the strength of members pre- and post-deterioration.
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Equipment/Instruments: Cube moulds, Compression testing machine, Rebound hammer, Ultrasonic pulse velocity test apparatus, sprinkler for spraying, containers for conditioning of cubes

Theory: Structures during their service life are subjected to different types of deteriorating mechanisms such as carbonation, salt crystallization, cracking due to thermal effect, moisture changes, excessive loading, acid attack, alkali aggregation reaction, corrosion, etc. Damages due to deterioration manifest in the structure in various forms such as spalling, leaching, staining, cracking, corrosion, deflection, exposure of reinforcement, etc. These damages if not repaired timely can result in major damages that can lead to a further irreversible deterioration in concrete structures. Excessive cracking and corrosion in reinforcement reduce the load-carrying capacity of the structural members.

Set up diagram: Draw a line sketch of the experimental setup.

Safety and necessary Precautions:

1. Ensure complete safety while working with Salt solutions.
2. Wear gloves while working.
3. Soak the cubes properly in tanks filled with solution.

Procedure:

1. Cast at least 9 Numbers of Concrete cubes of size 150 mm x 150 mm x 150 mm from the same Mix of the everyday concrete grade of M20.
2. Make a proper marking of the top face (Moulding side) of a cube with the date of testing & grade of concrete.
3. Properly cure the cubes with immersion curing for 28 days in a curing tank.
4. A set of 3 cubes is to be considered as Controlled specimens and the other 6 cubes are to be subjected to Accelerated Deterioration.

5. Immerse a set of 3 cubes in NaCl (Sodium Chloride) solution at a concentration of 5% by weight of water for a period of 28 days.
6. Immerse the remaining set of 3 cubes in Na_2SO_4 solution at a concentration of 5% by weight of water for a period of 28 days.
7. Prepare both solutions preferably using Distilled water.
8. The immersion of the cubes for simulating accelerated deterioration is to be done by placing the cubes in the solution kept in non-corrosive plastic tanks of sufficient size to accommodate a set of 3 cubes each for NaCl and Na_2SO4 solution.
9. Maintain at least a 10 mm level of the solution above the top surface of the cubes.
10. Record the Initial Weight of all 9 cubes after 28 days of curing. Assign it as W_o = Weight of the cubes before deterioration.
11. Record the weight of the six cubes subjected to accelerated deterioration, after taking them out of the solution tanks. Assign it as W_t = Weight of the cubes after exposure to salt solution for the period (t) in days.
12. Record the visual appearance of all the cubes post-deterioration. Record the appearance by assigning correct terminologies such as spalling, cracks, expansion, loss of paste, honeycombing, leaching, etc.
13. Test all the cubes for compressive strength in a Compression testing machine of 1000 kN capacity.

Observations:

1) Total Number of Cube specimens cast = N =
2) Grade of concrete used to cast cubes = f_{ck} =

Observation Table:

Type of Cube*	Initial Weight of the Cube (W_o) in kgs	Final Weight of the Cube after deterioration (W_t) in kgs	Loss in Weight in $\%\Delta W = \left(\frac{Wt-Wo}{Wo}\right) * 100\%$	Compressive Strength of the cubes in MPa	Average Value of the Loss in Mass in %	Average Value of the Compressive Strength in MPa
CO1						
CO2						
CO3						
T1S1						
T2S2						
T2S3						
T2S1						
T2S2						
T2S3						

*CO – Controlled specimen; T1S1 – Specimens treated with NaCl solution; T2S2 – Specimens treated with Na_2SO_4 solution

Result:

1. The average loss in Mass in % for Controlled specimens = ---------------
2. The average loss in Mass in % for Test specimens treated with NaCl Solution = ---------------
3. The average loss in Mass in % for Test specimens treated with Na_2SO_4 Solution = -------------
4. The average Compressive strength of controlled specimens at end of 56 days = ----------- in MPa
5. The average Compressive strength of Test specimens treated with NaCl Solution at end of 56 days = ----------- in MPa
6. The average Compressive strength of Test specimens treated with Na_2SO_4 Solution at end of 56 days = ----------- in MPa

Conclusion: Write the conclusion based on the values calculated and the appearance of all the cube specimens. Comment on the trend of the values (increased or decreased) in comparison to controlled specimens and cite the reasons for the same based on the chemistry involved in causing deterioration in appearance, mass, and strength.

