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MAINTENANCE AND REPAIRS OF STRUCTURES **Course Code : 316309**

Programme Name/s	**: Civil Engineering/ Civil & Rural Engineering/ Construction Technology/ Civil & Environmental Engineering/**
Programme Code	**: CE/ CR/ CS/ LE**
Semester	**: Sixth**
Course Title	**: MAINTENANCE AND REPAIRS OF STRUCTURES**
Course Code	**: 316309**

I. RATIONALE

A newly constructed structure, if not maintained properly leads to manifold losses such as reduced life of building, increased cost of repairs etc. Therefore, building maintenance work is assumed to be the backbone of ensuring the safety, longevity, functionality, enhanced property value and aesthetic appeal of structures and prevent costly repairs. It encompasses a spectrum of tasks and services aimed at preventing deterioration, addressing wear and tear, and promoting a safe and comfortable environment for the residents. It also subsumes regular inspections, repairs, and upkeep tasks designed to identify and address any structural issues, such as wear and tear, corrosion, or damage. A civil engineer is expected to have the knowledge of these areas and should be then capable of conducting the structural audit of building for enhancing the life of the building in the light of the prevailing legal framework. Therefore, this course emphasizes to develop the basic competency among the diploma students to apply the relevant methods and principles required for repairing and maintenance of building.

II. INDUSTRY / EMPLOYER EXPECTED OUTCOME

The aim of this course is to help the student to attain the following industry identified outcome through various teaching learning experiences: Maintain the given structure through relevant method of repairs.

III. COURSE LEVEL LEARNING OUTCOMES (COS)

Students will be able to achieve & demonstrate the following COs on completion of course based learning

- CO1 - Justify the need of repairs and maintenance for the given structure.
- CO2 - Undertake the Non-Destructive Testing (NDT) to carry structural audit of structures.
- CO3 - Propose the relevant materials for undertaking the repair of given structures.
- CO4 - Apply the relevant method of repair for the masonry work.
- CO5 - Suggest the relevant method of repair to regain the strength of the given RCC component.

IV. TEACHING-LEARNING & ASSESSMENT SCHEME

Course Code	Course Title	Abbr	Course Category/s	Learning Scheme					Credits	Assessment Scheme												
				Actual Contact Hrs./Week			SLH	NLH		Paper Duration	Theory				Based on LL & TL				Based on SL		Total Marks
															Practical							
				CL	TL	LL					FA-TH	SA-TH	Total		FA-PR		SA-PR		SLA		
											Max	Max	Max	Min	Max	Min	Max	Min	Max	Min	
316309	MAINTENANCE AND REPAIRS OF STRUCTURES	MRS	DSC	4	-	2	-	6	3	3	30	70	100	40	25	10	-	-	-	-	125

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Total IKS Hrs for Sem. : 2 Hrs
Abbreviations: CL- ClassRoom Learning , TL- Tutorial Learning, LL-Laboratory Learning, SLH-Self Learning Hours, NLH-Notional Learning Hours, FA - Formative Assessment, SA -Summative assessment, IKS - Indian Knowledge System, SLA - Self Learning Assessment
Legends: @ Internal Assessment, # External Assessment, *# On Line Examination , @$ Internal Online Examination
Note :

1. FA-TH represents average of two class tests of 30 marks each conducted during the semester.
2. If candidate is not securing minimum passing marks in FA-PR of any course then the candidate shall be declared as "Detained" in that semester.
3. If candidate is not securing minimum passing marks in SLA of any course then the candidate shall be declared as fail and will have to repeat and resubmit SLA work.
4. Notional Learning hours for the semester are (CL+LL+TL+SL)hrs.* 15 Weeks
5. 1 credit is equivalent to 30 Notional hrs.
6. * Self learning hours shall not be reflected in the Time Table.
7. * Self learning includes micro project / assignment / other activities.

