



INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad -500 043

CIVIL ENGINEERING

COURSE DESCRIPTOR

Course Title	REHABILITATION & RETROFITTING OF STRUCTURES				
Course Code	ACE505				
Programme	B. Tech				
Semester	VIII	CIVIL			
Course Type	Elective				
Regulation	IARE - R16				
Course Structure	Theory			Practical	
	Lectures	Tutorials	Credits	Laboratory	Credits
	3	-	3	-	-
Chief Coordinator	Ms. P Sruthilaya, Assistant Professor				
Course Faculty	Ms. P Sruthilaya, Assistant Professor				

I. COURSE OVERVIEW:

The primary objective of this course is to introduce the concept of Rehabilitation as a precise concept, and study how to overcome the defects in regular construction practices, establish their effectiveness in overcoming the problems faced, study their efficiency and memory needs. The course consists of Retrofitting components in addition to adapting new techniques in construction practices. Retrofitting reduces the vulnerability of damage of an existing structure during a future earthquake. It aims to strengthen a structure to satisfy the requirements of the current codes for seismic design. In this respect, seismic retrofit is beyond conventional repair or even rehabilitation. The applications include different types of buildings, industrial structures, bridges, urban transport structures, marine structures and earth retaining structures. The benefits of retrofitting include the reduction in the loss of lives and damage of the essential facilities, and functional continuity of the life line structures. For an existing structure of good condition, the cost of retrofitting tends to be smaller than the replacement cost. Thus, the retrofitting of structures is an essential component of long term disaster mitigation.

II. COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites	Credits
UG	ACE010	V	Concrete Technology	3

III. MARKS DISTRIBUTION:

Subject	SEE Examination	CIA Examination	Total Marks
Rehabilitation and Retrofitting of Structures	70 Marks	30 Marks	100

IV. DELIVERY / INSTRUCTIONAL METHODOLOGIES:

✗	Chalk & Talk	✓	Quiz	✓	Assignments	✗	MOOCs
✓	LCD / PPT	✓	Seminars	✗	Mini Project	✗	Videos
✗	Open Ended Experiments						

V. EVALUATION METHODOLOGY:

The course will be evaluated for a total of 100 marks, with 30 marks for Continuous Internal Assessment (CIA) and 70 marks for Semester End Examination (SEE). Out of 30 marks allotted for CIA during the semester, marks are awarded by taking average of two CIA examinations or the marks scored in the make-up examination.

Semester End Examination (SEE): The SEE is conducted for 70 marks of 3 hours duration. The syllabus for the theory courses is divided into five modules and each module carries equal weight age in terms of marks distribution. The question paper pattern is as follows. Two full questions with “either” or “choice” will be drawn from each module. Each question carries 14 marks. There could be a maximum of two sub divisions in a question.

The emphasis on the questions is broadly based on the following criteria:

50 %	To test the objectiveness of the concept.
50 %	To test the analytical skill of the concept OR to test the application skill of the concept.

Continuous Internal Assessment (CIA):

CIA is conducted for a total of 30 marks (Table 1), with 25 marks for Continuous Internal Examination (CIE), 05 marks for Quiz /Alternative Assessment Tool (AAT).

Table 1: Assessment pattern for CIA

Component	Theory		Total Marks
	CIE Exam	Quiz / AAT	
CIA Marks	25	05	30

Continuous Internal Examination (CIE):

Two CIE exams shall be conducted at the end of the 8th and 16th week of the semester respectively. The CIE exam is conducted for 25 marks of 2 hours duration consisting of five descriptive type questions out of which four questions have to be answered where, each question carries 5 marks. Marks are awarded by taking average of marks scored in two CIE exams.

Quiz - Online Examination

Two Quiz exams shall be online examination consisting of 25 multiple choice questions and are to be answered by choosing the correct answer from a given set of choices (commonly four). Such a question paper shall be useful in testing of knowledge, skills, application, analysis, evaluation and understanding of the students. Marks shall be awarded considering the average of two quiz examinations for every course.