Quiz:

1. Explain the deterioration in concrete due to salt attack
2. Mention the other deterioration mechanisms in concrete
3. Enlist the names of the structures in which deterioration due to acid attack, salt attack, and sulphate attack is most prominent.
4. Explain the consequences of chloride attack in RCC.

Suggested Reference:

1. Handbook on Repair and Rehabilitation of RCC buildings published by Director General (Works), Central Public Works Department, Government of India, Nirman Bhavan.
2. Poonam I. Modi; Chirag N. Patel, Repair and Rehabilitation of Concrete Structures, PHI Publication.
3. Zhiyu Tang, Nianchun Deng, "Effect of Salt Solution on the Mechanical Behaviours of Geopolymer Concrete under Dry-wet cycles," Advances in Material Science and Engineering, Hindawi, https://doi.org/10.1155/2022/9120821
4. Peter H. Emmons, Concrete Repair and Maintenance Illustrated, Kingston: 1994, R.S. Means Company, Inc.
5. P.C. Varghese, Maintenance Repair & Rehabilitation & Minor Works of Buildings, PHI Learning, 2014

References used by the students: (Duly mention all the references and literature used for the activity below)

Rubric-wise marks obtained:

Performance Indicators	Preparatory works carried out for the experimentation	Quality of the cubes cast	Interpretation of the results & clarity in concluding statements	Active engagement and cooperation with team members	**Total**
Marks	5	10	10	5	**30**

Experiment No: 3
Determine the flexural strength of repaired concrete beams

Date:

Competency and Practical Skills:

Relevant CO: CO1, CO2, CO3

Objectives:
(a) To understand the mechanism of cracking in structural members.
(b) To get conversant with the application of NDT test procedures.
(c) To be able to quantify the difference in the strength of members pre- and post-deterioration.

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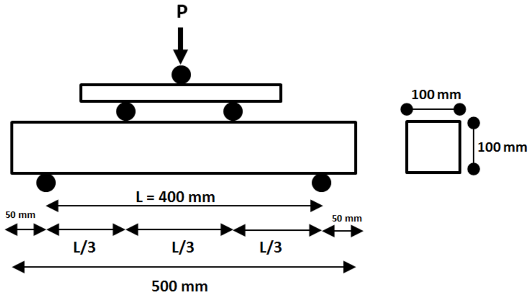
Equipment/Instruments: Beam moulds, Compression testing machine, Flexural testing assembly, Tools specific to repair technique, Crack comparator

Theory: Cracks in buildings are a common occurrence. A crack is an incomplete separation of concrete into one or more parts to a variable depth, but visible at the surface. The majority of buildings develop cracks either immediately after construction or at a later stage. Usually, cracks developed soon after the construction are superficial and can be repaired easily. However, the development of any crack in the structure, whether superficial or major, is a sign of damage.

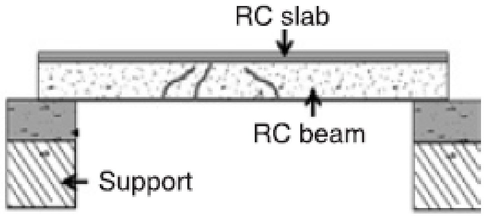
Cracks may affect only appearance, or they could also be an indication of significant structural distress or lack of durability. Cracks may represent the total extent of damage or might give indications of problems of greater magnitude. A building component can develop cracks when the stress in the component exceeds its strength in compression, tension, or shear. It is imperative to study these characteristics of the cracks in order to correctly diagnose the cause of cracking and accordingly adopt an appropriate repairing material and repair technique.