V. THEORY LEARNING OUTCOMES AND ALIGNED COURSE CONTENT

Sr.No	Theory Learning Outcomes (TLO's)aligned to CO's.	Learning content mapped with Theory Learning Outcomes (TLO's) and CO's.	Suggested Learning Pedagogies.
1	TLO 1.1 Explain the necessity of maintenance and repairs of the civil structure. TLO 1.2 Classify the maintenance based on given criteria. TLO 1.3 Discuss the factors influencing maintenance of given structure with justification. TLO 1.4 Implement the instructions provided in maintenance manual for the given structure.	**Unit - I Basics of Maintenance and Repairs** 1.1 Maintenance and Repairs-Definition, Necessity, Objectives, Importance. 1.2 Types of maintenance based on interval- Routine, Periodic, Annual maintenance, Types of maintenance based on season- Pre-monsoon and Post monsoon maintenance, Types of repairing technique, Retrofitting, Re-strengthening, Rehabilitation, Restoration. 1.3 Factors influencing, advantages and limitations of maintenance and repairs of structures. 1.4 Approach of effective team management for maintenance and repairs. Details of maintenance manual of building. (IKS*: Restoration of Sun Temple in Konark Ajanta and Ellora caves, Taj Mahal.)	Lecture Using Chalk-Board Video Demonstrations Presentations Demonstration
2	TLO 2.1 Identify the cause of damage occurred in the given structure. TLO 2.2 Detect the damages in structure using visual observation method. TLO 2.3 Undertake the non-destructive test (NDT) for measuring the given type of damage. TLO 2.4 Carry out the structural audit for given structure using the prescribed formats.	**Unit - II Causes, Detection & Estimation of Damages** 2.1 Causes of damages in structures- distress, earthquake, wind, flood, dampness, corrosion, fire, dilapidation, termites. 2.2 Systematic approach of damage detection, various aspects of visual observations for detection of damages. 2.3 Tests on damaged structures: rebound hammer, ultrasonic pulse velocity, rebar locator, cover gauge, crack detection microscope, Endoscope, chloride test, sulphate attack, pH measurement, half-cell potential meter. 2.4 Structural Audit- Objectives, Budget estimation, Steps involved Applicable Formats, Competent authorities, Rules and regulations.	Lecture Using Chalk-Board Video Demonstrations Site/Industry Visit Case Study

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Sr.No	Theory Learning Outcomes (TLO's)aligned to CO's.	Learning content mapped with Theory Learning Outcomes (TLO's) and CO's.	Suggested Learning Pedagogies.
3	TLO 3.1 Select the relevant materials to repair the given type of damages with justification. TLO 3.2 Justify the suitability of given type of anti-corrosive/mortar repairing material. TLO 3.3 Suggest the type of grout for given type of repairing work. TLO 3.4 Explain the use of adhesives/ joint sealants for the repairing of given structure. TLO 3.5 Choose the relevant waterproofing materials for given type of leakage with justification.	**Unit - III Materials for Maintenance and Repairs** 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. Surface coating materials- bituminous cutbacks, chlorinated rubber coating, Vinyl coatings, epoxy coating and coal tar epoxy. 3.3 Mortar repair materials- cementitious mortar, polymer modified cementitious mortar and resin mortar. Grout materials- cement grout, cement sand grout, cement sand grout with additives, polymer modified cement grout and normal epoxies. 3.4 Adhesives materials- solvent free adhesives, epoxy adhesive, polyester adhesive, acrylic adhesive and water borne adhesives: polyvinyl acetate and vinyl acetate co-polymer Joint sealants materials- oleo resinous mastics, bitumen/rubber-based sealants and acrylic resin sealant. 3.5 Waterproofing roof materials- polyisobutylene (PIP) sheet, glass fiber reinforced plastics, bitumen and bituminous emulsion and latex cement coating. (IKS*: Use of natural material for repairs like mud, clay, lime, jaggery, cow dung, neem oil.)	Lecture Using Chalk-Board Video Demonstrations Presentations Model Demonstration
4	TLO 4.1 Identify the location of the masonry cracks mentioning its cause to suggest the remedial measures for the same. TLO 4.2 Organize the sequential steps involved in repairing of masonry work of given structure. TLO 4.3 Explain the repairing methods for the different crack types for the given structure. TLO 4.4 Carry out the repairs of minor/medium cracks using the relevant method with appropriate material. TLO 4.5 Carry out the repairs of major cracks using the relevant method with appropriate material.	**Unit - IV Maintenance and Repair of Masonry Work** 4.1 Causes of wall cracks- Bulging, shrinkage, bonding, shear and tension, differential settlement of foundation, thermal movement and vegetation. Locations of crack in masonry- junction of main & cross wall, junction of RCC column & wall, junction of slab & wall, cracks in masonry joints. 4.2 Stages of repairing: material removal and surface preparation, fixing suitable formwork, bonding/passivating coat and repair applications. 4.3 Repair techniques: grouting, patch spalling replacement or delaminating and epoxy bonded mortar. 4.4 Repairing methods for minor & medium cracks include epoxy injection, grooving & sealing, shotcrete, stitching, grouting and guniting. 4.5 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.	Lecture Using Chalk-Board Video Demonstrations Presentations Site/Industry Visit