Alternative Assessment Tool (AAT)

This AAT enables faculty to design own assessment patterns during the CIA. The AAT converts the classroom into an effective learning centre. The AAT may include tutorial hours/classes, seminars, assignments, term paper, open ended experiments, METE (Modeling and Experimental Tools in Engineering), five minutes video, MOOCs etc.

VI. HOW PROGRAM OUTCOMES ARE ASSESSED:

Program Outcomes (POs)		Strength	Proficiency assessed by
PO 1	Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.	3	Presentation on real-world problems
PO 2	Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.	3	Assignments/Exams
PO 4	Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.	2	Guest Lectures

Program Outcomes (POs)		Strength	Proficiency assessed by
PO7	Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.	3	Presentation on real-world problems
PO10	Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.	2	Group Discussions/ Presentations

3 = High; 2 = Medium; 1 = Low

VII. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED:

Program Specific Outcomes (PSOs)		Strength	Proficiency assessed by
PSO 1	Engineering Knowledge: Graduates shall demonstrate sound knowledge in analysis, design, laboratory investigations and construction aspects of civil engineering infrastructure, along with good foundation in mathematics, basic sciences and technical communication.	3	Assignment/ Exams
PSO 2	Broadness and Diversity: Graduates will have a broad understanding of economical, environmental, societal, health and safety factors involved in infrastructural development, and shall demonstrate ability to function within multidisciplinary teams with competence in modern tool usage.	3	Mini Projects
PSO 3	Self-Learning and Service: Graduates will be motivated for continuous self-learning in engineering practice and/ or pursue research in advanced areas of civil engineering in order to offer engineering services to the society, ethically and responsibly.	-	-

3 = High; 2 = Medium; 1 = Low

VIII. COURSE OBJECTIVES :

The course should enable the students to:	
I	Explain different types of deterioration of structures, distress in structures and damage mechanism
II	Understand the aspects of repair and rehabilitation and facets of maintenance
III	Apply the various techniques of repair for corrosion protection in structures
IV	Illustrate different methods for strengthening the existing structures and methods of demolition of structures using engineered and non-engineered techniques.

IX. COURSE OUTCOMES (COs):

Cos	Course Outcome	CLOs	Course Learning Outcome
CO 1	Recognize the mechanisms of deterioration of structures and conduct Preliminary forensic assessment of deteriorated concrete structures.	CLO 1	Describe the deterioration of structures, rehabilitation and retrofitting.
		CLO 2	Identifying the causes for deterioration of structures and able to give the preventive measures for it.
		CLO 3	Describe the mechanism of damage and types of damage.
		CLO 4	Analyzing the damage of structures in detail.
		CLO 5	Understand the distress in structures.
CO 2	Analyze the maintenance and diagnosis of failure.	CLO 6	Understand what is meant by Maintenance, repair and rehabilitation.
		CLO 7	Understand the facets of maintenance: i)Prevention ii)Repair
		CLO 8	Describe the various aspects of inspection.
		CLO 9	Understand the Assessment procedure for evaluating a damaged structure.
		CLO 10	Identifying the diagnosis of construction failures.
CO 3	Able to Examine the damages occurred in reinforced concrete building and knowing the remedies for damages.	CLO 11	Describe the Corrosion damage of reinforced concrete.
		CLO 12	Describe the Corrosion inhibitors, Corrosion resistant steels, cathodic protection and rust eliminators.
		CLO 13	Describe the causes for deterioration of concrete, steel, masonry and timber structures.
		CLO 14	Discuss the concept of surface deterioration, efflorescence and corrosion protection.
		CLO 15	Discuss different causes and preventive measures of surface deterioration and efflorescence.
CO 4	Knowing about different types of special materials used for repair techniques	CLO 16	Describe special concrete and mortar.
		CLO 17	Discuss different types of special concrete such as polymer concrete sulphur infiltrated concrete, fiber reinforced concrete, ferro cement and expansive cement.
		CLO 18	Discuss different methods of repair in concrete, steel, masonry and timber structures.
		CLO 19	Describe about expansive cement.
		CLO 20	Describe about sulphur infiltrated concrete.
CO 5	Identifying different types of strengthening techniques used for existing structures	CLO 21	Describe strengthening techniques for existing structures.
		CLO 22	Describe Various repair works to overcome low member strength, deflection, cracking, chemical disruption, weathering, wear, fire, leakage, marine exposure.
		CLO 23	Describe the use of Non –destructive techniques for evaluation.
		CLO 24	Describe a case study of demolition of structure using engineered technique.
		CLO 25	Describe some of the non engineered techniques used for demolition of structures.