For RCC members there are different types of cracks such as flexure, tension, shear, torsion, and bond cracks. The flexural cracks in the beams originate in the maximum moment region, these cracks can be single or in groups. The maximum width of the crack is at the bottom or top of the beam based on the region of tension. Numbers of methods are available to repair concrete cracks such as Epoxy resin injection, grouting, routing, and sealing, stitching, drilling, plugging, and gravity filling.

Set up diagram: In the diagram below figure (a) represents the setup for the Two-point loading assembly for the beam of cross-section 100x100x500 mm and figure (b) represents a schematic diagram of the formation of flexural cracking in beams and the marking of developed cracks.



(a)



(b)

Safety and necessary Precautions:

1. Be very cautious while loading and unloading the beam specimens.
2. Wear gloves while repairing the beam.
3. Be careful while working with the drilling machine.

Procedure:

1. Cast at least 3 Numbers beams of size 100 mm x 100 mm x 500 mm or 150 mm x 150 mm x 750 mm based on the availability of the moulds.
2. Cast the beams using concrete of grade M25 or M30.
3. Cure the beams by sprinkling them with water until the maturity period. Sprinkle curing by water pipes or sprinklers is suggested in order to simulate the actual curing conditions of the site.
4. Load at least 2 nos. of beams onto the Compression testing machine by placing the beams on the flexural test assembly and initiate cracking until the width of the crack in the region of the maximum moment is in the range of 0.1 mm to 3.0 mm. Measure the crack width using a Crack monitor or crack comparator.
5. Use a Two-point loading assembly as shown in figure (a), in order to initiate crack only in the region of the maximum moment that lies in the middle third span measured between the supports.
6. Record the Value of Load and calculate the flexural strength of these beams in MPa. Also, mark the crack with a dark marker pen.
7. Repair these 2 beams using any repair technique and materials suitable for repairing such structural and non-active cracks that are dry in nature.
8. One out of 3 beams will be the Controlled Beam Specimen. This will be used for comparison against repaired beams.
9. Load the controlled beam specimen and 2 Nos. of repaired beam specimens again in the CTM as mentioned in Points No 4 & 5.
10. Record the load at failure and also mark the cracks developed in the beams with a marker.
11. Calculate the flexural strength in MPa for all three beam specimens.

Observations:

1. Cross-section of the beam specimens = B x D =
2. Length of the beam specimens = L =
3. Span of the beam = Le =
4. Distance between the
5. Line of crack and nearest support in cm = a =

Observation Table:

Type of* Beam Specimen	Flexural strength in (MPa) before repair	Width of the crack in (mm) before repair	Type of repair material & technique used to repair	Flexural strength in (MPa) after repair	Width of the crack in (mm) after repair	Remark / Comment on the position of a crack in repaired beams
CB1	-	-	-			-
RB1						
RB2						

***CB1- Controlled beam specimen; RB1 & RB2 – Repaired Beam specimens with respective repair material and technique.**
(Note: Controlled Beam specimen to be loaded and cracked along with the RB1 & RB2 post repair)

Calculation: Show a sample calculation for Flexural Strength

Result:

1. Percentage increase/decrease in the flexural strength of Repaired beam RB1 in comparison to the controlled beam specimen = --------------------
2. Percentage increase/decrease in the flexural strength of Repaired beam RB2 in comparison to the controlled beam specimen = --------------------

Conclusion: Interpret the results and write a conclusion based on the values of flexural strength, position, and width of the cracks. State which repair method appeared to be effective.

Quiz:

1. Draw SFD and BMD for all the 3 beam specimens
2. State the parameters that influence the selection of repair materials for cracks in flexural members.
3. State the reason for not loading the beams till complete failure.