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Sr.No	Theory Learning Outcomes (TLO's)aligned to CO's.	Learning content mapped with Theory Learning Outcomes (TLO's) and CO's.	Suggested Learning Pedagogies.
5	TLO 5.1 Explain location and causes of failure of RCC building elements. TLO 5.2 Explain the repairing method of dampness in roof slab. TLO 5.3 Illustrate the repair methods for the cracked RCC elements. TLO 5.4 Explain the relevant repair methods for corroded RCC elements. TLO 5.5 Suggest the relevant repair technique of honeycomb and large voids in the given RCC component.	**Unit - V Maintenance and Repair of Concrete Work** 5.1 Cracks in RCC elements-Locations, causes of RCC building elements. 5.2 Causes of dampness in roof slab, repair techniques of dampness- 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 of honeycomb and larger voids in RCC components.	Lecture Using Chalk-Board Video Demonstrations Presentations Site/Industry Visit

VI. LABORATORY LEARNING OUTCOME AND ALIGNED PRACTICAL / TUTORIAL EXPERIENCES.

Practical / Tutorial / Laboratory Learning Outcome (LLO)	Sr No	Laboratory Experiment / Practical Titles / Tutorial Titles	Number of hrs.	Relevant COs
LLO 1.1 Draft the maintenance strategies for given building.	1	Prepare the site visit report on pre-monsoon and post-monsoon maintenance strategies for given building.	2	CO1
LLO 2.1 Identify the damages and relevant remedial strategies of an existing building.	2	*Prepare the detailed photographic report on damages observed during the visit to suggest the remedial measures.	2	CO2
LLO 3.1 Identify the damages and relevant remedial strategies of non-residential structure.	3	*Prepare a photographic report on damage assessment and remedial measures of any one dam/bridge/industrial building.	2	CO2
LLO 4.1 Determine the strength and homogeneity of given structural elements using NDT.	4	*Determine the compressive strength of beam, column or slab of damaged or undamaged structure using Rebound Hammer at minimum 6 locations.	2	CO2
LLO 5.1 Determine the strength and homogeneity of given structural elements using NDT.	5	Determine the compressive strength of beam, column or slab using Ultrasonic Pulse Velocity test at minimum 3 locations.	2	CO2
LLO 6.1 Identify the location of reinforcing bar of the given RCC element using Rebar Locator.	6	Determine the dimensions and location of reinforcing bars of beam, column or slab using Rebar locator.	2	CO2
LLO 7.1 Determine the chloride extent in the given RCC element using Rapid Chloride Test.	7	Determine maximum chloride content in beam, column or slab in percent by weight of cement using Rapid Chloride Test. (Use cube if coring is not possible.)	2	CO2
LLO 8.1 Determine the deterioration of the given RCC element using phenolphthalein indicator.	8	Determine the depth of carbonation of beam, column or slab using phenolphthalein indicator.	2	CO2

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Practical / Tutorial / Laboratory Learning Outcome (LLO)	Sr No	Laboratory Experiment / Practical Titles / Tutorial Titles	Number of hrs.	Relevant COs
LLO 9.1 Predict the susceptibility of the RCC member against the dampness.	9	Determine the moisture content of beam, column or slab using Digital Moisture Meter.	2	CO2
LLO 10.1 Determine the corrosion extent in the given RCC member using Half-cell Potentiometer.	10	Determine the corrosion extent of reinforcing bar of beam, column or slab using Half-cell Potentiometer.	2	CO2
LLO 11.1 Identify the nature of efflorescence in given type of structure.	11	Determine the extent of efflorescence at minimum 3 locations in given damaged or undamaged masonry or concrete structure.	2	CO2
LLO 12.1 Predict the stability of existing building structure under consideration.	12	*Prepare the structural audit report mentioning budget estimation, task force, equipment's and methodology for the given damaged structure.	2	CO2
LLO 13.1 Compare the repairing materials in terms of various criterion.	13	*Prepare the check list of required materials with current market rates required for repair of the given damaged load bearing or framed structure.	2	CO3
LLO 14.1 Undertake the repairing of plaster the given masonry.	14	*Prepare the visit report on materials and techniques required for repairing of spalling/delamination of plaster by visit/demo video.	2	CO4
LLO 15.1 Undertake the repairing of leakage in the given sanitary unit.	15	*Prepare the visit report on repairing of roof slab/ sanitary unit using any one technique to remove leakage.	2	CO5

