ADAMAS UNIVERSITY

SCHOOL OF ENGINEERING & TECHNOLOGY

Department of Civil Engineering

M.Tech. Construction Engineering & Management Programme

Course File (Theory)

Course Name: Maintenance and Rehabilitation of Structures

Course Code: CEM21017

Course Coordinator: Mr. Sayanta Sikdar

Year: I
Semester: II

10. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**
11. Course : Maintenance and Rehabilitation of Structures **L: 3**
12. Program : M.Tech (CEM) **T: 0**
13. Target : 60% **P: 0**
C: 3

THEORY COURSE FILE CONTENTS

Check list Course Outcomes Attainment

S. No.	Contents	Available (Y/N/NA)	Date of Submission	Signature of HOD
1.	Authenticated Syllabus Copy	Y		
2.	Individual Time Table	Y		
3.	Students' Name List (Approved Copy)	Y		
4.	Course Plan, PO, PSO, COs, CO-PO Mapping, COA Plan, Session Plan and Periodic Monitoring	Y		
5.	Previous Year End Semester Question Papers	Y		
6.	Question Bank (All Units - Part A, Part B & C)	Y		
7.	Dissemination of Syllabus and Course Plan to Students	Y		
8.	Lecture Notes - Unit I, II & III	Y	07.04.2021	
9.	**Sample Documents and Evaluation Sheet for Internal Assessment** – Tutorials / Assignments / Class Test / Open Book Test / Quiz / Project / Seminar / Role Playif any (Before Mid Term)	Y		
10.	**Mid Term Examination** A. Question Paper / Any Other Assessment Tools Used B. Sample Answer Scripts (Best, Average,Poor) if required C. Evaluation Sheet D. Slow Learners List and Remedial Measures	Y	23.05.2021	
11.	Lecture Notes – Unit IV & V	Y		
12.	**Sample Documents and Evaluation Sheet for Internal Assessment**– Tutorials / Assignments / Class Test /Open Book Test / Quiz / Project / Seminar / Role Play if any (After Mid Term)	Y		
13.	Course End Survey (Indirect Assessment)& Consolidation	Y		
14.	**End Term Examination** A. Question Paper & Answer Key B. Sample Answer Scripts (Best, Average,Poor) if required	Y	26.08.2021	

Year: I
Semester: II

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C: 3

	C. Evaluation Sheet **D.** Slow Learners List and RemedialMeasures.			
15.	Content Beyond the Syllabus (Proof)	Y		
16.	Innovative Teaching Tools Used for TLP	Y		
17.	Details of Visiting Faculty Session / Industry Expert/ Guest Lecture / Seminar / Field Visit / Webinars / Flipped Class Room / Blended Learning / Online Resources etc.	Y		
18.	Consolidated Mark Statement	Y		
19.	CO Attainment (Mid Term + Internal Assessment + End Term)	Y		
20.	Gap Analysis & Remedial Measures	Y		
21.	CO - PO Attainment	Y		
22.	Class Record (Faculty Logbook)	Y	29.08.2021	

Signature of HOD/ Dean **Signature of Faculty**

Date: **Date:**

Year: I
Semester: II

10. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**
11. Course : Maintenance and Rehabilitation of Structures **L: 3**
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Syllabus Copy

CEM21017 (Previous code: ECE61148)	Maintenance and Rehabilitation of Structures	L	T	P	C
Version 1.0		3	0	0	3
Pre-requisites/Exposure	Construction Equipment and Management				
Co-requisites	Advanced Construction Techniques				

Course Objectives

1. To study about quality assurance of materials and environmental effects as well as corrosion effect on concrete structures.

2. To study about maintenance, repair strategies and techniques along with guidelines related to demolition of structures.

Course Content

UNIT-I: **9 Lecture Hours**
Introduction: Quality assurance for concrete construction as built concrete properties strength, permeability, thermal properties and cracking. Effects due to climate, temperature, chemicals, wear and erosion.

UNIT-II: **9 Lecture Hours**
Corrosion: Design and construction errors, corrosion mechanism, Effects of cover thickness and cracking, methods of corrosion protection.

UNIT-III: **9 Lecture Hours**
Maintenance and Repair strategies: Facets of maintenance, importance of Maintenance, Preventive measures on various aspects of Inspection, Assessment procedure for evaluating damaged structure causes of deterioration - testing techniques.

UNIT-IV: **9 Lecture Hours**
Materials and Techniques for repair: Special concretes and mortar, concrete chemicals, Expansive cement, polymer concrete, sulphur infiltrated concrete, Ferro cement, Fiber reinforced concrete. Rust eliminators and polymers coating for rebar during repair foamed concrete, mortar and dry pack, vacuum concrete, Gunite and Shotcrete, Epoxy injection, Mortar repair for cracks, shoring and underpinning.

UNIT-V: **9 Lecture Hours**
Demolition Techniques: Engineered demolition and other case studies.

Year: I
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13. Target : 60% **P: 0**
C: 3

Reference Books:

1. Campbell-Allen, Denison and Roper, Harold."Concrete Structures: Materials, Maintenance and Repair", Longman Scientific and Technical UK, 1991.
2. Allen, R.T and Edwards, S.C, "Repair of Concrete Structures", Blakie and Sons, UK, 1987.
3. Shetty, M.S, "Concrete Technology - Theory and Practice", S.Chand and Company, New Delhi, 2008.

Faculty Individual Time Table

ADAMAS UNIVERSITY, KOLKATA

SCHOOL OF ENGINEERING & TECHNOLOGY

DEPARTMENT OF CIVIL ENGINEERING

M. Tech (Construction Engineering & Management)

Course Code & Course: CEM21017 & Maintenance and Rehabilitation of Structures
Faculty Coordinator: Sayanta Sikdar

Day & Time	9:30-10:25	10:30-11:25	11:30-12:25	12:25-13:30	13:30-14:25	14:30-15:25	15:30-16:25	16:30-17:25
Monday				LUNCH		Maintenance and Rehabilitation of Structures	Soil Mechanics	
Tuesday	Foundation Engineering		Maintenance and Rehabilitation of Structures		Design of Environmental Engineering Systems			
Wednesday		Soil Mechanics			CAPSTONE PROJECT			
Thursday		Foundation Engineering	Soil Mechanics					
Friday	SEMINAR		Maintenance and Rehabilitation of Structures			Foundation Engineering		

Signature of HOD **Signature of Class Coordinator**

Date: 07.04.2021 **Date: 07.04.2021**

Year: I

Semester: II

10. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**

11. Course : Maintenance and Rehabilitation of Structures **L: 3**

12. Program : M.Tech (CEM) **T: 0**

13. Target : 60% **P: 0**

C: 3

Students Name List

Roll Number	Registration Number	Name of the Student
PG/02/MTCOEM/2020/001	AU/2020/0004499	ANINDYA GHOSH

Signature of HOD/Dean **Signature of Class Coordinator**

Date: 07.04.2021 **Date: 07.04.2021**

Year: I
Semester: II

10. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**
11. Course : Maintenance and Rehabilitation of Structures **L: 3**
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13. Target : 60% **P: 0**
C: 3

COURSE PLAN

Target	60% (marks)
Level-1	50% (population)
Level-2	60% (population)
Level-3	70% (population)

1. Method of Evaluation

UG	PG
Internal Assessment (30%) (Quizzes/Tests, Assignments & Seminars etc.)	Internal Assessment (30%) (Quizzes/Tests, Assignments & Seminars etc.)
Mid Semester Examination (20%)	Mid Semester Examination (20%)
End Semester Examination (50%)	End Semester Examination (50%)

*Keep as per Program (UG/PG)

2. Passing Criteria

Scale	PG	UG
Out of 10 Point Scale	CGPA – "5.00" Min. Individual Course Grade – "C" Passing Minimum – 40	CGPA – "5.00" Min. Individual Course Grade – "C" Passing Minimum – 35

*Keep as per Program (UG/PG)

3. Pedagogy

- **Direct Instruction**
- Kinesthetic Learning
- **Flipped Classroom**
- Differentiated Instruction
- Expeditionary Learning
- Inquiry Based Learning
- Game Based Learning
- Personalized Learning

4. Topics introduced for the first time in the program through this course

- (New Topic – Content Beyond Syllabus – Papercrete, Self-healing concrete and Light-weight concrete)

5. References:

Text Books	Web Resources	Journals	Reference Books
	4		3

Signature of HOD/Dean **Signature of Faculty**

Year: I

Semester: II

10. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**

11. Course : Maintenance and Rehabilitation of Structures **L: 3**

12. Program : M.Tech (CEM) **T: 0**

13. Target : 60% **P: 0**

C: 3

Date: 07.04.2021 **Date: 07.04.2021**

Year: I
Semester: II

10. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**

11. Course	**: Maintenance and Rehabilitation of Structures**	**L: 3**
12. Program	**: M.Tech (CEM)**	**T: 0**
13. Target	**: 60%**	**P: 0**
		C: 3

GUIDELINES TO STUDY THE SUBJECT

Instructions to Students:

1. Go through the 'Syllabus' in the LMS in order to find out the Reading List.
2. Get your schedule and try to pace your studies as close to the timeline as possible.
3. Get your on-line lecture notes (Content, videos) at Lecture Notes section. These are our lecture notes. Make sure you use them during this course.
4. check your LMS regularly
5. go through study material
6. check mails and announcements on blackboard
7. keep updated with the posts, assignments and examinations which shall be conducted on the blackboard
8. Be regular, so that you do not suffer in any way
9. C**ell Phones and other Electronic Communication Devices:** Cell phones and other electronic communication devices (such as Blackberries/Laptops) are not permitted in classes during Tests or the Mid/Final Examination. Such devices MUST be turned off in the class room.
10. **E-Mail and online learning tool:** Each student in the class should have an e-mail id and a pass word to access the LMS system regularly. Regularly, important information – Date of conducting class tests, guest lectures, via online learning tool. The best way to arrange meetings with us or ask specific questions is by email and prior appointment. All the assignments preferably should be uploaded on online learning tool. Various research papers/reference material will be mailed/uploaded on online learning platform time to time.
11. **Attendance:** Students are required to have minimum attendance of 75% in each subject. Students with less than said percentage shall NOT be allowed to appear in the end semester examination.

This much should be enough to get you organized and on your way to having a great semester! If you need us for anything, send your feedback through e-mail sayanta1.sikdar@adamasuniversity.ac.in Please use an appropriate subject line to indicate your message details.

There will no doubt be many more activities in the coming weeks. So, to keep up to date with all the latest developments, please keep visiting this website regularly.

Year: I
Semester: II

10. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**
11. Course : Maintenance and Rehabilitation of Structures **L: 3**
12. Program : M.Tech (CEM) **T: 0**
13. Target : 60% **P: 0**
C: 3

RELATED OUTCOMES

1. The expected outcomes of the Program are:

PO1	**Domain Knowledge:** Apply comprehensive knowledge of theories, concepts and principles for Maintenance and Rehabilitation of structures.
PO2	**Problem Analysis:** Identify and analyze the strategic methodology of concrete structure repairs and maintenance and its problems in the perspectives of client, context and constraints and obtain solution using mathematics, engineering and management principles.
PO3	**Design/Development of Solutions:** Planning and control of maintenance activities by managing resources and constraints with appropriate consideration for the quality assurance, public health and safety, and the cultural, societal, and economical considerations.
PO4	**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.
PO5	**Modern Tool Usage:** Create, select, and apply appropriate techniques, resources, and modern simulation tools for maintenance, repairing and demolition activities.
PO6	**Project Management, Governance and Finance:** Create comprehensive understanding of the techniques associated with the management of resources and finance, assessment and management of risk and subsequent corporate governance as appropriate to a maintenance manager operating in the Civil Engineering industry.
PO7	**Ethics and Environment:** Understand the impact of residential, commercial, industrial and infrastructural maintenance and repairing works in societal, ethical and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
PO8	**Individual and Team Work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO9	**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 moreover to give and receive clear instructions.
PO10	**Life-long Learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

2. The expected outcomes of the Specific Program are: (upto3)

PSO1	PG itself a Specific Programme. Henceforth no PSO is Required.
PSO2	

Year: I
Semester: II

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PSO3	

3. **The expected outcomes of the Course are: (minimum 4 and maximum 6)**

CO1	Illustrate the principles related to quality assurance of construction materials and weathering effects on concrete.
CO2	Predict construction error in concrete due to corrosion and improve design specification for protective measure.
CO3	Compile knowledge about maintenance and repair strategies.
CO4	Select repair materials and techniques depending on damages occur in structures.
CO5	Classify various demolition techniques and other case studies.

4. Co-Relationship Matrix

Indicate the relationships by1- Slight (Low) 2- Moderate (Medium) 3-Substantial (High)

Program Outcomes / Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	3	3	-	2	3	-	-	3	-	3
CO2	3	3	-	2	3	-	-	3	-	3
CO3	3	3	-	-	3	-	-	3	-	3
CO4	3	3	-	2	3	-	-	3	-	3
CO5	3	3	-	2	3	-	1	3	-	3
Average	3	3	-	2	3	-	1	3	-	3

Year: I
Semester: II

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12. Program : M.Tech (CEM) **T: 0**
13. Target : 60% **P: 0**
C: 3

5. Course Outcomes Assessment Plan (COA):

Course Outcomes	Internal Assessment* (30 Marks)		Mid Term Exam (20 Marks)	End Term Exam (50 Marks)	Total (100 Marks)
	Before Mid Term	AfterMid Term			
CO1	2	NA	12	8	22
CO2	2	NA	8	8	18
CO3	NA	12	NA	8	20
CO4	NA	7	NA	13	20
CO5	NA	7	NA	13	20
Total	4	26	20	50	100

* Internal Assessment – Tools Used: Assignment and Class Test.