Suggested Reference:

1. Handbook on Repair and Rehabilitation of RCC buildings published by Director General (Works), Central Public Works Department, Government of India, Nirman Bhavan.
2. Poonam I. Modi; Chirag N. Patel, Repair and Rehabilitation of Concrete Structures, PHI Publication.
3. S. Ashok Kumar, M. Santhanam "Detection of concrete damage Using Ultra Sonic Pulse Velocity Methos," Proc. National Seminar on Non-Destructive Evaluation, Hyderabad Chapter.
4. Peter H. Emmons, Concrete Repair and Maintenance Illustrated, Kingston: 1994, R.S. Means Company, Inc.
5. P.C. Varghese, Maintenance Repair & Rehabilitation & Minor Works of Buildings, PHI Learning, 2014

References used by the students: (Duly mention all the references and literature used for the activity below)

Rubric-wise marks obtained:

Performance Indicators	Preparatory works carried out for the experimentatio n	Quality of the beams cast	Interpretation of the results & clarity in concluding statements	Active engagement and cooperation with team members	**Total**
Marks	5	10	10	5	**30**

Experiment No: 4
Assessment of Concrete Strength & Quality of Distressed Beam, Slab & Column for the building in Experiment No.1 Using Rebound Hammer

Date:

Competency and Practical Skills:

1. Skill to carry out the Rapid Visual inspection of signs of distress
2. Ability to tackle the Non-destructive test instruments with caution and care
3. Ability to interpret the output based on relevant resources and articulate the quality of concrete.

Relevant CO: CO1, CO2, CO4

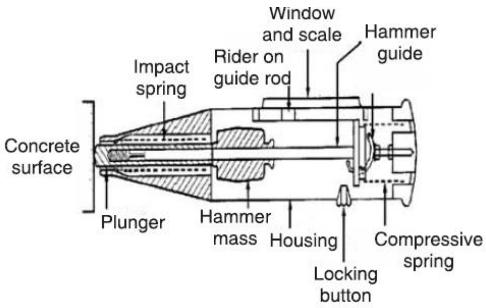
Objectives: (a) To get familiar with the working principle of Rebound Hammer
(b) To enable a thorough understanding of interpretation and relation of values with concrete quality.
.

Equipment/Instruments: Rebound Hammer, grinding stone

Theory: Non-destructive test equipment such as Rebound Hammer and PUNDIT (Portable Ultra Sonic Non-Destructive Digital Indicating Tester) are two of the most important laboratories as well as on-site tools used to evaluate the concrete structure performance and establish compliance for the quality of concrete.

Rebound Hammer Test – The principle of the test is the rebound of an elastic mass depends on the hardness of the surface against which the mass impinges. The compressive strength using Hammer is measured with the Standard Hammer duly calibrated in accordance with IS:13311(Part-I)

Set-up diagram: In the set-up diagram below, the figure (a) represents the Rebound Hammer and its parts and figure (b) represents the Rebound hammer in use.



(a)

(b)

Safety and necessary Precautions:

1. Handle the Rebound hammer with care.
2. Smoothen and level the concrete surface before impinging it with Hammer.
3. If required to use a ladder to reach the element exhibit caution in doing so.

Procedure:

1. Make sure that the Hammer is Calibrated
2. The surface must be smooth, clean, and dry, if trowelled surfaces are unavoidable, smoothen the surface using a grinding stone.
3. Release the plunger before use, it should be pressed strongly and touch the surface in a horizontal, vertical, or inclined position as per the suitability of the site condition. and locked in position.
4. Take a minimum of 6 readings of the area to be tested to get a more accurate value by taking an average of all these 6 readings.
5. The compressive strength of the concrete for the observed Average rebound number should be determined from the Calibration Graph available on the surface of the Rebound Hammer or available with the setup.