Note : Out of above suggestive LLOs -

- '*' Marked Practicals (LLOs) Are mandatory.
- Minimum 80% of above list of lab experiment are to be performed.
- Judicial mix of LLOs are to be performed to achieve desired outcomes.

VII. SUGGESTED MICRO PROJECT / ASSIGNMENT/ ACTIVITIES FOR SPECIFIC LEARNING / SKILLS DEVELOPMENT (SELF LEARNING)

Micro project

- Collect ten photographs of different types of damages in Masonry / RCC works in the area where student resides. Do the diagnosis of the ailments, suggest the remedial measures.
- Prepare the report on suggestion of the repair material and methods for the RCC beam as per type of crack developed.
- Prepare the budget with respect to material, task force, equipment's and methodology for the historical structure in your vicinity.
- Collect the details of advanced techniques used for repairing of masonry and RCC work.
- Collect the details of various types of the agencies working for repairs and maintenance of structures in actual practice.
- Collect the information of companies/firms of maintenance and repair work available nearby area.
- Prepare the report on study of environmental factors on maintenance and repair work of civil structure.
- Market survey for at least five materials used for repairs with respect specification, supplier, packaging and costing.
- Prepare the photographic report showing various types of cracks in damaged structures.
- Prepare the report on flexural strength of three RCC beams and three plain concrete beams and find the various types of cracks by applying one-point load, two-point loads etc. Collect the information of maintenance work made

for any one famous building such as Taj Hotel, Taj Mahal etc.

- Collect the information of advanced methods of repairs of water leakages of RCC water tank, plumbing works, sanitary works, flooring repairs, door and window frames/panels repairs.
- Identify various types of failures in steel structures and write a detailed case study on any one type of failure in steel structures.

Note :

- Above is just a suggestive list of microprojects and assignments; faculty must prepare their own bank of microprojects, assignments, and activities in a similar way.
- The faculty must allocate judicial mix of tasks, considering the weaknesses and / strengths of the student in acquiring the desired skills.
- If a microproject is assigned, it is expected to be completed as a group activity.
- SLA marks shall be awarded as per the continuous assessment record.
- For courses with no SLA component the list of suggestive microprojects / assignments/ activities are optional, faculty may encourage students to perform these tasks for enhanced learning experiences.
- If the course does not have associated SLA component, above suggestive listings is applicable to Tutorials and maybe considered for FA-PR evaluations.

VIII. LABORATORY EQUIPMENT / INSTRUMENTS / TOOLS / SOFTWARE REQUIRED

Sr.No	Equipment Name with Broad Specifications	Relevant LLO Number
1	Half-cell potentiometer; voltage 220, electric power source, frequency 50 Hz, corrosion monitoring technique standardized by ASTM	10
2	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	2,3,15
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.	4
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	5
5	Rebar locator: Model: GMS 120 professional, weight: 0.27 KG, detection depth for steel max : 120 mm and for copper max 80 mm	6
6	Cover gauge: concrete thickness gauge model of CTG-2 (Concrete Thickness Gauges), battery powered, ASTM Standard, frequency resolution 10Hz, thickness range 81 mm to 50.8 cm in standard mode.	6,10
7	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	7
8	Digital concrete moisture meter- Confirming to ASTM F2170 measuring range of 0-6.9% moisture content, a resolution of 0.1%, and an accuracy of ±0.3%.	9,14,15

IX. SUGGESTED WEIGHTAGE TO LEARNING EFFORTS & ASSESSMENT PURPOSE (Specification Table)

Sr.No	Unit	Unit Title	Aligned COs	Learning Hours	R-Level	U-Level	A-Level	Total Marks
1	I	Basics of Maintenance and Repairs	CO1	10	2	4	4	10

