Program Name : **Civil Engineering Program Group**

Program Code : **CE/CR/CS**

Semester : **Sixth**

Course Title : **Maintenance and Repairs of Structures**

Course Code : **22602**

1. RATIONALE

It is absolutely necessary to maintain the building structure in order to preserve the assets and protect the building 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.

2. COMPETENCY

The aim of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

- **Maintain different types of building structures.**

3. COURSE OUTCOMES (COs)

The theory, 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*** COs associated with the above mentioned competency:

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.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme			Credit (L+T+P)	Examination Scheme													
				Theory							Practical						
L	T	P		Paper Hrs.	ESE		PA		Total		ESE		PA		Total		
					Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	
4	-	2	6	3	70	28	30*	00	100	40	25#	10	25	10	50	20	

(*): Under the theory PA; Out of 30 marks, 10 marks of theory PA are for micro-project assessment to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessment of the UOs required for the attainment of the COs.

Legends: ***L****-Lecture;* ***T*** *– Tutorial/Teacher Guided Theory Practice;* ***P*** *- Practical;* ***C*** *– Credit,* ***ESE*** *- End Semester Examination;* ***PA*** *- Progressive Assessment.*

5. COURSE MAP (with sample COs, PrOs, UOs, ADOs and topics)

This course map illustrates an overview of the flow and linkages of the topics at various levels of outcomes (details in subsequent sections) to be attained by the student by the end of the course, in all domains of learning in terms of the industry/employer identified competency depicted at the centre of this map.