X. COURSE LEARNING OUTCOMES (CLOs):

CLO Code	CLO's	At the end of the course, the student will have the ability to:	PO's Mapped	Strength of Mapping
ACE505.01	CLO 1	Describe the deterioration of structures, rehabilitation and retrofitting.	PO 1, PO 2	2
ACE505.02	CLO 2	Identifying the causes for deterioration of structures and able to give the preventive measures for it.	PO 2	3
ACE505.03	CLO 3	Describe the mechanism of damage and types of damage.	PO 2	3
ACE505.04	CLO 4	Analyzing the damage of structures in detail.	PO 4	2
ACE505.05	CLO 5	Understand the distress in structures.	PO 7	1
ACE505.06	CLO 6	Understand what is meant by Maintenance, repair and rehabilitation	PO 2	3
ACE505.07	CLO 7	Understand the facets of maintenance: i)Prevention ii)Repair	PO 1	2
ACE505.08	CLO 8	Describe the various aspects of inspection.	PO 10	3
ACE505.09	CLO 9	Understand the Assessment procedure for evaluating a damaged structure.	PO 4	3
ACE505.10	CLO 10	Identifying the diagnosis of construction failures.	PO 2	3
ACE505.11	CLO 11	Describe the Corrosion damage of reinforced concrete.	PO 2, PO 4	2
ACE505.12	CLO 12	Describe the Corrosion inhibitors, Corrosion resistant steels, cathodic protection and rust eliminators.	PO 2	2
ACE505.13	CLO 13	Describe the causes for deterioration of concrete, steel, masonry and timber structures.	PO 2	2
ACE505.14	CLO 14	Discuss the concept of surface deterioration, efflorescence and corrosion protection.	PO 2, PO 4	3
ACE505.15	CLO 15	Discuss different causes and preventive measures of surface deterioration and efflorescence.	PO 1	2
ACE505.16	CLO 16	Describe special concrete and mortar.	PO 1, PO 10	2
ACE505.17	CLO 17	Discuss different types of special concrete such as polymer concrete sulphur infiltrated concrete, fiber reinforced concrete, ferro cement and expansive cement.	PO 2	3
ACE505.18	CLO 18	Discuss different methods of repair in concrete, steel, masonry and timber structures.	PO 7	3
ACE505.19	CLO 19	Describe about expansive cement.	PO 7, PO 4	3
ACE505.20	CLO 20	Describe about sulphur infiltrated concrete.	PO 4	2
ACE505.21	CLO 21	Describe strengthening techniques for existing structures.	PO 1	2
ACE505.22	CLO 22	Describe Various repair works to overcome low member strength, deflection, cracking, chemical disruption, weathering, wear, fire, leakage, marine exposure.	PO 4	3
ACE505.23	CLO 23	Describe the use of Non –destructive techniques for evaluation.	PO 4	3
ACE505.24	CLO 24	Describe a case study of demolition of structure using engineered technique.	PO 10	3
ACE505.25	CLO 25	Describe some of the non engineered techniques used for demolition of structures.	PO 4	2