Year: I
Semester: II

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13. Target : 60% **P: 0**
C: 3

OVERVIEW OF COURSE PLAN OF COURSE COVERAGE

Course Activities:

S. No.	Description	Planned			Actual			Remarks
		From	To	No. of Session	From	TO	No. of Session	
1.	**Introduction**	05.04.2021	23.04.2021	9	05.04.2021	23.04.2021	9	Completed as per Plan
2.	**Corrosion**	26.04.2021	14.05.2021	9	26.04.2021	14.05.2021	9	Completed as per Plan
3.	**Maintenance and Repair strategies**	24.05.2021	11.06.2021	9	24.05.2021	11.06.2021	9	Completed as per Plan
4.	**Materials and Techniques for repair**	14.06.2021	02.07.2021	9	14.06.2021	02.07.2021	9	Completed as per Plan
5.	**Demolition Techniques**	05.07.2021	23.07.2021	9	05.07.2021	23.07.2021	9	Completed as per Plan

Total No. of Instructional periods available for the course: 45 Sessions

Signature of HOD/Dean **Signature of Faculty**

Date: 16.08.2021 **Date: 16.08.2021**

Year: I
Semester: II

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11. Course : Maintenance and Rehabilitation of Structures **L: 3**
12. Program : M.Tech (CEM) **T: 0**
13. Target : 60% **P: 0**
C: 3

SESSION PLAN

Session Plan				Actual Delivery			
Lect.	Date	Topics to be Covered	CO Mapped	Lect.	Date	Topics Covered	CO Achieved
1	05.04.2021	Quality assurance for concrete construction as built concrete properties strength	CO1	1	05.04.2021	Quality assurance for concrete construction as built concrete properties strength	CO1
2	06.04.2021	Quality assurance for concrete construction as built concrete properties strength	CO1	2	06.04.2021	Quality assurance for concrete construction as built concrete properties strength	CO1
3	09.04.2021	Quality assurance for concrete construction as built concrete properties strength	CO1	3	09.04.2021	Quality assurance for concrete construction as built concrete properties strength	CO1
4	12.04.2021	Permeability, thermal properties Cracking	CO1	4	12.04.2021	Permeability, thermal properties Cracking	CO1
5	13.04.2021	Permeability, thermal properties Cracking	CO1	5	13.04.2021	Permeability, thermal properties Cracking	CO1
6	16.04.2021	Effects due to climate	CO1	6	16.04.2021	Effects due to climate	CO1
7	19.04.2021	Effects due to temperature	CO1	7	19.04.2021	Effects due to temperature	CO1
8	20.04.2021	Effects due to chemicals	CO1	8	20.04.2021	Effects due to chemicals	CO1
9	23.04.2021	Effects due to wear and erosion	CO1	9	23.04.2021	Effects due to wear and erosion	CO1

UNIT-I

Remarks: NA

Signature of Faculty

Date: 23.04.2021

Year: I
Semester: II

10. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**
11. Course : Maintenance and Rehabilitation of Structures **L: 3**
12. Program : M.Tech (CEM) **T: 0**
13. Target : 60% **P: 0**
C: 3

SESSION PLAN
UNIT-II

Session Plan				Actual Delivery			
Lect.	Date	Topics to be Covered	CO Mapped	Lect.	Date	Topics Covered	CO Achieved
1	26.04.2021	Design and construction errors	CO2	1	26.04.2021	Design and construction errors	CO2
2	27.04.2021	Design and construction errors	CO2	2	27.04.2021	Design and construction errors	CO2
3	30.04.2021	Corrosion mechanism	CO2	3	30.04.2021	Corrosion mechanism	CO2
4	03.05.2021	corrosion mechanism	CO2	4	03.05.2021	corrosion mechanism	CO2
5	04.05.2021	Effects of cover thickness and cracking	CO2	5	04.05.2021	Effects of cover thickness and cracking	CO2
6	07.05.2021	Effects of cover thickness and cracking	CO2	6	07.05.2021	Effects of cover thickness and cracking	CO2
7	10.05.2021	Methods of corrosion protection	CO2	7	10.05.2021	Methods of corrosion protection	CO2
8	11.05.2021	Methods of corrosion protection	CO2	8	11.05.2021	Methods of corrosion protection	CO2
9	14.05.2021	Methods of corrosion protection	CO2	9	14.05.2021	Methods of corrosion protection	CO2

Remarks: NA

Signature of Faculty

Date: 14.05.2021

Year: I
Semester: II

10. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**
11. Course : Maintenance and Rehabilitation of Structures **L: 3**
12. Program : M.Tech (CEM) **T: 0**
13. Target : 60% **P: 0**
C: 3

SESSION PLAN
UNIT-III

Session Plan				Actual Delivery			
Lect.	Date	Topics to be Covered	CO Mapped	Lect.	Date	Topics Covered	CO Achieved
1	24.05.2021	Facets of maintenance	CO3	1	24.05.2021	Facets of maintenance	CO3
2	25.05.2021	Importance of Maintenance	CO3	2	25.05.2021	Importance of Maintenance	CO3
3	28.05.2021	Preventive measures on various aspects of Inspection	CO3	3	28.05.2021	Preventive measures on various aspects of Inspection	CO3
4	31.05.2021	Preventive measures on various aspects of Inspection	CO3	4	31.05.2021	Preventive measures on various aspects of Inspection	CO3
5	01.06.2021	Assessment procedure for evaluating damaged structure	CO3	5	01.06.2021	Assessment procedure for evaluating damaged structure	CO3
6	04.06.2021	Assessment procedure for evaluating damaged structure	CO3	6	04.06.2021	Assessment procedure for evaluating damaged structure	CO3
7	07.06.2021	Causes of deterioration	CO3	7	07.06.2021	Causes of deterioration	CO3
8	08.06.2021	Testing techniques	CO3	8	08.06.2021	Testing techniques	CO3
9	11.06.2021	Testing techniques	CO3	9	11.06.2021	Testing techniques	CO3

Remarks: NA

Signature of Faculty

Date: 11.06.2021

Year: I
Semester: II

10. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**
11. Course : Maintenance and Rehabilitation of Structures **L: 3**
12. Program : M.Tech (CEM) **T: 0**
13. Target : 60% **P: 0**
C: 3

SESSION PLAN
UNIT-IV

Session Plan				Actual Delivery			
Lect.	Date	Topics to be Covered	CO Mapped	Lect.	Date	Topics Covered	CO Achieved
1	14.06.2021	Special concretes and mortar, concrete chemicals	CO4	1	14.06.2021	Special concretes and mortar, concrete chemicals	CO4
2	15.06.2021	Expansive cement, polymer concrete	CO4	2	15.06.2021	Expansive cement, polymer concrete	CO4
3	18.06.2021	Sulphur infiltrated concrete	CO4	3	18.06.2021	Sulphur infiltrated concrete	CO4
4	21.06.2021	Ferro cement, Fiber reinforced concrete	CO4	4	21.06.2021	Ferro cement, Fiber reinforced concrete	CO4
5	22.06.2021	Rust eliminators and polymers coating for rebar during repair	CO4	5	22.06.2021	Rust eliminators and polymers coating for rebar during repair	CO4
6	25.06.2021	Foamed concrete, mortar and dry pack	CO4	6	25.06.2021	Foamed concrete, mortar and dry pack	CO4
7	28.06.2021	Vacuum concrete, Gunite and Shotcrete	CO4	7	28.06.2021	Vacuum concrete, Gunite and Shotcrete	CO4
8	29.06.2021	Epoxy injection, Mortar repair for cracks	CO4	8	29.06.2021	Epoxy injection, Mortar repair for cracks	CO4
9	02.07.2021	Shoring and underpinning	CO4	9	02.07.2021	Shoring and underpinning	CO4

Year: I
Semester: II

10. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**
11. Course : Maintenance and Rehabilitation of Structures **L: 3**
12. Program : M.Tech (CEM) **T: 0**
13. Target : 60% **P: 0**
C: 3

Remarks: NA

Signature of Faculty

Date: 02.07.2021

SESSION PLAN
UNIT-V

Session Plan				Actual Delivery			
Lect.	Date	Topics to be Covered	CO Mapped	Lect.	Date	Topics Covered	CO Achieved
1	05.07.2021	Engineered demolition	CO5	1	05.07.2021	Engineered demolition	CO5
2	06.07.2021	Engineered demolition	CO5	2	06.07.2021	Engineered demolition	CO5
3	09.07.2021	Engineered demolition	CO5	3	09.07.2021	Engineered demolition	CO5
4	12.07.2021	Engineered demolition	CO5	4	12.07.2021	Engineered demolition	CO5
5	13.07.2021	Other case studies	CO5	5	13.07.2021	Other case studies	CO5
6	16.07.2021	Other case studies	CO5	6	16.07.2021	Other case studies	CO5

Year: I
Semester: II

10. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**
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7	19.07.2021	Other case studies	CO5	7	19.07.2021	Other case studies	CO5
8	20.07.2021	Other case studies	CO5	8	20.07.2021	Other case studies	CO5
9	23.07.2021	Other case studies	CO5	9	23.07.2021	Other case studies	CO5

Remarks: NA

Signature of Faculty

Date: 23.07.2021

Year: I
Semester: II

10. Name of the Faculty: Sayanta Sikdar — Course Code: CEM21017
11. Course : Maintenance and Rehabilitation of Structures — L: 3
12. Program : M.Tech (CEM) — T: 0
13. Target : 60% — P: 0
C: 3

PERIODIC MONITORING

Actual date of completion and remarks, if any

Components		From	To	From	To
Duration (Mention from and to Dates)		05.04.2021	21.05.2021	22.05.2021	16.08.2021
Percentage of Syllabus covered		40		60	
Lectures	Planned	1	18	19	45
	Taken	1	18	19	45
Tutorials	Planned	NA			
	Taken				
Test/Quizzes/ Mid Semester/ End Semester	Planned	-	1 (MID)	1 + 1	1 (END)
	Taken	-	1 (MID)	1 + 1	1 (END)
	CO's Addressed	-	CO1, CO2	CO3 + CO4, CO5	CO1, CO2, CO3, CO4, CO5
	CO's Achieved		CO1, CO2	CO3 + CO4, CO5	CO1, CO2, CO3, CO4, CO5
Assignments	Planned	1	-	1	1
	Taken	1	-	1	1
	CO's Addressed	CO1, CO2	-	CO3	CO4, CO5
	CO's Achieved	CO1, CO2	-	CO3	CO4, CO5
Signature of Faculty					
Head of the Department					
OBE Coordinator					

Signature of HOD/ Dean
Date: 16.08.2021

Signature of Faculty
Date: 16.08.2021

Year: I
Semester: II

6. Name of the Faculty: Sayanta Sikdar — Course Code: CEM21017
7. Course : Maintenance and Rehabilitation of Structures — L: 3
8. Program : M.Tech (CEM) — T: 0
9. Target : 60% — P: 0
C: 3

PERIODIC MONITORING

Attainment of the Course (Learning) Outcomes:

Components	Attainment level	Action Plan	Remarks
Assignment	CO1:	Submission Target 26.05.2021	Submitted as per schedule
	CO2:		Submitted as per schedule
	CO3:	Submission Target 15.06.2021	Submitted as per schedule
	CO4:	Submission Target 27.07.2021	Submitted as per schedule
	CO5:		Submitted as per schedule
Quiz/Test etc.	CO1:	----	
	CO2:		
	CO3:	Conducted on 04.06.2021	Conducted as per schedule
	CO4:	Conducted on 12.07.2021	Conducted as per schedule
	CO5:		Conducted as per schedule
Mid Semester	CO1:	Scheduled on 21.05.2021	Conducted as per schedule
	CO2:		
	CO3:	----	
	CO4:	----	
	CO5:	----	
End Semester	CO1:	Scheduled 16.08.2021	Conducted as per schedule
	CO2:		
	CO3:		
	CO4:		
	CO5:		
Any Other	CO1:	NA	
	CO2:		
	CO3:		
	CO4:		
	CO5:		

Signature of HOD/ Dean

Date: 16.08.2021

Signature of Faculty

Date: 16.08.2021

Year: I
Semester: II

6. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**
7. Course : Maintenance and Rehabilitation of Structures **L: 3**
8. Program : M.Tech (CEM) **T: 0**
9. Target : 60% **P: 0**
C: 3

Previous Year Question Paper

ADAMAS UNIVERSITY

END-SEMESTER EXAMINATION: JULY 2020

Name of the Program: M. Tech — Semester: II Stream: CE
PAPER TITLE: Maintenance and Rehabilitation of Structures — PAPER CODE: ECE61148
Maximum Marks: 40 — Time duration: 3 Hours
Total No of questions: 17 — Total No of Pages: 01

Instruction to the Candidate:
1. At top sheet, clearly mention Name, Univ. Roll No., Enrolment No., Paper Name & Code, Date of Exam.
2. All parts of a Question should be answered consecutively. Each Answer should start from a fresh page.
3. Assumptions made if any, should be stated clearly at the beginning of your answer.

Answer all the Groups

Group A

Answer all the questions of the following $5 \times 1 = 5$

1. **a)** Define shrinkage in concrete.
   b) What is concept of erosion in concrete?
   c) What is effective cover in a RC section?
   d) Why inspection of structures required?
   e) Compare the concept of shoring and underpinning.

GROUP –B

(**Short Answer Type Questions**) Answer *any three* of the following $3 \times 5 = 15$

2. Discuss about what are the causes of distress in concrete structures. (5)
3. Explain about the results of rate of freezing and thawing deterioration in concrete. (5)
4. Classify chemical attack on concrete and mention the resistance of concrete against it. (5)
5. Write short note on Epoxy injection. (5)

Year: I
Semester: II

6. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**

7. Course : Maintenance and Rehabilitation of Structures **L: 3**

8. Program : M.Tech (CEM) **T: 0**

9. Target : 60% **P: 0**

C: 3

GROUP –C

(Long Answer Type Questions) Answer *any two* of the following $2 \times 10 = 20$

6. Briefly explain about: (**any two**) (2 x 5 = 10)
   a) Sulphur infiltrated concrete
   b) Foamed concrete.
   c) Carbonation Process
   d) Sulphate attack in concrete structures

7. a) Discuss about the concept of surface hardness test on concrete as per IS code with neat sketches. (5)
   b) Also mention how quality of concrete can be assessed through this test. (5)

8. a) Explain about Pull out and pull of test on concrete with neat sketches. (5)
   b) Explain about different type of demolition techniques used in construction practice. (5)

Year: I
Semester: II

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9. Target : 60% **P: 0**
C: 3

Question Bank Sample

School: School of Engineering & Technology **Department: Civil Engineering**
Course Code: CEM21017 **Course Name: Maintenance and Rehabilitation of Structures**
Program: M.Tech (CEM) **Semester: II**

UNIT NUMBER: I **UNIT NAME: Introduction**

Sl. No.	Question	Level of Difficulty (Easy/ Medium/ Difficult)	Knowledge Level (Bloom's Taxonomy)	Course Outcome (CO)
	Part A (Multiple Choice Questions) (1 mark each)			
1.	**List** the effecting parameters on the quality assurance of concrete construction.	**Easy**	**Remember**	**CO1**
2.	**List** any four durability test parameters of concrete.	**Medium**	**Remember**	**CO1**
3.	**Define** Aggregate splitting.	**Difficult**	**Remember**	**CO1**
	Part B (Definition/Naming Questions) (2 marks each)			
1.	**Define** thermal conductivity of concrete.	**Easy**	**Remember**	**CO1**
2.	**What** are the factors affecting Chemical attack on concrete?	**Medium**	**Remember**	**CO1**
3.	**How** can we prevent the effect of Freezing and thawing in concrete?	**Difficult**	**Remember**	**CO1**
	Part C (Short Questions) (3-4 marks each)			
1.	**What** are the causes of cracking in concrete?	**Easy**	**Remember**	**CO1**
2.	**How** does a concrete structure get affected by heat?	**Medium**	**Remember**	**CO1**
3.	**Illustrate** the methods for controlling cracks in a structure.	**Difficult**	**Understand**	**CO1**