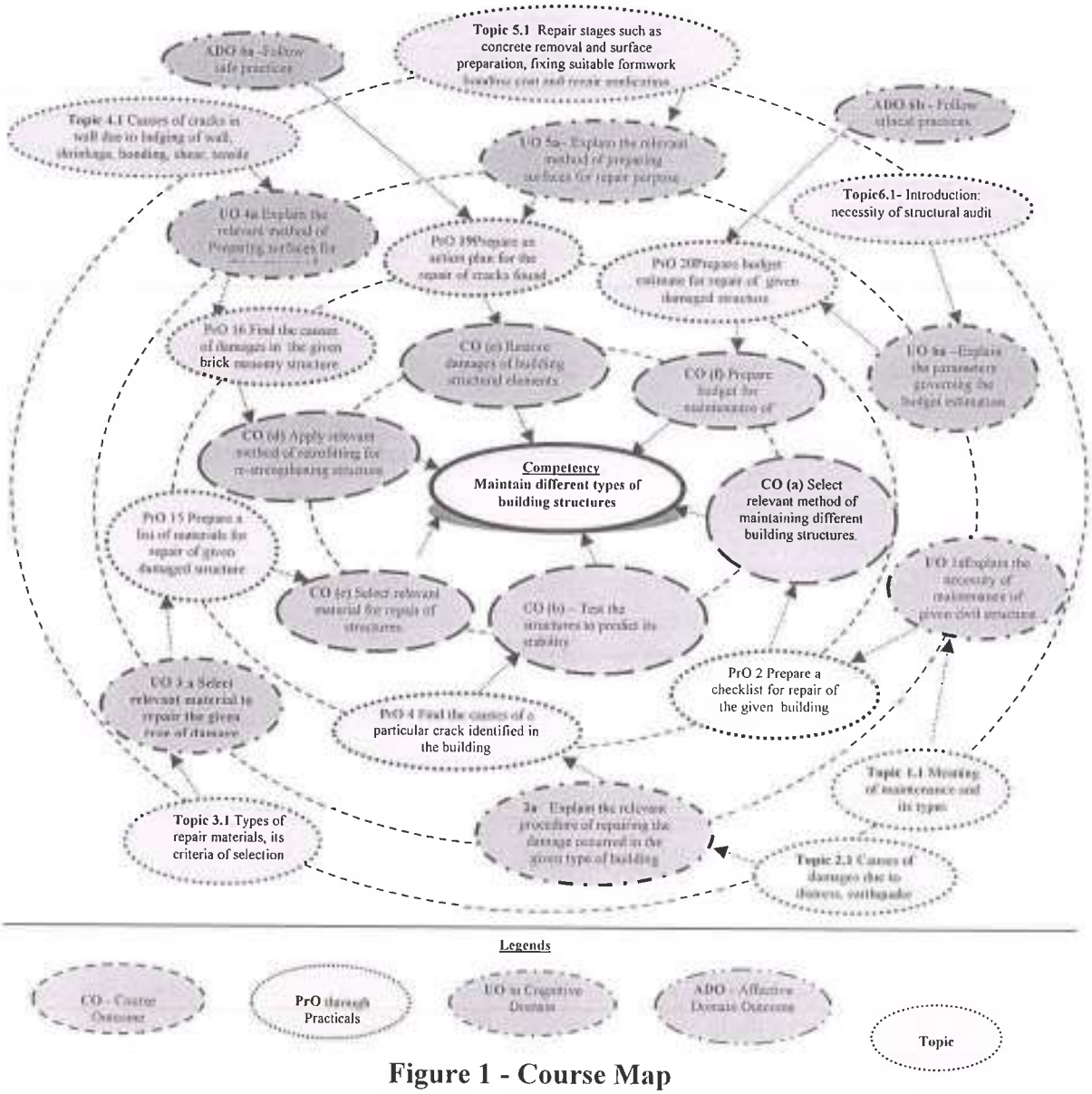

Figure 1 - Course Map

6. SUGGESTED PRACTICALS/ EXERCISES

The practical's in this section are PrOs (i.e. sub-components of the COs) to be developed and assessed in the student for the attainment of the competency.

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1	Find the **causes of damages** for the given building elements.	I	02*
2	Prepare the **check list** for materials required for repair of load bearing building and framed building.	I	02
3	Prepare a **check list** for repair of a load bearing building and framed building.	I & II	02

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
4	Determine the compressive strength of any two structural elements such as column, beam, slab etc for damaged or undamaged structure using **Rebound Hammer.**	II	04*
5	Determine the **extent of efflorescence** in masonry or concrete for damaged or undamaged structure.	II	02*
6	Determine the crack nature of any two structural elements such as column, beam, slab etc. for damaged structure using **Ultrasonic Pulse Velocity test.**	II	02
7	Determine the bond strength of any one structural element such as column, beam, and slab etc. using **pull out test.**	II	02
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.	II	02
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.	II	02*
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.	II	02*
11	Determine the moisture content using **Moisture Meter** of any two structural elements such as column, beam, slab etc. for damaged or undamaged structure.	II	02
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.	II	02
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.	II	02
14	Prepare a list of material requirements and check list for repair of wall cracks as per the damages found.	III	02
15	Prepare a report on damage assessment of non-residential structures such as dams, bridges, industrial buildings etc.	IV	02*
16	Prepare a check list for repair and material requirement for flooring of given structure.	IV	02
17	Prepare a check list for materials required and resources for repair of sanitary unit of the building.	IV	02
18	Repair the cracks for a damaged plane concrete member of size of 100×100×500 mm or 150×150×750 mm	V	02
19	Prepare a budget estimation considering materials, task force, equipment's and methodology for the given damaged structure.	VI	02*
20	Determine the flexural strength of repaired beam in practical no 18.	IV & V	02
	Total		**40**

Note

i. *A suggestive list of **PrOs** is given in the above table. More such PrOs can be added to attain the COs and competency. A judicial mix of minimum 12 or more practical UOs/tutorials need to be performed, out of which, the practicals marked as '*' are*

compulsory, so that the student reaches the 'Precision Level' of Dave's 'Psychomotor Domain Taxonomy' as generally required by the industry.

ii. *The 'Process' and 'Product' related skills associated with each PrO is to be assessed according to a suggested sample given below:*

S. No.	Performance Indicators	Weightage in %
1	Interpretation of given data and its presentation.	10
2	Selection of materials /Process of repairing of the given structural non structural components /writing of visit report.	30
3	Precision in check list for material list/equipment list and report and its neatness, cleanliness.	30
4	Individual work and working in groups	20
5	Submission of assigned work in time	10
Total		**100**

The above PrOs also comprise of the following social skills/attitudes which are Affective Domain Outcomes (ADOs) that are best developed through the laboratory/field based experiences:

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

The ADOs are not specific to any one PrO, but are embedded in many PrOs. Hence, the acquisition of the ADOs takes place gradually in the student when s/he undertakes a series of practical experiences over a period of time. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

- 'Valuing Level' in 1st year.
- 'Organization Level' in 2nd year.
- 'Characterization Level' in 3rd year.

7. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

The major equipment with broad specifications mentioned here to retain uniformity in conduct of experiments, as well as aid to procure equipment by administrators

S. No.	Equipment Name with Broad Specifications	PrO. S. No.
1	Universal Testing machine of capacity 400kN,600 kN/1000kN, analog type/digital type with all attachments and accessories.	4,7, 20
2	Compression testing machine of capacity 2000KN, analog /digital type having facility to measure deformation with all attachments and accessories.	4,13
3	Rebound Hammer: Manual Test Hammer of W-M-250, BS-1881-202, weight: 2.7 kg, size: 127 x 76 x 355 mm, shipping weight: 2.7 kg and minimum verifiable strength is 10 MPa to 62 MPa.	8
4	Ultrasonic Pulse Velocity test apparatus: range 0.1-7930 µs, resolution: 0.1 µs to 1 µs, display 7", color 800 x 480, pulse voltage100 – 450 Vpp, bandwidth 20 – 500 kHz	6
5	Cover gauge: concrete thickness gauge model of CTG-2 (Concrete Thickness Gauges), battery powered, ASTM Standard, frequency resolution 10Hz,	10

S. No.	Equipment Name with Broad Specifications	PrO. S. No.
	thickness range 81 mm to 50.8 cm in standard mode.	
6	Rapid chloride test apparatus: RCPT Apparatus is as per ASTM C 1202-05. 4 Port (230~250V AC power supply), plexi-glass chambers - 4 pairs,500mm vacuum desiccator, consumables - good for 1 doz	9
7	Crack detection microscope: magnification = x 35, measuring Range = 4 mm, divisions = 0.02mm, weight including battery and box = 560gm, box dimensions = 150 x 100 50mm deep	6
8	Rebar locator: Model: GMS 120 professional, weight: 0.27 KG, detection depth for steel max : 120 mm and for copper max 80 mm	8
9	Moisture meter: as per IS 12175 code practices	11
10	Half-cell potentiometer; voltage 220, electric power source, frequency 50 Hz, corrosion monitoring technique standardized by ASTM	12
11	Water permeability meter: as per IS 5529(Part 2):2006 in-situ permeability test, two versions available: with gaskets for 150 mm cube specimens **as 55-C0246/3** three place model and **55-C0246/6** six place model, air compressor, max. working pressure 8 bar.	15
12	Extensometer with least count 0.01mm, maximum extension 25 mm with single dial gauge/ digital display suitable for various gauge length	13,14

8. UNDERPINNING THEORY COMPONENTS

The following topics/subtopics should be taught and assessed in order to develop UOs in cognitive domain for achieving the COs to attain the identified competency. More UOs could be added.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit – I Basics of maintenance and repairs	1a. Explain the necessity of maintenance and repairs of the civil structure. 1b. Know the factors that influence on maintenance of given structure with justification. 1c. Explain the concept of retrofitting, re-strengthening, rehabilitation, and restoration 1d. Know the periodical maintenance and its manual, monsoon maintenance, maintenance history sheet.	1.1. Maintenance and its classifications, repair, retrofitting, re-strengthening, rehabilitation and restoration. 1.2. Necessity, objectives and importance of maintenance and repairs. 1.3. Factors influencing the maintenance and repairs 1.4. Advantages and limitations of maintenance and repairs. 1.5. Approach of effective management for maintenance and repairs. 1.6. Periodical maintenance, maintenance manual containing building plan, reinforcement details, material sources, maintenance frequency, pre and post monsoon maintenance.
Unit– II Causes and detection of damages	2a Explain the causes of damages occurred in the given structures. 2b Know the systematic approach of damages	2.1 Causes of damages due to distress, earthquake, wind, flood, dampness, corrosion, fire, dilapidation, termites 2.2 Systematic approach of damages detection, various aspects of visual

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	detection 2c Explain non-destructive test with respect to the given damaged structural elements 2d Explain the procedure of non-destructive test used to detect the damages.	observations for detection of damages. 2.3 Tests on damaged structures: rebound hammer, ultrasonic pulse velocity, rebar locator, cover gauge, crack detection microscope, chloride test, sulphate attack, pH measurement, half-cell potential meter.
Unit III- Materials for maintenance and repairs	3a. Select the relevant materials to repair the given type of damages with justification. 3b. Explain the suitable materials for the anti-corrosion, adhesives and mortar repairs. 3c. Explain the relevant materials for waterproofing, and joint sealants for the repairing of given structure. 3d. Explain the relevant materials for surfacing coating and grout for the repairing of given structure. 3e. Choose the relevant materials for the repair of damaged structures with justification.	3.1 Factors influencing the material selection for maintenance and repairs. 3.2 Anti-corrosion coating materials: cement slurry mortar, polymer modified cement slurry and epoxy zinc. 3.3 Adhesives materials: solvent free adhesives: epoxy adhesive, polyester adhesive, acrylic adhesive and water borne adhesives: polyvinyl acetate and vinyl acetate co-polymer. 3.4 Mortar repair materials: cementitious mortar, polymer modified cementitious mortar and resin mortar. 3.5 Joint sealants materials: oleo resinous mastics, bitumen/rubber based sealants and acrylic resin sealant. 3.6 Grout materials: cement grout, cement sand grout, cement sand grout with additives, polymer modified cement grout and normal epoxies. 3.7 Waterproofing roof materials: polyisobutylene (PIP) sheet, glass fiber reinforced plastics, bitumen and bituminous emulsion and latex cement coating. 3.8 Surface coating materials for concrete protection: bituminous cutbacks, chlorinated rubber coating, Vinyl coatings, epoxy coating and coal tar epoxy. 3.9 Additional repairing materials: plastic or aluminum nipples, polyester putty or 1:3 cement sand mortar and galvanized steel wire fabrics & clamping rods.
Unit –IV Maintenance and repair methods for masonry	4a. Explain the various causes of wall cracks and their probable locations 4b. Select the relevant repair techniques for the damages in the given civil structures with justification. 4c. Explain the repairing	4.1 Causes of wall cracks due to bulging of wall, shrinkage, bonding, shear and tension, differential settlement of foundation, thermal movement and vegetation. 4.2 Probable crack location such as junction of main & cross wall, junction of RCC column & wall, junction of slab & wall,