3= High; 2 = Medium; 1 = Low

XI. MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:

Course Outcomes (COs)	Program Outcomes (POs)						
	PO 1	PO 2	PO 4	PO 7	PO 10	PSO1	PSO 2
CO 1	2	2	2	1			3
CO 2	2	3	3	3	3		3
CO 3	2	2	2			2	2
CO 4	2	3	2	3	2	2	3
CO 5	3		2		3	3	2

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XII. MAPPING COURSE LEARNING OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:

Course Learning Outcomes (CLOs)	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CLO 1	2	2												3	
CLO 2		3												3	
CLO 3		3												3	
CLO 4				2										3	
CLO 5							1							3	
CLO 6		3												3	
CLO 7	2												2		
CLO 8										3			2		
CLO 9				3									2		
CLO 10		3											2		
CLO 11		2		2									2		
CLO 12		2												2	
CLO 13		2												2	
CLO 14		3		3										2	
CLO 15	2												2		
CLO 16	2									2			2		

Course Learning Outcomes (CLOs)	Program Outcomes (POs)												Program Specific Outcomes (PSOs)		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CLO 17		3											2		
CLO 18							3							3	
CLO 19				3			3							3	
CLO 20				2										3	
CLO 21	3												3		
CLO 22				3									3		
CLO 23				3										3	
CLO 24										3				2	
CLO 25				2										2	

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XIII. ASSESSMENT METHODOLOGIES – DIRECT

CIE Exams	PO1,PO2, PO 4, PO7, PO10,PSO1 PSO 2	SEE Exams	PO1,PO2, PO 4, PO7, PO10,PSO1 PSO 2	Assignments	PO2, PSO1	Seminars	PO7.
Laboratory Practices	-	Student Viva	-	Mini Project	-	Certification	-
Term Paper	-						

XIV. ASSESSMENT METHODOLOGIES - INDIRECT

✓	Early Semester Feedback	✓	End Semester OBE Feedback
✗	Assessment of Mini Projects by Experts		

XV. SYLLABUS

UNIT – I	INTRODUCTION
Deterioration of structures; distress in structures; causes and prevention, mechanism of damage; types of damage; damage under accidental and cyclic loads, cracking in structures, evaluation of damage.	
UNIT – II	MAINTENANCE AND DIAGNOSIS OF FAILURE
Maintenance, repair and rehabilitation, facets of maintenance, importance of maintenance, various aspects of inspection; Assessment procedure for evaluating a damaged structure; Diagnosis of construction failures.	

UNIT – III	DAMAGES AND THEIR REMEDIES
Corrosion damage of reinforced concrete, methods of corrosion protection, corrosion inhibitors, corrosion resistant steels, cathodic protection, rust eliminators. Causes of deterioration of concrete, steel, masonry and timber structures, surface deterioration, efflorescence, causes and preventive measures; coatings for embedded steel and set concrete.	
UNIT – IV	MATERIALS AND TECHNIQUES OF REPAIR
Special concrete and mortar, concrete chemicals, expansive cement, polymer concrete sulphur infiltrated concrete, ferro cement, fiber reinforced concrete, methods of repair in concrete, steel, masonry and timber structures. Guniting and shotcrete, epoxy injection.	
UNIT – V	STRENGTHENING AND DEMOLITION ASPECT
Strengthening of existing structures; repairs to overcome low member strength, deflection, cracking, chemical disruption, weathering, wear, fire, leakage, marine exposure, use of non-destructive testing techniques for evaluation, load testing of structure; demolition of structures using engineered and non engineered techniques; case studies.	
Text Books:	
1. Shetty .M.S., "Concrete, Technology", Theory and Practice, S.Chand and Company, New Delhi 2010. 2. Allen .R.T. and Edwards .S.C., "Repair of Concrete Structures" Blakie and Sons, UK 1987.	
Reference Books:	
1. Raiker .R.N. "Learning from Failures, Deficiencies in Design, Construction and Service", R&D Centre (SDCPL), Raikar Bhavan, Bombay 1987. 2. "Repair & Rehabilitation" "Compilation from The Indian Concrete Journal", - ACC - RCD Publication 2001. 3. Revision compbell, Allen and Itarold Roper, "Concrete Structures Materials Maintenance and Repair" Longman Scientific and Technical UK 1991.	