Year: I
Semester: II

6. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**
7. Course : Maintenance and Rehabilitation of Structures **L: 3**
8. Program : M.Tech (CEM) **T: 0**
9. Target : 60% **P: 0**
C: 3

Part D (Explanation Based Questions) (5 marks each)				
1.	**Explain** the functions of Quality assurance and needs for Quality assurance for concrete construction.	**Easy**	**Understand**	**CO1**
2.	**Explain** the importance of quality assurance with respect to strength of concrete.	**Medium**	**Understand**	**CO1**
3.	**Explain** the effects due to chemicals on concrete constructions.	**Difficult**	**Understand**	**CO1**
Part E (Questions Based on Reasoning/ Problems Based Questions) (5 marks each)				
1.	**Explain** any two tests briefly for assessing frost damage on concrete.	**Easy**	**Understand**	**CO1**
2.	**Explain** the various components of Quality assurance for concrete.	**Medium**	**Understand**	**CO1**
3.	**Classify** cracks in concrete structures in terms of their effects.	**Difficult**	**Understand**	**CO1**
Part F (Application Based Questions) (5-10 marks each)				
1.	**Explain** about the thermal properties of concrete.	**Easy**	**Understand**	**CO1**
2.	**Identify** the measures to control cracks in a concrete structure after site inspection and **plan** accordingly to solve the cracking issue.	**Medium**	**Apply**	**CO1**
3.	**Identify** the development and operation of Quality assurance system and also **identify** the causes of poor quality assurance in concrete construction.	**Difficult**	**Apply**	**CO1**
Part G (Short Notes) (5 marks each)				
1.	**Illustrate** about Permeability of concrete.	**Easy**	**Understand**	**CO1**
2.	**Illustrate** the effects due to wear and erosion on concrete constructions.	**Medium**	**Understand**	**CO1**
3.	**Illustrate** the effects due to climate on concrete constructions.	**Difficult**	**Understand**	**CO1**

Year: I
Semester: II

6. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**
7. Course : Maintenance and Rehabilitation of Structures **L: 3**
8. Program : M.Tech (CEM) **T: 0**
9. Target : 60% **P: 0**
C: 3

School: School of Engineering & Technology **Department: Civil Engineering**
Course Code: CEM21017 **Course Name: Maintenance and Rehabilitation of Structures**
Program: M.Tech (CEM) **Semester: II**

UNIT NUMBER: II **UNIT NAME: Corrosion**

Sl. No.	Question	Level of Difficulty (Easy/ Medium/ Difficult)	Knowledge Level (Bloom's Taxonomy)	Course Outcome (CO)
	Part A (Multiple Choice Questions) (1 mark each)			
1.	**Define** corrosion.	**Easy**	**Remember**	**CO2**
2.	**List** the methods of corrosion protection.	**Medium**	**Remember**	**CO2**
3.	**List** out some coating for reinforcement to prevent corrosion.	**Difficult**	**Remember**	**CO2**
	Part B (Definition/Naming Questions) (2 marks each)			
1.	**Define** effective cover and corrosion inhibitor.	**Easy**	**Remember**	**CO2**
2.	**List** one example in each for corrosion inhibitor and corrosion coating.	**Medium**	**Remember**	**CO2**
3.	**Explain** the effects of corrosion in RCC structures.	**Difficult**	**Understand**	**CO2**
	Part C (Short Questions) (3-4 marks each)			
1.	**Classify** constructional defects in different groups.	**Easy**	**Understand**	**CO2**
2.	**Explain** the effects of cover thickness on corrosion.	**Medium**	**Understand**	**CO2**
3.	**Illustrate** the mechanism of Cathodic protection for corrosion.	**Difficult**	**Understand**	**CO2**

Year: I
Semester: II

6. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**
7. Course : Maintenance and Rehabilitation of Structures **L: 3**
8. Program : M.Tech (CEM) **T: 0**
9. Target : 60% **P: 0**
C: 3

Part D (Explanation Based Questions) (5 marks each)				
1.	**Explain** briefly the methods commonly used for corrosion protection.	**Easy**	**Understand**	**CO2**
2.	**Explain** how poor construction methods can lead to failure of structure.	**Medium**	**Understand**	**CO2**
3.	**Explain** how design errors can contribute to the failure of structures.	**Difficult**	**Understand**	**CO2**
Part E (Questions Based on Reasoning/ Problems Based Questions) (5 marks each)				
1.	**Explain** the use of epoxy coatings as a corrosion protection method.	**Easy**	**Understand**	**CO2**
2.	**Explain** how the incorrect selection of raw materials can cause errors and defects in concrete construction.	**Medium**	**Understand**	**CO2**
3.	**Illustrate** the mechanism behind corrosion.	**Difficult**	**Understand**	**CO2**
Part F (Application Based Questions) (5-10 marks each)				
1.	**Explain** design and construction errors in structures.	**Easy**	**Understand**	**CO2**
2.	**Identify** the steps to be taken to prevent corrosion of reinforcement.	**Medium**	**Apply**	**CO2**
3.	**Identify** the factors that contribute to the failure of structures.	**Difficult**	**Apply**	**CO2**
Part G (Short Notes) (5 marks each)				
1.	**Illustrate** about corrosion inhibitors.	**Easy**	**Understand**	**CO2**
2.	**Illustrate** corrosion resisting steel.	**Medium**	**Understand**	**CO2**
3.	**Explain** Hot-dip galvanization for corrosion protection.	**Difficult**	**Understand**	**CO2**

Year: I
Semester: II

6. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**
7. Course : Maintenance and Rehabilitation of Structures **L: 3**
8. Program : M.Tech (CEM) **T: 0**
9. Target : 60% **P: 0**
C: 3

School: School of Engineering & Technology **Department: Civil Engineering**
Course Code: CEM21017 **Course Name: Maintenance and Rehabilitation of Structures**
Program: M.Tech (CEM) **Semester: II**

UNIT NUMBER: III **UNIT NAME: Maintenance and Repair strategies**

Sl. No.	Question	Level of Difficulty (Easy/ Medium/ Difficult)	Knowledge Level (Bloom's Taxonomy)	Course Outcome (CO)
	Part A (Multiple Choice Questions) (1 mark each)			
1.	**Define** maintenance and repair.	**Easy**	**Remember**	**CO3**
2.	**What** are the objectives of maintenance?	**Medium**	**Remember**	**CO3**
3.	**What** are the steps in selecting a repair procedure?	**Difficult**	**Remember**	**CO3**
	Part B (Definition/Naming Questions) (2 marks each)			
1.	**Define** physical inspection of a damaged structure.	**Easy**	**Remember**	**CO3**
2.	**Define** the load test method of evaluating the strength of existing structure.	**Medium**	**Remember**	**CO3**
3.	**What** aspects are covered in Weekly routine inspection or maintenance?	**Difficult**	**Remember**	**CO3**
	Part C (Short Questions) (3-4 marks each)			
1.	**What** are the general considerations to be taken into account for assessment of damage of a structure?	**Easy**	**Remember**	**CO3**
2.	**What** are the possible decisions that can be made after evaluating the strength of a structure?	**Medium**	**Remember**	**CO3**
3.	**Explain** about the environmental effects which lead to deterioration of concrete structures.	**Difficult**	**Understand**	**CO3**

Year: I
Semester: II

6. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**
7. Course : Maintenance and Rehabilitation of Structures **L: 3**
8. Program : M.Tech (CEM) **T: 0**
9. Target : 60% **P: 0**
C: 3

Part D (Explanation Based Questions) (5 marks each)				
1.	**Explain** the facets of maintenance.	**Easy**	**Understand**	**CO3**
2.	**Explain** about the preventive aspects of maintenance.	**Medium**	**Understand**	**CO3**
3.	**Explain** about the repairing aspect of maintenance.	**Difficult**	**Understand**	**CO3**
Part E (Questions Based on Reasoning/ Problems Based Questions) (5 marks each)				
1.	**Why** is inspection needed for damaged structures?	**Easy**	**Remember**	**CO3**
2.	**Illustrate** about the necessary maintenance strategy when the structure still has adequate strength.	**Medium**	**Understand**	**CO3**
3.	**Illustrate** about the necessary maintenance and repairing strategy when the present strength of a structure is inadequate.	**Difficult**	**Understand**	**CO3**
Part F (Application Based Questions) (5-10 marks each)				
1.	**Illustrate** the steps in the assessment procedure for evaluating a damaged structure.	**Easy**	**Understand**	**CO3**
2.	**Identify** different causes for deterioration of concrete structures.	**Medium**	**Apply**	**CO3**
3.	**Identify** various methods for evaluation of the strength of existing structures.	**Difficult**	**Apply**	**CO3**
Part G (Short Notes) (5 marks each)				
1.	**What** are the important testing techniques used for evaluating damaged structures? Write a short note on that.	**Easy**	**Remember**	**CO3**
2.	**Explain** the importance of maintenance.	**Medium**	**Understand**	**CO3**
3.	**Explain** daily routine maintenance and yearly routine maintenance.	**Difficult**	**Understand**	**CO3**

Year: I
Semester: II

6. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**
7. Course : Maintenance and Rehabilitation of Structures **L: 3**
8. Program : M.Tech (CEM) **T: 0**
9. Target : 60% **P: 0**
C: 3

School: School of Engineering & Technology **Department: Civil Engineering**
Course Code: CEM21017 **Course Name: Maintenance and Rehabilitation of Structures**
Program: M.Tech (CEM) **Semester: II**

UNIT NUMBER: IV **UNIT NAME: Materials and Techniques for repair**

Sl. No.	Question	Level of Difficulty (Easy/ Medium/ Difficult)	Knowledge Level (Bloom's Taxonomy)	Course Outcome (CO)
	Part A (Multiple Choice Questions) (1 mark each)			
1.	**What** is self-stressing cement?	**Easy**	**Remember**	**CO4**
2.	**How** can Sulphur infiltrated concrete be manufactured?	**Medium**	**Remember**	**CO4**
3.	**List** the different monomers used in polymer concrete.	**Difficult**	**Remember**	**CO4**
	Part B (Definition/Naming Questions) (2 marks each)			
1.	**What** is dry pack?	**Easy**	**Remember**	**CO4**
2.	**What** are the uses of gas forming and expansive chemicals in concrete?	**Medium**	**Remember**	**CO4**
3.	**What** are the applications of Sulphur infiltrated concrete?	**Difficult**	**Remember**	**CO4**
	Part C (Short Questions) (3-4 marks each)			
1.	**What** are the uses of curing compounds and sealants in concrete construction?	**Easy**	**Remember**	**CO4**
2.	**Illustrate** the factors affecting the properties of fiber reinforced concrete.	**Medium**	**Understand**	**CO4**
3.	**Explain** vacuum concrete in brief.	**Difficult**	**Understand**	**CO4**

Year: I
Semester: II

6. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**
7. Course : Maintenance and Rehabilitation of Structures **L: 3**
8. Program : M.Tech (CEM) **T: 0**
9. Target : 60% **P: 0**
C: 3

Part D (Explanation Based Questions) (5 marks each)				
1.	**Explain** in brief about expansive cement.	**Easy**	**Understand**	**CO4**
2.	**Explain** about polymer concrete and its types.	**Medium**	**Understand**	**CO4**
3.	**Explain** gunite and shotcrete with their processes.	**Difficult**	**Understand**	**CO4**
Part E (Questions Based on Reasoning/ Problems Based Questions) (5 marks each)				
1.	**Explain** the procedures of manufacturing sulphur infiltrated concrete.	**Easy**	**Understand**	**CO4**
2.	**Illustrate** rust eliminators.	**Medium**	**Understand**	**CO4**
3.	**Illustrate** about polymer coating for rebar during repair.	**Difficult**	**Understand**	**CO4**
Part F (Application Based Questions) (5-10 marks each)				
1.	**Illustrate** Epoxy injection.	**Easy**	**Understand**	**CO4**
2.	**Explain** shoring and underpinning.	**Medium**	**Understand**	**CO4**
3.	**Identify** methods of mortar repair for cracks.	**Difficult**	**Apply**	**CO4**
Part G (Short Notes) (5 marks each)				
1.	**What** is foamed concrete? Briefly discuss.	**Easy**	**Remember**	**CO4**
2.	**Explain** ferro cement with its advantages.	**Medium**	**Understand**	**CO4**
3.	**Explain** Fiber reinforced concrete.	**Difficult**	**Understand**	**CO4**

Year: I
Semester: II

6. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**
7. Course : Maintenance and Rehabilitation of Structures **L: 3**
8. Program : M.Tech (CEM) **T: 0**
9. Target : 60% **P: 0**
C: 3

School: School of Engineering & Technology **Department: Civil Engineering**
Course Code: CEM21017 **Course Name: Maintenance and Rehabilitation of Structures**
Program: M.Tech (CEM) **Semester: II**

UNIT NUMBER: V **UNIT NAME: Demolition Techniques**

Sl. No.	Question	Level of Difficulty (Easy/ Medium/ Difficult)	Knowledge Level (Bloom's Taxonomy)	Course Outcome (CO)
	Part A (Multiple Choice Questions) (1 mark each)			
1.	**What** are the major factors for selecting a demolition procedure?	**Easy**	**Remember**	**CO5**
2.	**What** is the protective clothing given before demolition?	**Medium**	**Remember**	**CO5**
3.	**List** the categories of demolition techniques.	**Difficult**	**Remember**	**CO5**
	Part B (Definition/Naming Questions) (2 marks each)			
1.	**List** out the cases where demolition by machines can be adopted.	**Easy**	**Remember**	**CO5**
2.	**What** is deliberate collapse?	**Medium**	**Remember**	**CO5**
3.	**How** a demolition technique can be selected? Mention the parameters on which this selection depends.	**Difficult**	**Remember**	**CO5**
	Part C (Short Questions) (3-4 marks each)			
1.	**What** is pre-weakening?	**Easy**	**Remember**	**CO5**
2.	**Illustrate** about the supervision of demolition work.	**Medium**	**Understand**	**CO5**
3.	**Explain** processes for demolition.	**Difficult**	**Understand**	**CO5**

Year: I
Semester: II

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9. Target : 60% **P: 0**
C: 3

Part D (Explanation Based Questions) (5 marks each)				
1.	**Explain** about preliminary investigation of demolition techniques.	**Easy**	**Understand**	**CO5**
2.	**Explain** wrecking ball application for demolition of structures.	**Medium**	**Understand**	**CO5**
3.	**Explain** the use of Hydraulic Pusher Arm for demolition of structures.	**Difficult**	**Understand**	**CO5**
Part E (Questions Based on Reasoning/ Problems Based Questions) (5 marks each)				
1.	**Explain** engineered demolition briefly.	**Easy**	**Understand**	**CO5**
2.	**Illustrate** demolition sequence for demolition activities by hand.	**Medium**	**Understand**	**CO5**
3.	**Illustrate** demolition sequence for mechanical demolition.	**Difficult**	**Understand**	**CO5**
Part F (Application Based Questions) (5-10 marks each)				
1.	**How** can you develop a demolition strategy?	**Easy**	**Remember**	**CO5**
2.	**Explain** briefly about demolition methods.	**Medium**	**Understand**	**CO5**
3.	**Identify** the considerations to be taken care of before any demolition activity.	**Difficult**	**Apply**	**CO5**
Part G (Short Notes) (5 marks each)				
1.	**What** is demolition by hand? Write a short note.	**Easy**	**Remember**	**CO5**
2.	**Explain** demolition by machines.	**Medium**	**Understand**	**CO5**
3.	**Illustrate** about the use of explosives for demolition of a structure.	**Difficult**	**Understand**	**CO5**

Lecture Notes – Sample

UNIT – I: INTRODUCTION

Year: I
Semester: II

6. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**
7. Course : Maintenance and Rehabilitation of Structures **L: 3**
8. Program : M.Tech (CEM) **T: 0**
9. Target : 60% **P: 0**
C: 3

Quality assurance for concrete construction as built concrete properties strength, permeability, thermal properties and cracking:

Brief overview –

A Quality Assurance scheme is a management system is a management system, which increases confidence that a material, product or service will conform to specified requirements. It outlines the commitments, policies, designated responsibilities and requirements of the owner.