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	methods for the different crack types for the given structure. 4d. Explain the damping effect and its repair techniques 4e. Explain the various methods of improving the bearing capacity of foundation	cracks in masonry joints. 4.3 Stages of repair: material removal and surface preparation, fixing suitable formwork, bonding/passivating coat and repair applications. 4.4 Repair techniques: grouting, patch spalling replacement or delaminating and epoxy bonded mortar. 4.5 Repairing methods for minor & medium cracks include epoxy injection, grooving & sealing, shotcrete, stitching, grouting and guniting. 4.6 Repairing methods for major cracks (width more than 5mm) include fixing mesh across cracks, dowel bars, RCC band and installing ferro-cement plates at corners and propping. 4.7 Effects of dampness in wall, damping repair techniques such as replacement or inserting DPC in brick wall, bituminous painting, painting using water proof solution and cement with adhesive gum. 4.8 Causes and remedies of foundation settlement, improvement techniques by compaction, intruding sand piles, stone columns and grouting cement slurry.
Unit –V Maintenance and repair methods for RCC	5a. Explain the probable crack location in RCC and causes of RCC failure 5b. Explain the causes of dampness in roof slab and its various repair techniques 5c. Know the repair methods for the cracked RCC elements 5d. Explain the relevant repair methods for cracks in RCC structures 5e. Know the repair of corroded RCC elements, honeycomb and large voids in the given structure	5.1 Probable location of cracks in RCC elements, various causes of RCC failure. 5.2 Causes of dampness in roof slab and its repair techniques such as mud phuska with brick tile topping, lime concrete terracing, ferro-cement topping and brick coba. 5.3 Repair methods for cracks in RCC structures such as epoxy injection, grooving & sealing, stitching, rebaring, grouting, spalling replacement, jacketing, shotcrete and gunitting. 5.4 Repair of corroded RCC element: exposing and undercutting rebar, cleaning reinforcing steel, compensating reinforcement and protective coating. 5.5 Repair methods for honeycomb and larger voids.
Unit –VI Structural audit and Budget	6a. Explain the necessity and importance of structural audit & budget estimation 6b. Explain the procedure involved in structural audit and budget estimation	6.1 Necessity and importance of structural audit and budget estimation. 6.2 Distress survey, detailed inspection, recommendations for budget estimation. 6.3 Steps involved in structural audit and budget estimation.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	6c. Explain the step-by-step procedure for maintenance of the given structure. 6d. Know the formats preparation for the process of structural audit and budget preparation 6e. Explain the rules & regulations of structural audit and budget estimation as recommended by competent authority.	6.4 Format preparation for structural audit including general information of building, building data, complain reported by users, inspection of internal and external areas of building. 6.5 Overview on rules and regulations of structural audit and budget estimation as recommended by competent authority such as Public Work Department.