XVI. COURSE PLAN:

The course plan is meant as a guideline. Probably there may be changes.

Lecture No	Topics to be covered	Course Learning Outcomes (CLOs)	Reference
1	Introduction to Rehabilitation and Retrofitting of Structures.	CLO 1	T2:26.3
2-3	Describe the deterioration of structures.	CLO 1	T2:22.2
4-5	What are the causes for deterioration of structures and able to give the preventive measures for it.	CLO 2	T2:22.2
6	Describe the mechanism of damage and types of damage.	CLO 3	T2:22.2
7-8	Analyzing the damage of structures in detail.	CLO 4	T1:8.1
9	Understand the distress in structures.	CLO 5	T1:7.1
10-11	What are the causes for distress in structures and able to give the preventive measures for it.	CLO 5	T2:32.3
12	What is meant by Maintenance, repair and rehabilitation.	CLO 6	T2:42.3
13-14	Understand the facets of maintenance: i)Prevention ii)Repair	CLO 7	T2:45.2
15	Describe the various aspects of inspection.	CLO 8	T2:47.9
16-17	Write the Assessment procedure for evaluating a damaged structure.	CLO 10	T2:52.1
18	Identifying the diagnosis of construction failures.	CLO 10	T2:54
19-20	Describe the Corrosion damage of reinforced concrete.	CLO 11	T2:55.3
21-22	Different methods of corrosion protection.	CLO 11	T2:62.2

Lecture No	Topics to be covered	Course Learning Outcomes (CLOs)	Reference
23-24	Describe the Corrosion inhibitors, Corrosion resistant steels, cathodic protection and rust eliminators.	CLO 12	R1:2.5
25-26	Describe the causes for deterioration of concrete, steel, masonry and timber structures.	CLO 13	R2:2.2.5
27	Discuss the concept of surface deterioration, efflorescence.	CLO 15	R3:56.2
28-29	Discuss different causes and preventive measures of surface deterioration and efflorescence.	CLO 15	R3:54.8
30-31	Describe special concrete and mortar.	CLO 16	T2:81.2
32-33	Discuss different types of special concrete such as polymer concrete sulphur infiltrated concrete, fiber reinforced concrete, ferro cement and expansive cement.	CLO 17	T2:83.5
34-35	Discuss different methods of repair in concrete, steel, masonry and timber structures.	CLO 18	T2:85.6
36-37	Describe strengthening techniques for existing structures.	CLO 21	T2:89.2
38-39	Describe Various repair works to overcome low member strength, deflection, cracking, chemical disruption, weathering, wear, fire, leakage, marine exposure.	CLO 22	T2:92.1
40-41	Describe the use of Non –destructive techniques for evaluation.	CLO 23	T2:95.3
42-43	Describe a case study of demolition of structure using engineered technique.	CLO 24	T2:96.2
44-45	Describe some of the non engineered techniques used for demolition of structures.	CLO 25	T2:97.5

XVI. GAPS IN THE SYLLABUS-TO MEET INDUSTRY / PROFESSION REQUIREMENTS:

S No	Description	Proposed Actions	Relevance With POs	Relevance With PSOs
1	Different strengthening techniques to improve the quality of existing structures.	Seminars	PO 1	PSO 2
2	Assessment procedure for evaluating a damaged structure.	Seminars / NPTEL	PO 2	PSO 1
3	Various NDT methods for evaluating a structure.	Guest lecture	PO 4	PSO 2

Prepared by:

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HOD, CE