QA scheme of one type or another is used. Depending on the value of the product and methods used in its manufacture, such schemes may themselves become extremely complex and involve individuals, who have little empathy for a particular material or process, even as being very competent in their understanding of others.

The assumptions made during the planning and the design, adequate QA measures shall be taken. The construction should results in satisfactory strength, serviceability and long term durability so as lower the overall life cycle cost.

QA in construction activity results to proper design, use of adequate materials and components to be supplied by the producers, proper workmanship in the execution of works by the contractor and ultimately, proper care during the use of structure, including timely maintenance and repair by the owner.

QA assure are both organizational and technical. Some common cases should be specified in a general QA plan, which shall identify the key elements, necessary to provide fitness of the structure, and the means by which they are to be provided, and the overall purpose to provide confidence that the realized project will work satisfactory in service, fulfilling intended needs.

The job of QA and QC would involve both the inputs as well as the outputs. Inputs are in the form of materials for concrete; workmanship in all stages of batching, mixing, transportation placing, compaction and curing; and the related plant, machinery and equipments; resulting in the output in the form of concrete in place.

QA plan shall define the tasks and responsibilities of all persons involved, adequate control and checking procedures and the organization and maintaining adequate documentation of the building process and its results, such documentation should generally include:

- Test reports and manufacturer's certificate for materials, concrete mix design.
- Pour cards for site organization and clearance for concrete placement.
- Record of site inspection of workmanship, field tests.
- Non-conformance reports, change orders.
- Quality control charts.
- Statistical analysis.

Year: I
Semester: II

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Need for quality Assurance –

The quality necessary to give good performance and appearance throughout its intended life is attained.

- The client requires it in promoting his next engineering scheme.
- The designer depends on it, for his reputation and professional satisfaction.
- The materials producer is influenced by the quantity of work in his future sales.
- The building contractor also relies on it, to promote his organization in procuring future contracts, but his task is often complicated by the problems of time scheduling and costs.

Most faults in structures are attributable to deign errors, and poor workmanship on site with only 10% being due to inadequate materials.

Causes of design faults may include –

- Misinterpretation of the client's needs.
- Lack of good communication between members of the design team.
- Misinterpretation of design standards or codes of practice.
- Use of incorrect or out-of-date data.
- Production of and reference to inadequate and imprecise specifications.

Causes of faults in construction may include -

- Misinterpretation of design drawings or specifications.
- Lack of effective communication with suppliers and sub contractors.
- Inefficient co-ordination of sub-contracted work.
- Inadequate on-site supervision.
- Poor workmanship due to inadequate skills and experience of the labour force satisfactory instructions.

Strength of concrete:

The compressive strength of concrete is one of the most important and useful properties of concrete. In most structural applications concrete is employed primarily to resist compressive stresses. In most structural applications concrete is employed primarily to resist compressive stresses. In those cases where strength in tension or in shear is of primary importance, the compressive strength is frequently used as a measure of these properties.

The compressive strength of concrete is generally determined by testing cubes or cylinders made in laboratory or field or cores drilled from hardened concrete at site. Strength of concrete is its resistance to rupture; It may be measured in a number of ways, such as Strength in compression, in tension, in shear or in flexure. All these indicate strength with Reference to a particular method

of testing. When concrete fails under a compressive load the failure is essentially a mixture of crushing and shear failure.

The strength that may be developed by workable, properly placed mixture of cement, aggregate and water is influenced by -

- Ratio of cement to mixing water.
- Ratio of cement to aggregate.
- Grading, surface texture, shape, strength and stiffness of aggregate particles.
- Maximum size of aggregate.

Permeability of concrete:

The rates at which liquids and gases can move in the concrete are determined by its permeability. Permeability of Concrete is often referred to as root cause for lack of durability. Permeability affects the way, in which concrete resists external attack, and the extent to which a concrete structure can be free of leaks. Theoretically, the introduction of aggregate of low permeability into cement paste. it is expected to reduce the permeability of the system, because the aggregate particles intercept the channels of flows and makes it take a circuitous route. Compared to neat cement paste, concrete with the same W/C ratio and degree of maturity, should give lower coefficient of permeability. But in practice, it is seen from test data it is not the case. The introduction of aggregate, particularly larger size of aggregates increases the permeability considerably.

The use of pozzolanic materials in optimum proportion reduces the permeability of concrete. This is evidently due to the conversion of calcium hydroxide, otherwise soluble and leachable, into cementitious product.

Though air-entrainment makes the concrete porous, when used upto 6%, makes the concrete more impervious, contrary to general belief.

High-pressure steam cured concretes in conjunction with crushed silica decreases the permeability. This is due to the formation of coarser C-S-H gel, lower drying shrinkage and accelerated conversion of Ca $(OH)_2$ into cementitious products.

Thermal properties of concrete:

Thermal properties of concrete to understand the behavior of concrete to heating and cooling. The study of thermal properties of concrete is an important aspect while dealing with the durability of concrete.

Concrete is a material used in all climatic regions for all kinds of structures.The important properties that will be discussed are:

- Thermal conductivity

6. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**
7. Course : Maintenance and Rehabilitation of Structures **L: 3**
8. Program : M.Tech (CEM) **T: 0**
9. Target : 60% **P: 0**
C: 3

- Thermal diffusivity
- Specific heat
- Coefficient of thermal expansion

Thermal Conductivity –

This measures the ability of material to conduct heat. Thermal conductivity is measured in joules per second per square meter of are conductivity of concrete depends on type of aggregate of a body when the temperature difference is 1degree C per meter thickness of the body.

The conductivity of concrete depends on type of aggregate moisture content, density and temperature of concrete. When the concrete is saturated, the conductivity ranges generally between about 1.4 and 3.4 J/S/m^2.

Thermal Diffusivity –

Diffusivity represents the rate at which temperature changes within the concrete mass. Diffusivity is simply related to the conductivity by the following equation:

Diffusivity=Conductivity/CP

Where C is the specific heat, and P is the density of Concrete. The range of diffusivity of concrete is between 0.002 and 0.006 m^2/h.

Specific heat -

It is defined as the quantity of heat, required to raise the temperature of a unit mass of a material by one degree centigrade. The common range of values for concrete is between 840 and 1170 j/kg^3/C.

Coefficient of thermal expansion –

It is defined as the change in unit length per degree change of temperature. In concrete, it depends upon the mix proportions. The coefficient of thermal expansion of hydrated cement paste varies between 11x10^-6 and 20x10^-6 per degree C. The coefficient of thermal expansion of aggregates varies between 5x10^6 and 12x10^-6 per degree C Limestone and Gabbros will have low values and gravel and Quartzite will have high values of coefficient of thermal expansion.

Cracking in Concrete:

Cracking will occur whenever the tensile strain, to which concrete is subjected, exceeds the tensile strain capacity of the concrete. The tensile strain capacity of concrete varies with age and with the rate of application of strain.

Classification of cracks -

It may be classified in terms of their effects:

- Those cracks which indicate immediate structural distress.

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- Those cracks which may lead in the long run to a reduction of safety, through corrosion of steel.
- Cracks which lead to malfunction of the structure, as evidenced by leakage, sound transfer, damage to finishes and unsatisfactory operation of windows and doors.
- Cracks which are aesthetically unacceptable.

Class I - Cracks leading to Structural Failure -

Little difficulty arises in relation to this class. Those cracks that indicate that failure is near and that margin of safety are seriously reduced, may have formed in concrete, which was expected by the designer, to carry load in its un cracked condition .Such cracks are necessarily wide, and may lead to the detachment of parts of the structure.

Class II - Cracks causing Corrosion -

There is no unique relationship between crack width and the onset of corrosion. Part of the difficulty arises from the nature of cracks themselves. For flexural members, many cracks taper from a certain width at the surface of the concrete, the near zero width at the steel-concrete interface. However, flexural cracks that are controlled by the overall depth of the beam are not of the tapered shape, and it is likely that cracks due to temperature and shrinkage are nearer to being parallel sided. It has been assumed for many years that, since wider cracks would give easier access to aggressive substances, corrosion could be controlled by controlling crack widths and that permissible widths should be a function of how aggressive the environment was many complicated formulas for the calculation of crack widths in flexural members have been devised with the object of controlling corrosion. But extensive tests on beams in which the cracks are normal to the axis of the bars show evidence of any relationship between corrosion damage and crack width.

When cracks run along a bar, much more of the bar is in an exposed position, and it might be expected that there would be a closer relationship between crack width and corrosion in this situation. There is a little evidence however, that cracks whether transverse to the bars or running along the bars, pose any create risk of increased corrosion, if they are less than 0.3mm in width.

Some cracks, which are parallel to a bar, may have been caused by the corrosion of that bar. These cracks will widen as corrosion proceeds, and will eventually lead to spalling and exposure of the corroded bar. A crack of any width, which is judged to be brought about by corrosion, is an indication of a deteriorating structure, and therefore no minimum width, below which the crack is not significant, can be set. A crack that indicates the corrosion of the bar is actually showing that the corrosion will continue, unless positive measures are taken. Merely filling the crack will not achieve the result.

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Class III - cracks affecting Function -

The cracks in this class, which have the most serious consequences are those that allow liquid-retailing structures to leak, or that occur in roofs or other structures, intended to be waterproof. BS 8007 prescribes limiting crack widths and details methods of predicting the widths. The maximum design surface crack width, for direct tension and flexure or restrained temperature and moisture effects are:

Severe or very severe exposure - 0.2mm

There are only limited test data available on what constitutes the limiting crack, for preventing leakage. Flow through a parallel-sided smooth crack, can be calculated in terms of head, crack width, crack length and fluid viscosity. The difficulty with concrete is that the cracks are not smooth or parallel-sided.

Class IV - cracks affecting appearance -

For class 4cracks,it has been suggested that crack widths up to 0.3mm in width are acceptable aesthetically, but there are no good guidelines. Various attempts have been made to establish what constitutes an acceptable crack on an aesthetic basis, but in the end, there is no rational basis for aesthetic decisions. The aesthetic objection to cracks may be summarized as:

- Cracks cause alarm about the safety of the structure
- Cracks lower the visual acceptance of the structure (a) by modifying surface textures and damaging the visual effect intended by the designer and (b) by giving an appearance of cheapness or bad building.

Causes of cracking -

Cracking in plastic concrete may be due to: The removal of water from the top surface by evaporation exceeds the rate, at which bleed water is coming to the surface.	Cracking in Hardened concrete may be due to: The structural response to applied loads and external displacements
Early shrinkage of concrete	The intrinsic nature of the concrete and its constituent materials

Other types of cracks due to -

- Delayed curing
- Formwork movement

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- Excess vibration
- Sub grade settlement
- Finishing
- Early frost damage
- Unsound materials
- Long-term drying shrinkage

Effects due to climate, temperature, chemicals, wear and erosion:

Effects due to Climate on Concrete -

The lack of durability of concrete on account of freezing and thawing action of frost is not of great importance to Indian conditions. But it is of greatest considerations in most part of the world.

The most severe climatic attack on concrete occurs, when concrete containing moisture is subjected to cycle of freezing and thawing. The capillary pores in the cement paste are of such a size that water in them will freeze, when the ambient temperature is below 0degree C.

The gel pores are so small that water in them does freeze at normal winter temperatures. As water, when freezing expands by 9% of its volume, excess water in the capillaries has to move. Since the cement paste is relatively impermeable high pressures are necessary to move the excess water even over quite small distances. For normal strength concrete, it has been found that movement of the order of 0.2mm is sufficient to require pressures which approach the tensile strength of the paste.

Concrete can be protected from freeze-thaw damage by the entrainment of the appropriate quantities of air distributed through the cement paste, with spacing between bubbles of not more than about 0.4mm. The air bubbles must remain partially empty, so that they can accommodate the excess water moved to them. This will generally be the case, since the bubbles constitute the coarsest pore system, and are therefore the first to, most moisture as the concrete dries. Fully saturated concrete, if permanently submerged, will not need protection against freezing, but concrete which has been saturated and is exposed to freezing as for example in the tidal range, may not be effectively protected by air entrainment.

For effective protection, an air entraining agent must be added to the mix, to entrain the appropriate amount of air, and to induce a bubble system, with an appropriate spacing. When AEA is used, it is only the amount of air entrained which can be measured in the wet concrete. The amount of air required is between 4-8%, depending on the maximum size of aggregate. Air is entrained during the mixing action, even when no AEA is added. The effect of AEA is to stabilize the air bubbles in the form desired.

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More air is entrained with a larger dose of AEA but the effect is not linear and with most agents levels off larger doses. For mixes with higher slump, more air is entrained. It is difficult to entrain air is very stiff mixes; the grading and nature of the particles in the fine aggregates have a very marked effect, on the amount of air entrained. It has been shown that the sand is the most important single factor in air entrainment.

It has been suggested that if concrete can be so dense, that there are no inter-connected capillary pores, and then resistances to freeze- thaw deterioration will exist without the need for air entrainment.

The use of high cement content and low w/c ratio will lead in this direction as will the introduction of silica flume, but there is yet firm evidence to show that, it would be wise to dispense with air-entrainment, if freeze-thaw resistance is wanted.