Observations:

Observation Table:

Identification* of Structural building/ Element	Rebound No as Noted						Average Rebound No.	Position of Rebound Hammer	Compressive strength Kg/cm^2(MPa)
	R1	R2	R3	R4	R5	R6			
FBi…n									
FCi…n									
FSi…n									
***In the nomenclature F- Indicates the floor i.e., Ground, First, second etc. B, C, S – indicates Beam, Column and Slab; Subscript i is the number of the beam as mapped in Practical No 1**									

Calculation: Show a sample calculation for Average Rebound No and Compressive strength calculation based on Correlation chart.

Result:

1. The lowest compressive strength in MPa was found for which elements? State the reason for the same.--- --- ---

Conclusion: Interpret the results and write a conclusion correlating the strength of concrete as determined in relation to the condition of the element assessed. Also, cite factors that might have influenced the Rebound Number

Quiz:

1. How will you use the Rebound Hammer test on Masonry structures?
2. Will the Dry or wet condition of the substrate affect the Rebound Number? Justify the same.
3. Will the angle of inclination of the hammer affect the Rebound Number? Justify the same.
4. Was the Rebound Hammer used by you, Analogue or Digital?

Suggested Reference:

1. Handbook on Repair and Rehabilitation of RCC buildings published by Director General (Works), Central Public Works Department, Government of India, Nirman Bhavan.
2. Poonam I. Modi; Chirag N. Patel, Repair and Rehabilitation of Concrete Structures, PHI Publication.
3. Guidebook on Non-Destructive Testing of Concrete Structures, ISSN 1018-5518
4. Peter H. Emmons, Concrete Repair and Maintenance Illustrated, Kingston: 1994, R.S. Means Company, Inc.
5. P.C. Varghese, Maintenance Repair & Rehabilitation & Minor Works of Buildings, PHI Learning, 2014

References used by the students: (Duly mention all the references and literature used for activity below)

Rubric-wise marks obtained:

Performance Indicators	Appropriateness of the Site & elements chosen for distress mapping & checking	Dexterity to handle the apparatus	Interpretation of the results & clarity in concluding statements	Active engagement and cooperation with team members	**Total**
Marks	5	10	10	5	**30**

Experiment No: 5
Assessment of Concrete Strength & Quality of Distressed Beam, Slab & Column for the building in Experiment No.1 Using Ultra-Sound Pulse Velocity Test

Date:

Competency and Practical Skills:

1. Skill to identify the relevant distress for which the test can be used.
2. Skill to handle the test equipment in order to avoid erroneous readings.
3. Interpretation of output and skill to recommend the state of the assessed concrete.

Relevant CO: CO1, CO2, CO4

Objectives: (a) To determine the homogeneity, and changes in the structure of concrete with time, to assess the extent and depth of cracks

(b) To understand the principle and workings of the USPV apparatus.

(c) To develop an apt interpretation of the output of this Non-destructive test.

(d) To be able to comprehend the factors that can influence the results and hence the recommendation on the quality of concrete that is assessed.

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Equipment/Instruments: Ultra Sonic Pulse Velocity Meter tester, ladder

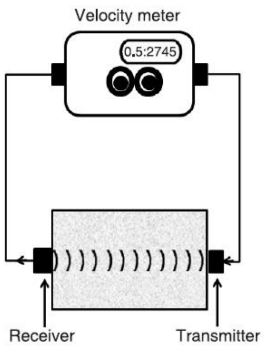
Theory: Non-destructive test equipment such as Rebound Hammer and PUNDIT (Portable Ultra Sonic Non-Destructive Digital Indicating Tester) are two of the most important laboratories as well as on-site tools used to evaluate the concrete structure performance and establish compliance for the quality of concrete.

Ultrasonic pulse velocity Test – The principle of the test is the velocity of an ultrasonic pulse through any material depends upon the density, modulus of elasticity, presence of reinforcing steel, and Poisson's ratio of the material. The equipment consists of a Transducer, a receiver, and an indicator for showing the time of travel from the transducer to the receiver.