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Sr.No	Unit	Unit Title	Aligned COs	Learning Hours	R-Level	U-Level	A-Level	Total Marks
2	II	Causes, Detection & Estimation of Damages	CO2	14	2	4	10	16
3	III	Materials for Maintenance and Repairs	CO3	10	2	4	6	12
4	IV	Maintenance and Repair of Masonry Work	CO4	12	2	4	10	16
5	V	Maintenance and Repair of Concrete Work	CO5	14	6	4	6	16
Grand Total				**60**	**14**	**20**	**36**	**70**

X. ASSESSMENT METHODOLOGIES/TOOLS

Formative assessment (Assessment for Learning)

- Term work (Lab Manual), Self-Learning (Assignment) Question and Answers in class room, quiz and group discussion. Note: Each practical will be assessed considering 60% weightage to process related and 40 % weightage to product related.

Summative Assessment (Assessment of Learning)

- N.A.

XI. SUGGESTED COS - POS MATRIX FORM

Course Outcomes (COs)	Programme Outcomes (POs)							Programme Specific Outcomes* (PSOs)		
	PO-1 Basic and Discipline Specific Knowledge	PO-2 Problem Analysis	PO-3 Design/ Development of Solutions	PO-4 Engineering Tools	PO-5 Engineering Practices for Society, Sustainability and Environment	PO-6 Project Management	PO-7 Life Long Learning	PSO-1	PSO-2	PSO-3
CO1	1	1	1	1	1	-	1			
CO2	2	2	3	3	2	-	2			
CO3	2	2	1	2	1	-	2			
CO4	2	2	2	2	2	-	2			
CO5	2	2	2	2	2	-	2			

Legends :- High:03, Medium:02,Low:01, No Mapping: -
*PSOs are to be formulated at institute level

XII. SUGGESTED LEARNING MATERIALS / BOOKS

Sr.No	Author	Title	Publisher with ISBN Number
1	Gahlot, P. S. Sharma, Sanjay	Building Repair and maintenance management	CBS Publishers & Distributors Pvt. Ltd. New Delhi, ISBN: 81-239-1243-9

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Sr.No	Author	Title	Publisher with ISBN Number
2	Nayak B. S.	Maintenance Engineering for civil Engineers	Khanna Publication, New Delhi ISBN: 978-81-7409-051-7
3	Guha,P. K.	Maintenance and Repairs of Buildings	New Central book Agencies, New Delhi, ISBN 10: 8173810737 ISBN: 9788173810732
4	Hutchin Son, BD	Maintenance and Repairs of Buildings	Newnes-Butterworth, London (UK) ISBN : 0408001917
5	PWD, Maharashtra.	Maintenance Manual by PWD	PWD, Maharashtra.
6	BIS, New Delhi.	IS:15183-Part-I-2002- Guidelines for maintenance management of building.	BIS, New Delhi.

XIII . LEARNING WEBSITES & PORTALS

Sr.No	Link / Portal	Description
1	https://www.youtube.com/watch?v=PojJX4VSnbc	Structural audit of buildings
2	https://nptel.ac.in/courses/105106202	NPTEL course on Maintenance & Repairs of Structures
3	https://www.youtube.com/watch?v=ANORiqAJ7kc	Repair of crack in plaster
4	https://www.youtube.com/watch?v=Zp4f_ReeSO0	Crack repair by epoxy injection method
5	https://www.youtube.com/watch?v=y1rOtvvxRzY	Concrete slab crack repair instructional video
6	https://www.youtube.com/watch?v=q_JeGja1Yb4	Repair a Crack in a Concrete Slab Floor
7	https://www.youtube.com/watch?v=eEXAWukRfD4	Repair Concrete with Epoxy Injection Techniques
8	https://www.youtube.com/watch?v=uvOBcjD4BVM	Cracks Repair Techniques
9	https://www.youtube.com/watch?v=mUnQfEYwZao	How to repair rusted iron bar | Interior design | Anti rust
10	https://www.youtube.com/watch?v=WEJPpCidJmg	Budget Estimation of Repairs

Note :

- Teachers are requested to check the creative common license status/financial implications of the suggested online educational resources before use by the students