Effects due to temperature -

Temperatures of concrete, other than special refractory concrete, have to be kept below 300° C. Heat may affect concrete as result of -

- The removal of evaporable water
- The removable of combined water
- Alteration of cement paste
- Disruption from disparity of expansion and resulting thermal stress
- Alteration of aggregate
- Change of the bond between aggregate and paste

Effects due to Chemicals -

Some of the factors, which increases the vulnerability of concrete to external chemical attack, are -

- High porosity, and hence high permeability
- Improper choice of cement type for the conditions of exposure
- Inadequate curing prior to exposure
- Exposure to alternate cycles of wetting and drying and to a lesser extent heating and cooling, with allowance for the fact that higher temperature increase reactivity
- Increased fluid velocities
- Expansive reactions of any sort which may cause cracking and any other physical phenomena, which lead to greater exposure of reactant surfaces
- Suction forces
- Unsatisfactory choice of shape and surface to volume ratios of concrete section

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Effects due to wear and erosion –
Erosion is one form of wearing of concrete that is observed in contact with flowing water. The water body that results erosion may carry solid particles which leads to serious erosion to concrete. The factors that determine the degree of erosion are –

- Quantity of the transported particles.
- Shape of these particles.
- Size of these particles.
- Hardness of these particles.
- Velocity of particle movement.
- Formation of eddies.
- At last quality of concrete.

The concrete quality, especially in surface zone is very important to resist erosion of concrete. We will provide factors and ways to control erosion in the very next post. Like abrasion the resistance against erosion is also related to the strength of concrete but mix composition of concrete is also vital.
Erosion is a mechanical damage of concrete which is frequently associated with corrosion. Marine concrete is the ideal example of such damage. With this corrosion effects, erosion is happened when mechanical damage to concrete is occurred by the waves of water with gravel and sand carried by them. Sometimes crystallized salt takes the part of impacting from carried particles.

UNIT – II: CORROSION

Corrosion is defined as the process of deterioration (or destruction) and consequent loss of a solid metallic material, through an unwanted (or unintentional) chemical or electro-chemical attack by its environment, starting at its surface, is called Corrosion. Thus corrosion is a process of 'reverse of extraction of metals'.

Concrete design and construction errors:

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Misconceptions of Structural Action -

Design procedures often include simplifying assumptions as to the way, in which the final structure will behave. It the designer does not ensure that the structure can, in fact, behave in the assumed way, cracking occurs to the extent necessary. A common example is when moment free condition is assumed and not achieved. A wall-floor joint in a 1 Million Liter water tank is shown fig. In the design of the tank, this joint had been assumed to behave as a pin, but the face marked bitumen paint did not have enough separation.

As a result, when the tank wall rotated under water load, the faces came into contact and the corner behaved as a knee-joint, transmitting moment. The compression components of this moment produced a diagonal tensile resultant, which caused a substantial piece of un-reinforced concrete to spall off, as shown in figure and exposed reinforcement then corroded.

When connected members have very different rigidities forces may tend to migrate from the path, provided by the designer into an alternative rigid member.

The primary beam shown in the figure below as to transfer the negative moments from the secondary beams, to the supporting columns. As the columns and the primary beams are both stiff members, this transfer involves a torque in the primary beam, for which torsion reinforcement is needed. When this reinforcement was omitted from the design, helical cracks appeared.

Reinforcement Detailing -

Inadequate detailing of reinforcement is a widespread cause of cracking and particularly of those severe cracks, which affect the limit state of collapse. Designers given the opportunity, learn from experience and in many organizations, this source of trouble is steadily reduced. Members, which appear to be particularly susceptible to severe cracking as a result of insufficient steel or broadly arranged steel, are those which carry local loads, such as corbels, supports for bridge bearings, walls supporting column bases, pre-stressing anchorages and column capitals.

Conventional drawings tend to ignore the physical size of the bars, and the limitations on bend shape in practical reinforcing. Equally important is the need, to ensure that the steel is incorporated in the way it was designed.

Extensive tests on corbels identified 6 different failure mechanisms, which may occur and against which, reinforcement is needed. An arrangement of reinforcing which takes account of these potential failure modes in shown in the figure below. A very common source of trouble arises from locating the outer edge of the bearing, beyond where the steel can possibly be located. The designer should ensure that with normal tolerances on steel bending and placing, there is still adequate steel located outside the edge of the bearing, when it is located at the extreme of its tolerance.

Some arrangements of reinforcement actually cracks, and these should be carefully avoided. For example severe cracking can be seen, when all the top bars in a slab are terminate at the same cross section.

Construction Errors -

Construction & supervision deficiencies are the major cause of defects, leading to cracking. It has been found that 36% of the defects were due to these causes. A well-known expect on structural failures said that, he never found a failure caused by poor concrete, but he had never investigated one that did not contain poor or interior concrete. This comment related to collapses of structures, but when the definition of failure is extended as we are doing here, the quality of concrete does become much more important. For example, the protection afforded to steel is greatly of concrete depended on the compaction & curing of the cover concrete.

Survey revealed that construction defects could be grouped into 4 classes.

A. Deficiencies in the control of concrete materials, batching & mixing -

• Use of salt water as mixing water • Excess fines in the aggregates

B. Inadequate preparation before concreting -

• Salt water contamination of reinforcement • Lack of cover to reinforcement

C. Inadequacies of placing & subsequent treatment -

• Plastic cracking & settlement cracking • Lack of curing

D. Faults of construction planning &procedure -

• Overloading of members by construction loads • Loading of partially constructed members • Differential shrinkage between section of construction • Omission of designed movement joints • Unexpected behavior and restraint during prestressing.

Corrosion Mechanism:

Wet or Electro-Chemical Corrosion - Corrosion of steel concrete is an electro-chemical process. When there is a difference in electrical potential, along the reinforcement in concrete, an electro-chemical cell is set up. In the steel, one part becomes anode (an electrode with a +ve charge) and other part becomes cathode, (an electrode with a -ve charge) connected by electrolyte in the form of pore water, in the hardened cement paste. The +vely charged ferrous ions Fe^{+} at the anode pass into solution, while the -vely charged free electrons -pass through the steel into cathode, where they are absorbed by the constituents of the electrolyte, and combine with water and oxygen to form hydroxyl ions (OH). These travel through the electrolyte and combine with the ferrous ions to form ferric hydroxide, which is converted by further oxidation to rust.

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The reactions are described below -

Anodic Reactions:

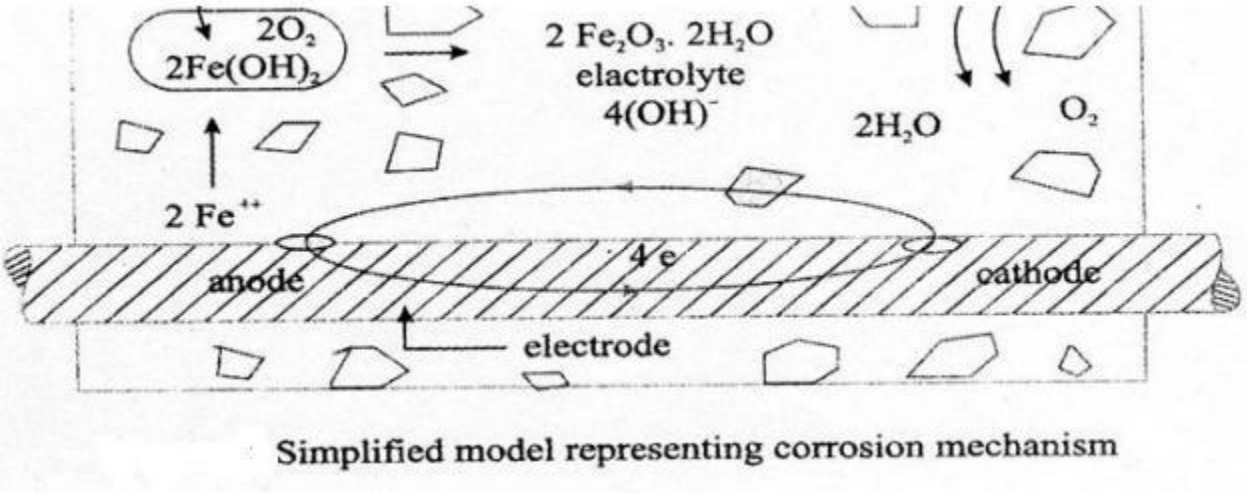
$Fe - - > Fe^{++} + 2e^-$

$Fe^{++} + 2(OH)_2 - - > Fe(OH)_2$

$Fe(OH)_2.2H_2O + O_2 -- > 4Fe(OH)_3$

Cathodic Reaction:

$4e^- + O_2 + H_2O \quad -- - > \quad 4(OH)$



Simplified model representing corrosion mechanism

It can be noted that no corrosion takes place if the concrete is dry probably below relative humidity of 60%, because enough water is not there to promote corrosion. it can also be noted that corrosion does not take place, id concrete is fully immersed in water, because diffusion of oxygen does not take place into the concrete. Probably the optimum relative humidity for corrosion is 70-80%. The products of corrosion occupy a volume as much as 6 times the original volume of steel, depending upon the oxidation state. Figure below shows the increase in volume of steel, depending upon the oxidation state.

It may be pointed out that though the 2 reactions Fe2 and OH originate iron the anode and cathode respectively, their combination occurs more commonly at the cathode, because the Sn alert Fe2+ ions diffuse more rapidly than the larger OH ions. So, corrosion occurs at the anode, but rust is deposited at or near the cathode.

Increase the oxygen content has 2 effects -

- It forces the cathode reaction to the right, producing more OH- ions
- It removes more electrons and therefore, accelerates the corrosion at the anode.

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Each of these effects, in turn, supplies more reactants for the forming reaction. Obviously, presence of oxygen greatly accelerates both corrosion and rust formation, with the corrosion occurring the entire anode, but the rust forming at the cathode.

Effects of cover thickness & cracking:

In reinforced concrete structures, sufficient cover of concrete has to be provided to avoid exposure of reinforcement to aggressive environmental conditions and consequent rusting and deterioration of the cross sectional area in the structural elements. The most common construction defect, particularly in buildings, is lack of adequate thickness of cover.

It provides the nominal cover requirements to meet -

- The durability requirements
- Specified period of fire resistance

Requirements of concrete cover -

The protection of the steel in concrete against corrosion depends upon an adequate thickness of good quality of concrete.

Methods of corrosion protection:

Reinforcement in concrete can be protected from corrosion in three main ways: (1) seal the surface of the concrete to minimize the ingress of chloride ions, carbon dioxides, and water, (2) modify the concrete to reduce its permeability, and (3) protect the reinforcing bars to reduce the effects of chlorides and carbon dioxide when they do reach the steel.

Other methods include –

1. **Barrier coatings -** One of the easiest and cheapest ways to prevent corrosion is to use barrier coatings like paint, plastic, or powder. Powders, including epoxy, nylon, and urethane, are heated to the metal surface to create a thin film. Plastic and waxes are often sprayed onto metal surfaces. Paint acts as a coating to protect the metal surface from the electrochemical charge that comes from corrosive compounds. Today's paint systems are actually a combination of different paint layers that serve different functions. The primer coat acts as an inhibitor, the intermediate coat adds to the paint's overall thickness, and the finish coat provides resistance to the environmental factors. The biggest drawback with coatings is that they often need to be stripped and reapplied. Coatings that aren't applied properly can quickly fail and lead to increased levels of corrosion. Coatings may also contain volatile organic compounds, which can make them vulnerable to corrosion.

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2. **Hot-Dip galvanization -** This corrosion prevention method involves dipping steel into molten zinc. The iron in the steel reacts with the zinc to create a tightly-bonded alloy coating which serves as protection. The process has been around for more than 250 years and has been used for corrosion protection of things like artistic sculptures and playground equipment. Compared to other corrosion prevention methods, galvanization is known for lower initial costs, sustainability, and versatility. Unfortunately, galvanization can't be done on-site, meaning companies have to pull equipment out of work to be treated. Some equipment may simply be too large for the process, forcing companies to abandon the idea altogether. In addition, if the process isn't done properly, the zinc can chip or peel. And high exposure to environmental elements can speed up the process of zinc wear, leading to increased maintenance check-ups. Lastly, the zinc fumes that release from the galvanizing process are toxic.
3. **Alloyed steel or Stainless steel -** Alloyed steel is one of the most effective corrosion prevention methods around, combining the properties of various metals to provide added strength and resistance to the resulting product. Corrosion-resistant nickel, for example, combined with oxidation-resistant chromium results in an alloy that can be used in oxidized and reduced chemical environments. Different alloys provide resistance to different conditions, giving companies greater flexibility. Despite its effectiveness, alloyed steel is very expensive. Companies with limited financial resources will likely have to turn to other methods. Monitoring surface conditions are critical, as cracks or scratches can result in an increase of corrosion. Companies also need to make sure the agents used in maintenance don't include corrosion properties.
4. **Cathodic protection -** Cathodic protection protects against galvanic corrosion, which occurs when two different metals are put together and exposed to a corrosive electrolyte. To prevent this, the active sites on the metal surface need to be converted to passive sites by providing electrons from another source, typically with galvanic anodes attached on or near the surface. Metals used for anodes include aluminum, magnesium, or zinc. While cathodic protection is highly effective, anodes need to be checked often which can drive up costs of maintenance. They also increase the weight on the attached structure and aren't always effective in high-resistivity environments. Finally, anodes lead to increased water flow on ships and other underwater equipment.

UNIT – III: MAINTENANCE AND REPAIR STRATEGIES

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Facets of maintenance:

Maintenance operations have many facets such as –

a) Emergency maintenance: Necessitated by unforeseen breakdown drainage or damage caused by natural calamity like fire, floods, cyclone earthquake etc.

b) Condition Based maintenance: Work initiated after due inspection

c) Fixed time maintenance: Activities repeated at predetermined intervals of time.

d) Preventive maintenance: This is intended to preserve by preventing failure and detecting incipient faults (Work is done before failure takes place)

e) Opportunity maintenance: Work did as and when possible within the limits of operation demand.

f) Day-to-Day care and maintenance

g) Shut down maintenance: Thorough overhaul and maintenance after closing a facility.

h) Improvement plans: This is essentially maintenance operation wherein the weak links in the original construction are either replaced by new parts or strengthened.

Importance of Maintenance:

- Improves the life of structure
- Improved life period gives better return on investment
- Better appearance and aesthetically appealing
- Better serviceability of elements and components
- Leads to quicker detection of defects and hence remedial measures
- Prevents major deterioration and leading to collapse
- Ensures safety to occupants
- Ensures feeling of confidence on the user
- Maintenance is a continuous cycle involves every element of building science namely – Structural, Electrical wiring, Plumbing-water-supply-sanitation, Finishes in floors and walls, Roof terrace, Service platform/verandah, Lifts, Doors windows and other elements.