***Note**: To attain the COs and competency, above listed UOs need to be undertaken to achieve the 'Application Level' of Bloom's 'Cognitive Domain Taxonomy'.*

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Basics of maintenance and repairs	06	04	04	0	08
II	Causes and detection of damages	10	02	04	04	10
III	Materials for maintenance and repairs	10	02	08	04	14
IV	Maintenance and repair methods for masonry	12	02	04	06	12
V	Maintenance and repair methods for RCC	14	02	06	06	14
VI	Structural audit and budget	12	02	04	06	12
Total		**64**	**14**	**30**	**26**	**70**

***Legends:** R=Remember, U=Understand, A=Apply and above (Bloom's Revised taxonomy)*
***Note**: This specification table provides general guidelines to assist student for their learning and to teachers to teach and assess students with respect to attainment of UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may vary from above table.*

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should conduct following activities in group and prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews:

a) Collect six photographs of different types of damages in Masonry works in the area where student resides. Do the diagnosis of the ailments, suggest the remedial measures.
b) Collect six photographs of different types of damages in RCC works in the area where student resides. Do the diagnosis of the ailments, suggest the remedial measures.

c) Collect the brand names and uses of repair materials available in the market in the area where student resides.
d) Download the videos related to the repairs of water leakages of RCC water tank, plumbing works, sanitary works, flooring repairs, door and window frames/panels repairs.
e) Prepare a power point presentation on the activity (d)
f) Carrying a Repairing work of spalling of plaster from a ceiling.
g) Analyzing light and ventilation of a room having common walls and suggesting remedies.
h) Prepare journals based on practical performed in laboratory.
i) Give seminar on relevant topic.
j) Undertake micro-projects.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various learning outcomes in this course:

a) Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.
b) ***'L' in item No. 4*** does not mean only the traditional lecture method, but different types of teaching methods and media that are to be employed to develop the outcomes.
c) About ***15-20% of the topics/sub-topics*** which is relatively simpler or descriptive in nature is to be given to the students for ***self-directed learning*** and assess the development of the COs through classroom presentations (see implementation guideline for details).
d) With respect to item No.10, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
e) Guide student(s) in undertaking micro-projects.
f) Demonstrate students thoroughly before they start doing the practice.
g) Encourage students to refer different websites to have deeper understanding of the subject.
h) Observe continuously and monitor the performance of students in Lab.
i) Demonstrate students thoroughly before they start doing the practice.
j) Encourage students to refer different websites to have deeper understanding of subject.

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project are group-based. However, in the fifth and sixth semesters, it should be preferably be ***individually*** undertaken to build up the skill and confidence in every student to become problem solver so that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should ***not exceed three.***

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The total duration of the micro-project should not be less than ***16 (sixteen) student engagement hours*** during the course. The student ought to submit micro-project by the end of the semester to develop the industry oriented COs.

A suggestive list of micro-projects is given here. Similar micro-projects could be added by the concerned faculty

a) Collect the information of various materials used in actual practice for repairs of cracks.

b) Collect the details of various types of the agencies working for repairs and maintenance of structures in actual practice.
c) Collect the details of new techniques used for repair.
d) Compare damages caused by various natural hazards.
e) Prepare a budget with respect to material, task force, equipment's and methodology for the historical structure in your vicinity.
f) Prepare collection of photographs showing various types of cracks in damaged structures.
g) Carry out market survey for at least five materials used for repairs with respect specification, supplier, packaging and costing.
h) Cast three RCC beams and three plain concrete beams and find the various types of cracks by applying one point load, two point loads etc. and find the flexural strength.
i) Repair the above beams and find out the strength regained by the beams.
j) Suggest the repair material and methods for the above beam as per type of crack developed.
k) Micro projects relevant on topics as per the guidance subject teacher.

13. SUGGESTED LEARNING RESOURCES :

S. 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

14. SOFTWARE/LEARNING WEBSITES

a) https://www.youtube.com/watch?v=7ypSU6ZDJlwhttps://www.youtube.com/watch?v=zX8HNbHmToM
b) https://www.youtube.com/watch?v=zZsstKuFl4s
c) https://www.youtube.com/watch?v=zXg1x8BXR-Y
d) https://www.youtube.com/watch?v=EmmzpQd5I0E
e) https://www.youtube.com/watch?v=ANORiqAJ7kc
f) https://www.youtube.com/watch?v=Zp4f_ReeSO0
g) https://www.youtube.com/watch?v=wPBq0yVLEa8
h) https://www.youtube.com/watch?v=lqwtoHpWgbU
i) https://www.youtube.com/watch?v=y1rOtvvxRzY
j) https://www.youtube.com/watch?v=q_JeGja1Yb4
k) https://www.youtube.com/watch?v=tztOejzcGEo
l) https://www.youtube.com/watch?v=eEXAWukRfD4
m) https://www.youtube.com/watch?v=CJUDJk1fFb0
n) https://i.ytimg.com/an_webp/reuxFdNJcLk/mqdefault_6s.webp?du=3000&sqp=CILn4ewF&rs=AOn4CLC_MQ_GI3_HKKE-zVEilBfG0gSwFA