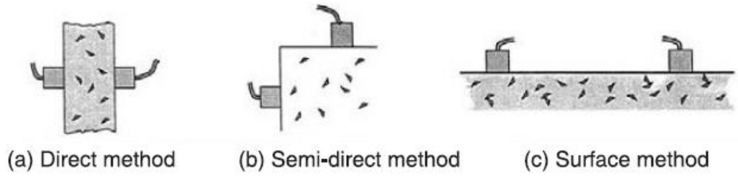
A pulse of longitudinal vibration is produced by an electro-acoustical transducer, which is held in contact with one surface of the concrete member under test. After traversing a known path length (L) in the concrete, the pulse of vibration is converted into an electrical signal by a second electro-acoustical transducer, and electronic timing circuit enables the transit time (T) of the pulse to be measured. The pulse velocity (V) is given by:

$V = L/T$, where V is the pulse velocity in km/s; L is the path length in cm; T is the transit time in µs.

Setup diagram: In the set-up diagram below, the figure in (a) represents the setup of the USPV tester and figure in (b) represents the methods of conducting the USPV test based on availability of the sides of the components to be assessed.



(a)



(b)

Safety and necessary Precautions:

1. Ensure to maintain good contact between concrete surfaces and transducers.
2. Be careful while accessing the concrete surface through the ladder.
3. Ensure a minimum path length of 150 mm and 400 mm for direct and indirect testing.

Procedure:

1. Identify and properly clean the surface of the concrete to be assessed.
2. Identify the points of application of two ends of the USPV tester.
3. Apply the acoustical coupling material provided with the setup or any other material such as petroleum jelly, grease, liquid soap, or kaolin glycerol to both the transducer and the receiver.
4. Attach the transmitting and the receiving ends to the identified points of application in a direct, indirect, or semi-direct manner based on the availability of surface sides.
5. If the surface is rough, then smoothen and level it prior to placing the transducers.
6. Note down the path length (L).
7. Switch on the mains and allow the ultrasonic pulses to be generated, transmitted, and received based on the denseness and homogeneity of the concrete under assessment.
8. Note down the Transit Time (T) as displayed on the unit of USPV tester.
9. Calculate the ultrasonic pulse velocity in km/sec.
10. Repeat the Steps 1-8 for all the other identified distressed components.
11. Determine the quality of the concrete based on the values of velocity as per the table given below:

Sr. No.	Pulse velocity in km/s	Quality grade of concrete
1	Above 4.5	Excellent
2	3.5-4.5	Good
3	3.0-3.5	Medium
4	< 3.0	Poor

Observation Table:

Identification* of Structural building/ Element	Path length / Thickness (mm)	Time as on USPV (μs)	Velocity observed (km/sec)	Corrected velocity in (km/sec) for an indirect method	Quality of concrete
FBi…n					
FCi…n					
FSi…n					
***In the nomenclature F- Indicates the floor i.e., Ground, First, second, etc. B, C, S – indicates Beam, Column, and Slab; Subscript i is the number of the beam as mapped in Practical No 1**					

Calculation: Show a sample calculation for the ultrasonic pulse velocity.

Result:

1. The highest pulse velocity was found for which elements? State the reason for the same.

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2. The lowest pulse velocity was found for which elements? State the reason for the same.

Conclusion: Interpret the results and write a conclusion correlating the quality of concrete as determined in relation to the condition of the element in terms of denseness, homogeneity or presence of internal flaws, cracks, and segregation etc.

Quiz:

1. State the limitations of this test
2. Identify the reasons for the values observed in accordance with IS 516-Part V-Section1
3. Can USPV be used to test quality of masonry. Justify your answer.
4. What factors can influence the value of USPV?
5. Is there any relationship between USPV and Compressive strength of concrete. Identify and cite the relevant resource of this relation.

Suggested Reference:

1. Handbook on Repair and Rehabilitation of RCC buildings published by Director General (Works), Central Public Works Department, Government of India, Nirman Bhavan.
2. Poonam I. Modi; Chirag N. Patel, Repair and Rehabilitation of Concrete Structures, PHI Publication.
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