Preventive measures on various aspects of Inspection:

The following are the various maintenance aspects –

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a) Daily Routine Maintenance
b) Weekly Routine Maintenance
c) Monthly Routine Maintenance
d) Yearly Routine Maintenance
a) Daily Routine Maintenance –

- Basically an inspection oriented and may not contain action to be taken
- Help in identifying major changes, development of cracks, identifying new cracks etc
- Inspection of all essential items by visual observation
- Check on proper function of sewer, water lines, wash basins, sinks etc
- Check on drain pipes from roof during rainy season.

b) Weekly Routing Maintenance –

- Electrical accessories
- Cob webs cleaning
- Flushing sewer line
- Leakage of water line

c) Monthly Routing Maintenance –

- Cleaning doors, windows‟ latches etc
- Checking septic tank/ sewer
- Observation for cracks in the elements
- Cleaning of overhead tanks
- Peeling of plaster, dampness, floor cracks

d) Yearly Routing Maintenance –

- Attending to small repairs and white washing
- Painting of steel components exposed to weather
- Check of displacements and remedial measures

Repair:
Repair is the technical aspect of rehabilitation. Refers to modification of a structure partly or wholly which is damaged in appearance or serviceability.
Stages of repair - Repair of concrete structure is carried out in the following stages:
a) Removal of damaged concrete
b) Pre treatment of surfaces and reinforcement
c) Application of repair materials
d) Restoring the integrity of individual sections and strengthening of structure as a whole.

Assessment procedure for evaluating damaged structure:
For assessment of damage of a structure the following general considerations have to be take account -1) Physical inspection of damaged structure.
2) Presentation and documenting the damage.
3) Collection of samples and carrying out tests both in situ and in lab.
4) Studying the documents including structural aspects.

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5) Estimation of loads acting on the structure.
6) Estimate of environmental effects including soil structure interaction.
7) Diagnosis.
8) Taking preventive steps not to cause further damage.
9) Retrospective analysis to get the diagnosis confirmed.
10) Assessment of structural adequacy.
11) Estimation of future use.
12) Remedial measures necessary to strengthen and repairing the structure.
13) Post repair evaluation through tests.
14) Load test to study the behavior.
15) Choice of course of action for the restoration of structure.

A simple flow chart incorporating the above points is presented in fig 1.1.

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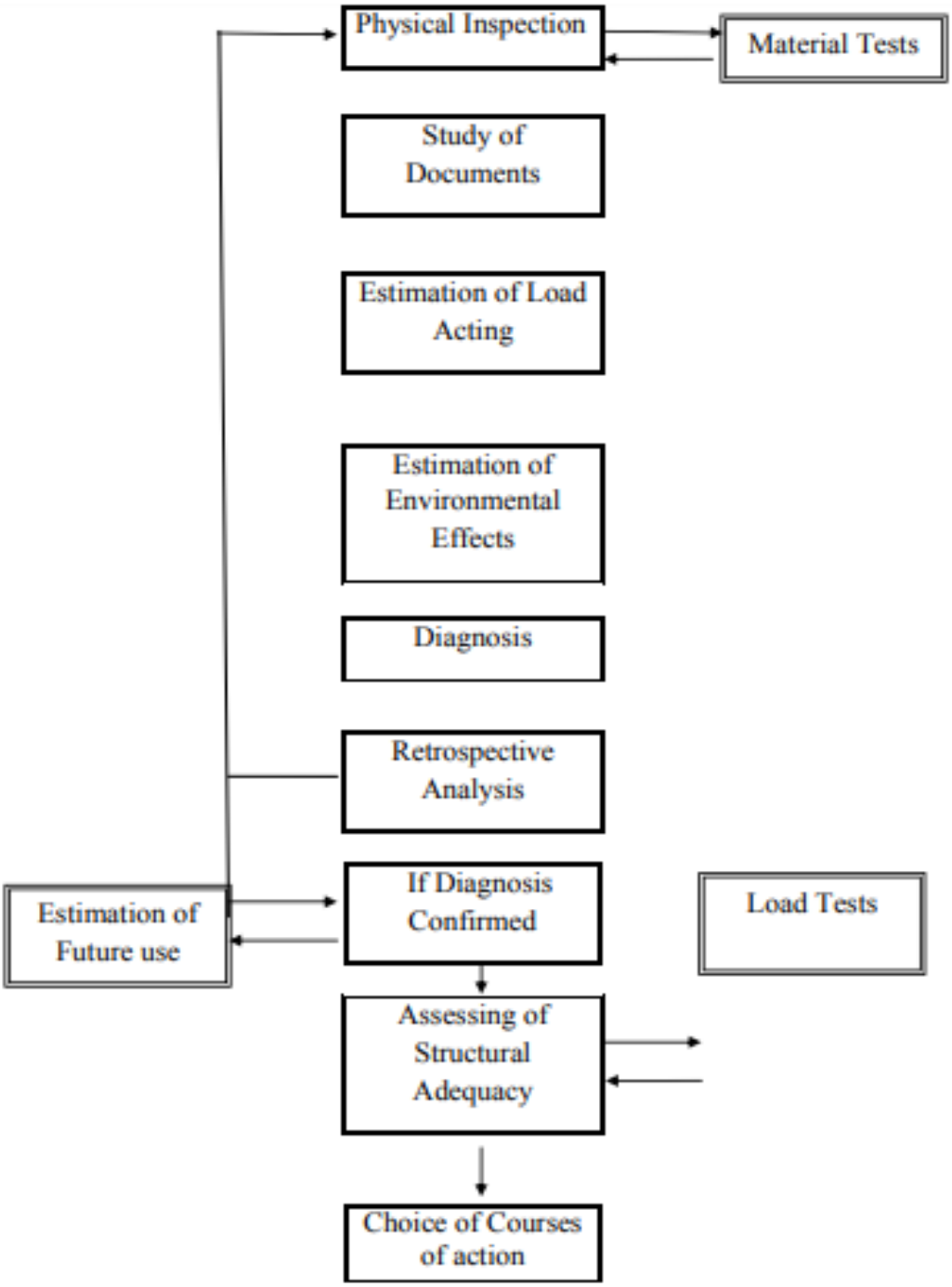

Fig. 1.1 Assessment Procedure of Damage

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Causes of Deterioration:
The following are the causes of failure of structure –
a) Occurrences incidental to construction stage. This could be attributed to -
1. Local settlement of sub grade.
2. Movement of formwork.
3. Vibrations.
4. Internal settlement of concrete suspension.
5. Setting Shrinkage.
6. Premature removal forms.

b) Drying Shrinkage
c) Temperature stresses – This may be due to -
1. Difference in temperatures between the inside of the building with its environment.
2. Variation in internal temperature of the building or structure.

d) Absorption of moisture by concrete
e) Corrosion of reinforcement – This could be caused by –
1. Entry of moisture through cracks or pores.
2. Electrolytic action

f) Aggressive action of chemical
g) Weathering action
h) Action of shock waves
i) Erosion
j) Poor design details at –
1. Re-entrant corners
2. Changes in cross section
3. Rigid joints in precast elements
4. Deflections

k) Errors in design
l) Errors in earlier repairs
m) Overloading
n) External influences such as –
1. Earthquake
2. Wind
3. Fire
4. Cyclones etc.

Testing Techniques:
A number of non-destructive, partially destructive and destructive techniques for assessment of concrete structure and to predict the cause of deterioration of the concrete in the existing structures are available. Interest in the field of Non-Destructive Testing (NDT) of structure is increasing worldwide. These NDT techniques can be broadly classified into following four groups –

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1. Strength Tests –

- Schmidt Hammer Test
- Ultrasonic Pulse Velocity
- Pull out and Pull off Tests
- Break off
- Core Test
- Windsor Probe
- Pulse Eco Technique

2. Durability Tests –

- Corrosion Tests
- Absorption and Permeability
- Test for Alkali Aggregate Reaction
- Abrasion Resistance Tests
- Rebar Locator Test

3. Performance and Integrity Tests –

- Infrared Thermography Test
- Radar Test
- Radiography and Radiometry Tests
- Acoustic Emission
- Optical Fibre Test
- Impact Echo Tests
- Load Testing test
- Dynamic Response
- X-Ray Diffraction

4. Chemical Tests –

- Carbonation test
- Suphate Determination Test
- Chloride Determination Test
- Thermo-luminescence Test
- Thermo gravimetric analysis Test
- Differential Thermal analysis
- Dilatometric Test

With these tests it would be possible to know in-situ strength/quality of concrete to precise identify the damage and causes of the deterioration of the structure, to predict the residual life measures to enhance the life of the structure.

UNIT – IV: MATERIALS AND TECHNIQUES FOR REPAIR

Special concretes:

Year: I
Semester: II

6. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**
7. Course : Maintenance and Rehabilitation of Structures **L: 3**
8. Program : M.Tech (CEM) **T: 0**
9. Target : 60% **P: 0**
C: 3

Special Concrete means the concrete used or made for special cases, frequently, concrete may be used for some special purpose for which special properties are more important than those commonly considered. Sometimes, it may be of great importance to enhance one of the ordinary properties. These special applications often become apparent as new development using new materials or as improvements using the basic materials. Some utilize special aggregates (lightweight aggregate, steel fiber, plastic fiber, glass fiber, and special heavy aggregate).

Some special properties of special concrete may include - increased compressive and tensile strength, water proofing, and improved chemical resistance are achieved with polymers, either as admixtures or surface treatment of hardened concrete. Admixtures for coloring concrete are available in all colors. The oldest and cheapest is perhaps carbon black. Admixtures causing expansion for use in sealing cracks or under machine bases, etc., include powdered aluminum and finely ground iron. Special admixtures are available for use where the natural aggregate is alkali reactive, to neutralize this reaction. Proprietary admixtures are available that increase the tensile strength or bond strength of concrete. They are useful for making repairs to concrete surfaces.

Uses and Applications of Special Concrete -

1. Special concrete is used in extreme weather.
2. HPC has been used in large structures such as the Petronas Towers and the Troll Platform. Petronas Towers was the tallest concrete building in the world built in Malaysia in the mid-1990s. In 1998, the deepest offshore platform, the Troll platform, was built in Norway — a structure taller than the Eiffel Tower.
3. Good cohesiveness or sticky in mixes with very high binder content
4. Some delay in setting times depending on the compatibility of cement, fly ash and chemical admixture
5. Slightly lower but sufficient early strength for most applications
6. Comparable flexural strength and elastic modulus
7. Better drying shrinkage and significantly lower creep
8. Good protection to steel reinforcement in high chloride environment
9. Excellent durability in aggressive sulphate environments
10. Lower heat characteristics
11. Low resistance to de-icing salt scaling
12. PC pipes with good resistance to chemical attack from both acidic and caustic effluents inside the pipe, and from chemical attack on the outside of the pipe.

Different types of special concretes are –

1. Polymer Concrete
2. Roller Compacted Concrete
3. Fiber Reinforced Concrete
4. Saw Dust Concrete
5. Preplaced Aggregate Concrete
6. Vacuum-Processed Concrete
7. Colcrete etc.

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1. Polymer Concrete:

Polymer Concrete may be classified into the following groups -

i. Polymer Cement Concrete (PCC).
ii. Polymer Concrete (PC).
iii. Partially impregnated and surface coated polymer concrete.

i. Polymer Cement Concrete (PCC):
Polymer cement concrete can be prepared by mixing cement, aggregates, water and monomers as usual in ordinary concrete. The plastic mixture is cast in moulds, cured, dried and polymerized.

Following monomers may be used in Polymer Cement Concrete (PCC):
(a) Epoxy-styrene
(b) Polyster-styrene
(c) Furans, and
(d) Vinylidene chloride.

However polymer cement concrete produced in this way has shown a very modest improvement in strength and durability. RUSSIAN authors have reported recently that superior polymer cement concrete can be produced by using Furfuryl alcohol and Aniline hydrochloride in the wet mix. This product has been found specially dense, non-shrinking and high resistant to corrosion, low permeability, high resistant to vibrations and axial extension etc.
Whereas U.S. researchers have found that the use of epoxy resin has produced polymer cement concrete having some superior characteristics over ordinary concrete. The PCC using polymer latex has given a tensile strength of 5.8 MPa with w/c ratio of 0.25 compared with control specimen of 4.4 MPa. The increase in tensile strength is very modest.

Uses: Polymer cement concrete can be used for flooring in deck steel over bridges, food processing and chemical industries, wear resistant floors etc. It is also useful for repair of sea defense structures due to early development of strength.

ii. Polymer Concrete (PC):
It is a composite in which cement water matrix of cement concrete is replaced by a polymer binder. The main technique in producing polymer concrete is to minimize the volume of voids in the aggregate mass, so that minimum quantity of binder polymer is needed to bind the aggregates. This can be achieved by properly grading and mixing the aggregates to obtain the maximum density and minimum volumes of voids.
The graded aggregates are pre-packed in a form and vibrated. After this, the monomer is diffused through the aggregates and polymerization is initiated by chemical or radiation process. To improve the bond between the monomer and aggregates an adhesive agent is added to the monomer. In case polyester resins are used then no polymerization is needed.
Polyester resin concrete with binder content varying from 20 to 25% has shown tensile strength in the range of 9 to 10 MPa at 7 days. The compressive strength of P.C. has been found of the order of 140 MPa with a short curing period.

Necessity for Developing the Polymer Concrete:
The most important reason for the development of polymer concrete is to overcome the short comings of the conventional concrete under the following situations -
i. On curing the alkaline port-land cement concrete forms internal voids. In these voids water can be entrapped, which on freezing expands, resulting cracks in concrete.

ii. The alkaline port-land cement concrete is easily attacked by chemically aggressive (reactive) material, which causes rapid deterioration of the concrete.
iii. The polymer concrete can be made compact with minimum voids and hydrophobic (water replant) and resistant to chemical attack.

However polymer concrete suffers from certain short comings. Its main short coming is its brittleness. It has been found that the tensile strength and toughness of polymer concrete can be increased by the dispersion of fiber reinforcement. The use of fibrous polyester concrete (FPC) in the compressive region of reinforced concrete beams provides a high strength and ductile concrete at reasonable cost.
Also the polyester concrete is visco-elastic in nature and will fail under sustained compressive loading stress at 50% higher than the ultimate stress. Thus the polyester concrete can be used for structures with a high ratio of live load to dead load and for composite structures in which polymer concrete may relax during long term loading.

iii. Partially Impregnated and Surface Coated (SC) Concrete:
In situations where in addition to strength increase, the major requirement is the surface resistance to chemical and mechanical attack, the partial impregnation may be sufficient. Partial impregnation has been found quite effective in the increase of the strength of the original concrete.
The partially impregnated concrete can be produced by soaking the initially dried specimens in liquid monomer like methyl methacrylate and then sealing them by keeping under hot water at 70°C to prevent or minimize the loss due to evaporation. The polymerization can be done by using thermal catalytic method. Benzoyl peroxide is added as a catalyst to the monomer.

The depth of penetration of the monomer depends upon the following factors -
i. Pore structure of hardened and dried concrete
ii. The viscosity of the monomer, and
iii. The duration of soaking of specimens in the monomer.

Use of Partially Impregnated and Surface Coated Concrete:
The main use of this concrete has been done in improving the durability of concrete where the abrasive wear, freezing and thawing, spalling and corrosion of reinforcement are the main cause of deterioration as in bridge decks. Bridge deck deterioration is a major problem everywhere. Excellent penetration can be achieved by ponding the monomer on the concrete surface.
While monomer is ponded on the surface due care should be taken to prevent the evaporation of monomer. By soaking a 5 cms thick slab for 25 hours with Methyl methacrylate (MMA), the polymer was found to penetrate upto 2.5 cm depth i.e., upto 50% depth of the slab. By surface treating and partial impregnation of the concrete surface, its tensile and compressive strength, modulus of elasticity and resistance to acid attack can be increased significantly.

Application of Monomers in the Field:
The application of monomers in the field like bridge decks, impregnation is more difficult than laboratory application and poses more problems.

A typical procedure for surface treatment in the field may be adopted as follows -
i. First dry the surface for several days with-electric heating blanket.
ii. After drying the surface, remove the heating blanket and cover the slab with over dried light weight aggregate at the rate of 0.64 m^3 per 100 square metre of surface.
iii. Initially apply monomer system at the rate of 2.0 to 3.0 litre per square metre of surface.
iv. To retard the evaporation of monomer cover the surface with polythene.

v. To prevent the temperature rise, which may initiate the polymerization prematurely, shade the surface. Premature polymerization will reduce the penetration of monomer into the concrete.
vi. To keep the aggregates moist for the minimum soak time of 8 hours, additional monomer should be added into the concrete.
vii. Now apply heat to polymerise the monomer. For this purpose steam, hot water or heating blanket may be used.
Monomer System to be used for the above Purpose. Following monomer system is suggested for this purpose -
(a) Methyl methacrylate (MMA), 1% Benzoyl Peroxide (BP), 10% Trimetholpropane trimethacrylate (TMPTMA). It acts as cross linking agent which helps in polymerization at low temperature of 52°C and BP acts as catalyst.
(b) Isodecyl metha crylate (IDMA), 1% BP. 10% TMPTMA
(c) Isobutyl metha crylate (IBMA), 1% BP, 10% TMPTMA

2. Roller Compacted Concrete:

Roller compacted concrete, abbreviated as R.C.C. is of recent origin. It is also known as lean rolled concrete. Roller compacted concrete is almost a dry concrete having no slump. This concrete is consolidated by vibratory rollers. The applications of this concrete are mainly in the construction of dams, rapid placement of single layer paving for highways and runways and also for multi-layer placement for foundations.

Mix:

The cement content of this concrete varies from 60 to 360 kg/m^3 of concrete. To minimize the heat of hydration in massive concrete placements, and also to minimize cracking, the cement content should be kept as low as possible and the maximum possible size of aggregate should be used. The use of minimum quantity of cement and large size aggregate will help in controlling the segregation of the concrete.
The use of pozzolana often has been found very economical than cement alone. The use of pozzolana is also advantageous in reducing the heat of hydration. In some cases high value fly ash has been added to the extent of 60 to 80% of the volume of cementitious materials in the construction of dams.
The mixture of cementitious material, aggregate and water is mixed in a conventional batch mixer or in any other suitable mixer.

Placement:

To allow complete compaction, the roller compacted concrete is placed in thin layers. The optimum layer thickness should be between 20 to 30 cms. To ensure adequate bond between the new and old layer called as cold joint, segregation of concrete must be avoided. To achieve this objective a high plasticity bedding mix must be used at the start of the placement. The concrete can also be used for continuous placement without cold joints. The compressive strength of roller compacted concrete of the order of 7 MPa to 30 MPa has been obtained.
For effective compaction, the roller compacted concrete must be dry enough to support the mass of the vibrating equipment, but wet enough to allow the cement paste to be evenly distributed throughout the mass during the mixing and consolidation processes.
The first Roller compacted concrete dam was started in Japan during 1978 and was completed in 1980. Since then many other dams were built by this technique in different parts of the world. By the end of 1985, seven Roller compacted concrete dams were completed and by the end of 1992 the number of such dams rose to 96 in 18 different countries, mainly in Japan, U.S.A. and Spain etc.
In India though no dam has been built by this techniques but the technique has been used in the road construction. The roller compacted concrete has been used as a base concrete in the construction of Delhi-Mathura Concrete road Project. Similarly RCC (Roller Compacted Concrete) has also been used as a base course concrete in Pune-Mumbai express high way construction.
In both the projects the roller compacted concrete is called as “Dry lean concrete”. The thickness of the concrete was kept 15 cm and the grade of concrete was M_{10}. The concrete was thoroughly compacted by vibratory rollers, over which pavement quality concrete of grade M_{40} was placed. The thickness of pavement layer was kept as 35 cm.

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3. Fiber Reinforced Concrete:

Plain concrete has a very low tensile strength, limited ductility and little resistance to cracking. Internal micro-cracks are inherently present in the concrete. The poor tensile strength of concrete is due to the development of such micro-cracks. These micro-cracks eventually lead to brittle fracture of the concrete.

Thus the purpose of reinforcing the cement based matrix with steal or fibres is to increase the tensile strength by delaying the growth of cracks and to increase the toughness by transmitting stress across a cracked section so that much larger deformation is possible beyond the peak stress than without fibre reinforcement.

Thus fibre reinforced concrete may be defined as concrete made with hydraulic cement, containing fine or coarse and fine both aggregate and discontinuous discrete fibres. The fibre reinforced concrete generally has higher cement content, and higher fine aggregate content and smaller size of coarse aggregate in comparison with conventional concrete.

In plain concrete and similar brittle materials micro cracks (structural cracks) develop even before applying load. These cracks develop due to drying shrinkage or volume changes. The initial width of these cracks is very small and seldom exceeds a few microns, but their other dimensions may be much higher.

After loading, these micro cracks propagate and open up. Due to the stress concentration, additional cracks form in place of these minor cracks. These structural cracks spread very slowly due to the resistance at inter surface of cement paste and bigger aggregate particles and changes of direction bypassing the more resistant particles in matrix. Actually the main cause of development of such micro cracks is of inelastic deformations in concrete.

Fibers Used:

The fibers can be classified into two groups as follows -

1. Natural materials as asbestos, cellulose, sisal.
2. Artificial manufactured products as steel, glass, carbon and polymer etc.

Each type of fibre has its own characteristic properties and limitations. Hence all of them cannot be used effectively and economically.

Quantity of Fibers:

The quantity of fibers used in fiber reinforced concrete is small usually 1 to 5% by volume.

Properties of Fibers:

To make the fibers effective as reinforcement, the tensile strength, modulus of elasticity and the elongation of fibers at failure should be substantially higher than the corresponding properties of the matrix. The typical properties of some fibers are shown in the following Table 24.4.

Table 24.4. Properties of fibres

S. No.	*Type of fibre*	*Specific gravity*	*Tensile strength MPa*	*Modulus of elasticity GPa*	*Elongation at failure %*	*Poisson's ratio*
1.	Crysotile asbestos	2.55	3.0 to 4.5	164	3.0	0.30
2.	Alkali resistant glass	2.71	2.0 to 2.8	80.0	2 to 3.0	0.22
3.	Steel	7.84	1.0 to 3.2	200.0	3.0 to 4.0	0.30
4.	Carbon	1.74-1.99	1.4 to 3.2	250 to 450	0.4 to 1.0	0.2 to 0.4
5.	Poly propylene	0.91	780-850	8	8	0.29 to 0.46
6.	Kevlar	1.45	3.6	65 to 130	2 to 4	0.32
7.	Nylon	1.1	4.2	78 to 85	16 to 20	—
8.	Rayon	1.5	7.3	42 to 63	10 to 25	—

Further the creep of fibers used as reinforcement should be very low. Their Poisson's ratio should be similar as that of the matrix.

Some other significant characteristics of the fibers are as follows:

1. Aspect ratio. It is the ratio of length to mean diameter of the fiber. The stress bearing capacity of fibre depends upon its aspect ratio. Typical aspect ratio varies from 30 to 150.
2. Shape
3. Surface texture
4. Length, and
5. Structure.

It has been observed that aspect ratio influences the properties and behavior of the composite to a great extent. The increase in aspect ratio upto 75, increases the ultimate strength of concrete linearly and relative toughness, but beyond this value of aspect ratio both ultimate strength and relative toughness decrease. Table 24.5 shows the effect of aspect ratio on strength and toughness.

Table 24.5. Effect of aspect ratio on strength and relative toughness

S. No.	*Type of Concrete*	*Aspect Ratio*	*Relative strength*	*Relative toughness*
1.	Plain concrete with	0	1.0	1.0
2.	Randomly dispersed fibres	25	1.5	2.0
3.	do	50	1.6	8.0
4.	do	75	1.7	10.5
5.		100	1.5	8.5

Description of Different Fibers Used:

1. Steel Fiber:

It is the most commonly used fiber. Generally round fibers of diameter ranging from 0.25 to 0.75 mm are used. The steel fiber is likely to get rusted and lose some of its strength, however rusting takes only at the surface. A significant improvement in impact, fatigue and flexural strength of concrete has been observed by the use of steel fiber. It has been used extensively in various types of structures, specially for overlays of roads, air field pavements, bridge decks etc. It has also been used successfully for the construction of thin shells and plates.

2. Asbestos:

It is a natural fiber and has proved to be the most successful of all fibres as it can be mixed with port-land cement. The tensile strength of asbestos has been found varying between 560 to 980 N/mm^2.

The flexural strength of the composite product known as asbestos cement has been found considerably higher than the port-land cement paste.

3. Polypropylene and Nylon Fibers:

These fibers possess very high tensile strength. These fibers are found useful to increase the impact strength of the composite. They have low modulus of elasticity and higher elongation, which do not contribute to its flexural strength.

4. Glass Fiber:

It has been introduced recently for the production of fiber concrete. It has been found to have very high tensile strength varying from 1020 to 4080 N/mm^2. Originally glass fibre used along with port-land cement was found to be affected by alkaline nature of cement. Thus an alkali resistant glass fibre has been developed. The trade name of this

glass fiber is "CEMFILL". Concrete made with alkali resistant glass fiber showed considerable improvement in its durability in comparison to the conventional E, glass fiber.

5. Carbon Fibers:

Perhaps the carbon fibers possess very high tensile strength and Young's modulus. Their tensile strength has been observed of the order of 2110 to 2815 N/mm^2. The concrete made with carbon fibre as reinforcement showed very high flexural strength and modulus of elasticity. It has been found quite durable. It can be used for the construction of protective covering panels and shells. It has bright future.

Factors Affecting the Properties of Fiber Reinforced Concrete:

The fiber reinforced concrete is a composite material consisted of fibers in cement matrix either in the orderly manner or randomly distributed manner.

Thus its properties would depend upon the efficient transfer of stress between the fibres and the matrix, which is dependent on the following factors:

1. Type of fiber and its geometry
2. Orientation and distribution of the fibre
3. Mixing and compaction of concrete
4. Amount, shape and size of aggregate.

These factors are discussed briefly below:

1. Type of Fiber and its Geometry:

For effective and efficient transfer of stress, the modulus of elasticity of the matrix must be much lower than that of fiber used. The fibers of low modulus of elasticity as polypropylene and nylon impart greater degree of toughness and resistance to impact as they have the capacity of absorption of large amount of energy, but they do not contribute to the improvement of strength. On the other hand, high modulus fibers as steel, glass and carbon contribute more to the improvement of strength and stiffness of concrete.

The interfacial bond between the matrix and the fibers also determine the effectiveness of transfer of stress from the matrix to the fiber. For improving the tensile strength of the composite a good bond is essential. The interfacial bond could be improved by providing larger area of contact, improving the degree of gripping and frictional properties by treating the steel fibers with acetone or sodium hydroxide.

Volume of Fibers:

Usually the quantity of fibers is used between 1 to 5% by volume. The strength of the composite largely depends on the quantity of fibers used in it. The effect of volume between 0 to 1.25% by volume on strength and toughness of fiber reinforced composite is shown in Fig. 24.4.

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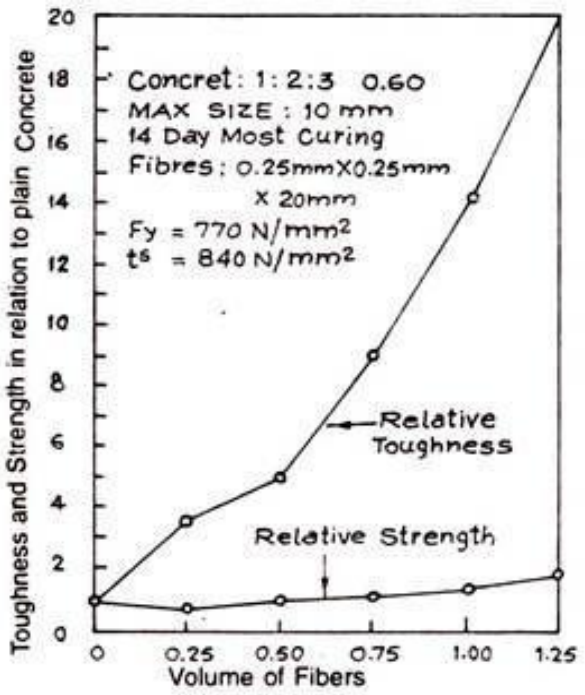

Fig. 24.4. Effect of Fibre volume on flexure strength

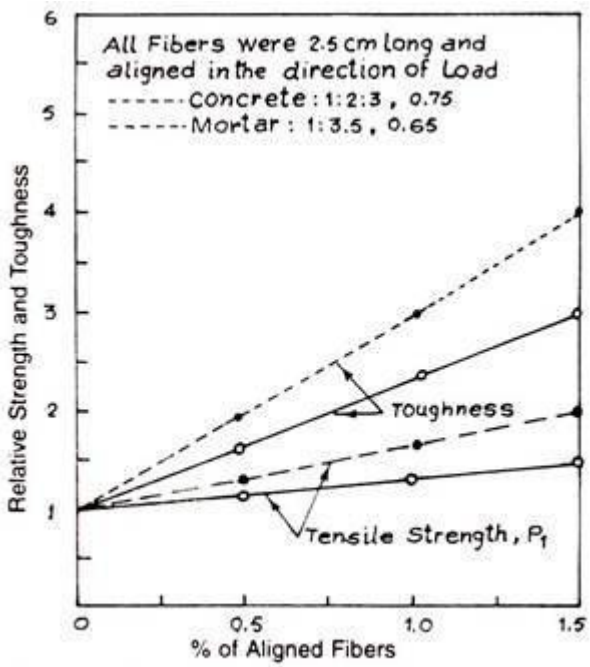

Fig. 24.5. Effect of Fibre volume on tensile and toughness

The effect on the toughness is more than on strength. From Fig. 24.5 it can be seen that the increase in tensile strength and toughness of the composite is liner with the increase in volume of fibers upto 1.5%. The use of higher percentage of fiber is likely to cause segregation and harshness of concrete and mortar.

2. Orientation of Fibers:
It has been observed that the orientation of the fiber relative to the plane of crack in concrete influences the reinforcing capacity of the fiber. The maximum benefit occurs when the fiber is unidirectional and parallel to the tensile stress. Experiments have shown that the fibers aligned parallel to the applied load offered more tensile strength and toughness than randomly or perpendicular distributed fibers.

3. Workability and Compaction of Concrete:
The addition of fibers decreases the workability of the concrete considerably. The workability of fiber reinforced concrete decreases with the increase in fiber content and its aspect ratio. The decrease in workability effects the consolidation of concrete to a great extent. Even prolonged external vibration has no effect at this low workability. The fiber volume at which this situation arises depends upon the aspect ratio of the fiber i.e. on its length and diameter.
Another effect of low workability is non-uniform distribution of fibers. The workability can be increased by increasing the water-cement ratio or by the use of some water reducing admixtures.

4. Size of the Coarse Aggregate:
In order to avoid appreciable reduction in the strength of the composite, many researchers have recommended the maximum size of coarse aggregate as 10 mm. In fact fibers also act as aggregate. Though, the geometry (shape) of fibroses simple, but their influence on the properties of the fresh concrete is complex. The inner particle friction between fibers and between aggregates and fibers controls the orientation and distribution of the fibers and thus the

properties of the composite. The use of friction reducing admixtures and admixtures which can improve the cohesiveness of the mix will be useful.

Proportion of Fiber Reinforced Concrete:

A typical mix proportion of fibre reinforced concrete is shown below -

Cement content	325 to 550 kg/m^3
Water-cement ratio	0.4 to 0.6
Percentage of fine to total aggregate	50 to 100%
Maximum size of aggregate	10 mm
Air entrainment (Content)	6 to 9%
Fibre content	0.5 to 2.5% by volume of mix
	Steel fibre 1%, 78 kg/m^3
	Glass fibre 1% .25 kg/m^3
	Nynol 1% 11 kg/m^3
Fibre aspect ratio	50 to 100

Mixing of the Mix:
To avoid balling (bundling) of fibers, segregation and difficulty in mixing the materials uniformly careful handling is necessary. Increase in the aspect ratio, volume percentage of fibers and size and quantity of coarse aggregate all intensify the balling tendency and difficulties. Steel fiber content more than 2% by volume and an aspect ratio more than 100% is difficult to mix. It is important to note that the fibers are dispersed uniformly throughout the mix.
The uniform dispersement of fibers can be achieved by the addition of fibers before the water is added. While mixing in laboratory mixer, the addition of fibres through a wire mesh basket will help the even distribution of fibers. For the use in the field some other suitable method may be adopted,

Methods of Determining Workability:
For determining the workability of fiber concrete usual methods are slump and Vee Bee methods, but slump test is not always a good indicator of workability. For this reason a new method known as inverted slump test has been developed to find the workability of fibrous mixes. The time taken for loosely filled inverted standard cone into a standard container by internal vibration is the measure of the fluidity of the mix.
Some researchers have suggested cone penetration test for measuring the workability of fiber reinforced concrete. They have reported that the depth of penetration in mm of a metallic cone with an apex angle of 30° and weight of 40N has been found to give representative workability for normal range mixes. The depth of penetration for normal range of mixes has been found to vary from 30 mm to 50 mm.

Factors Affecting Workability:
Aspect ratio and fiber volume concentration predominantly affect the workability of fiber reinforced concrete. A minimum fiber volume concentration is known as critical concentration and is needed to increase its strength. The critical concentration is inversely proportional to the aspect ratio. For aspect ratio l/d = 100, a volume concentration of 0.5% for flexural strengthening and 1.7% for tensile strengthening is required.

Properties of Fibrous Concrete:
Following properties of fibrous concrete have been observed -

1. It has increased static and dynamic strength.
2. It has higher energy absorbing characteristics.
3. It has better fatigue strength.
4. It has better isotropic properties than normal reinforced concrete due to uniform dispersion of fibers throughout the concrete.

Application or Uses of Fiber Concrete:
There are many uses of fibrous concrete as follows -
1. The glass fiber reinforced concrete is used for precast, flat or shaped decorative panels and facings for architectural and outer coverings known as cladding.
2. The asbestos cement is cheaper and is used for the production of flat and corrugated sheets. The asbestos cement is fire resistant also. Thus it has been widely used for covering the cheap houses, garages, fire resistant panels and pipes etc.
3. Polypropylene fiber concrete. The modulus of elasticity of polypropylene fibers is low under normal rate of loading but it increases subsequently under impact loading. Thus this concrete is used for making casing for conventionally driven reinforced concrete piles.
4. Steel and glass fiber concrete. As the flexural, fatigue and impact strength of these fibers is good, they are used as the overlays (bases) to concrete pavements and airfield pavements. Steel fiber can also be used in shotcrete. However the steel fibers may get corroded especially near or at the surface exposed to weather.
Other general uses of fiber reinforced concrete products are permanent and reusable form works and protection and strengthening of the skin of concrete members. In general it can be said that fiber reinforced concrete can be used for all types of works as road pavements, floorings, bridge decks, canal lining, beams, boats, roof and wall panels, manhole covers etc. It is resistant to cavitations or erosion effect, hence used in hydraulic structures.

4. Saw Dust Concrete:
Sometimes in partition walls and some types of roofs, nailing properties of the concrete are essential. Nailing is that property of the material by virtue of which nails can be driven in it and are firmly held. This type of concrete can be obtained by using saw dust as aggregate.
The shrinkage and moisture movement of saw dust is high and it is used basically as a light-weight aggregate in this type of special concrete. Saw dust concrete consists roughly equal parts by volume of port-land cement, sand and saw dust with water sufficient to give a slump of 25 to 50 mm i.e. cement to saw dust may be 1:2 to 1:3 by volume. Such a concrete bonds well with ordinary concrete and is a good insulator. The saw dust should be clean and without a large amount of bark.
In order to avoid adverse effect on setting, hydration, and rotting of saw dust and to reduce moisture movement, chemical treatment of saw dust is advisable. To offset the delay in setting and hardening addition of about 5% calcium hydroxide has been found effective. The density of saw dust concrete varies from 652 to 1600 kg/m3.
As the properties of this concrete depend on the quality of saw dust, use of trial mix is recommended. The size of saw dust may vary from 1.18 mm to 6.3 mm. Saw dust concrete can be used in the manufacture of precast concrete products, joint less flooring and roofing tiles etc.

5. Preplaced Aggregate Concrete:
This type of concrete is produced in two operations. In the first operation, coarse aggregate is placed in the form and compacted by form vibrators. In the second operation the voids from 30 to 35% of the overall volume to be concreted are filled with cement mortar. Preplaced aggregate concrete is also known as pre-packed concrete or intrusion concrete or grouted concrete.

Aggregate used. In this concrete, usually gap graded aggregate is used. Typical grading's of coarse and fine aggregates are shown in Table 24.6 and 24.7 respectively. The coarse aggregate must be free from dust and dirt as

these will impair the bond between cement paste and aggregate. The coarse aggregate should also be thoroughly wetted or inundated before the mortar is intruded, but water should not be allowed to stand for long.

Table 24.6. Typical grading for coarse aggregate

Seive size in mm	150	75	38	19	13
Cumulative % passing	100	67	40	6	1
	—	100	62	4	1
	—	100	97	9	1

Table 24.7. Typical grading for fine aggregate

Sieve size in mm	2.36 mm	1.18 mm	600 micron	300 micron	150 micron
Cumulative % passing	100	98	72	34	11

Mortar:
Mortar may consist two parts of port-land cement, one part of very finely divided and highly active pozzolana, and three to four parts of fine sand with sufficient water to form fluid mixture. Pozzolana is added to improve fluidity of the mortar. It also reduces bleeding and segregation of the mortar. An intrusion aid is also added to improve the fluidity of the mortar and to hold the solid constituents in suspension and delaying the stiffening of the mortar. The mortar is made of a thick cream consistency.
The mortar is pumped under pressure through about 35 mm diameter perforated or slotted pipe spaced at 2.0 m apart starting from the bottom of the mass. These pipes are gradually withdrawn after the grouting is complete.
Preplaced concrete is economical in cement as about 120 kg/m^3 to 150 kg/m^3 of cement is used, but the strength obtained is low of the order of 200 kg/cm^2 only due to high water/cement ratio.

Advantages:
Following are the advantages and disadvantages of preplaced concrete –
1. Preplaced concrete can be placed in locations which are not easily accessible for ordinary concreting.
2. It can be placed in sections containing a large number of embedded items such as in nuclear shields.
3. Segregation of heavy and coarse aggregate is eliminated.
4. Pumping over long distances is possible.
5. Under water construction is also possible by its use.
6. Its drying shrinkage is lower than that of ordinary concrete.
7. Its use is preferable in mass concrete construction where temperature has to be controlled.
8. It is also used to provide an exposed aggregate finish.

Disadvantages:
1. It develops shrinkage cracks.
2. It needs special skill and experience in application, hence costly.

6. Vacuum-Processed Concrete:
The problem of obtaining high workability with a minimum water/cement ratio is solved by the use of vacuum processing of freshly placed concrete. In this method a part of water mixed with concrete for suitable workability is sucked back by the pump after the concrete is laid in position. This concrete is known as vacuum concrete.

Procedure:

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8. Program : M.Tech (CEM) **T: 0**
9. Target : 60% **P: 0**
C: 3

A mix with suitable workability is placed in the forms in the usual manner as fresh concrete contains a continuous system of water filled channels, the application of a vacuum to the surface of the concrete results in a large amount of water being extracted from a certain depth of concrete. Thus the final water/cement ratio before setting is reduced, which controls the strength. The magnitude of the decrease in the water cement ratio is shown in Table 24.8.

Table 24.8.

Water/cement ratio		*Compressive strength*	
Before processing	*After processing*	*Before processing in kg/cm^2*	*After processing in kg/cm^2*
0.74	0.68	177	230
0.71	0.59	150	223
0.65	0.57	206	270
0.60	0.55	297	328

Effect of Vaccum Processing:
It has following effects -
1. The final strength of concrete increases by about 25% and 28 days strength is reached in 8 to 9 days.
2. The permeability of concrete decreases sufficiently.
3. It gives high density concrete.
4. The increase in bond strength of concrete is found about 20%. It's modulus of elasticity is always higher.
5. The overall durability of concrete is increased.
6. Coarser grading of aggregate yields more water than finer grading i.e. more water is extracted.

However, some of the water extracted leaves behind voids, so that full theoretical advantage of water removal may not be achieved in practice. The increase in strength on vacuum treatment is proportional to the amount of water removed upto a critical value, beyond which there is no significant increase.
Thus prolonged vacuum treatment is not useful. The critical value depends on the thickness of concrete and on the mix proportions. It has been observed that the strength of vacuum processed concrete broadly follows the usual dependence on the final water/cement ratio as shown in Fig.24.6.

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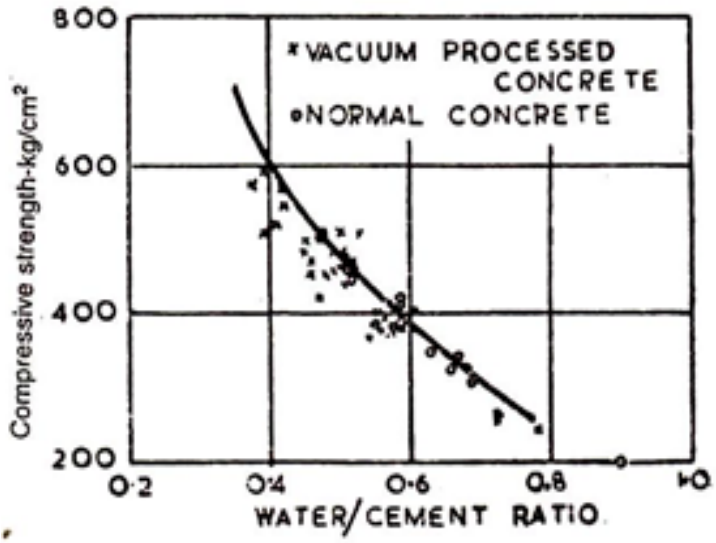

Fig. 24.6. Relation between compressive strength and w/c ratio on vaccum processed concrete

Procedure of Applying Vacuum:

The vacuum is applied through porous mats connected to a vacuum pump. The mats consist of an air tight cover, usually made of plywood, with a vacuum chamber formed by expanded metal. This is faced with a fine wire gauge covered by muslin which prevents the removal of cement particles along with water. Fig. 24.7 shows a cross section of a vacuum mat. The mat can be placed on the top of the concrete surface immediately after finishing it and also be incorporated inside the faces of the forms.

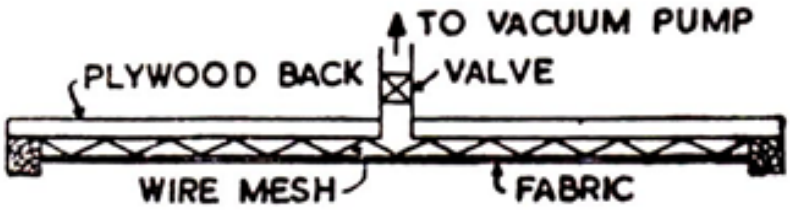

Fig. 24.7. Cross section of vaccum mat

Vacuum is created by a vacuum pump, the capacity of which is governed by the perimeter of the mat and not on its area. The magnitude of pressure usually ranges between 40 cms to 65 cms of mercury. This vacuum reduces the water content upto 20% over a depth of 15 cms to 30 cms. The reduction is greater nearer to the mat and usually the suction is assumed to be effective upto 15 cms to 20 cms depth only. Thus for a concrete section mat about 30 cms thick vacuum should be applied from two opposite sides.

The withdrawal of water produces settlement of the concrete to the extent of about 3% of the depth over which the suction acts. The rate of withdrawal of water falls with time. Duration of processing of 15 to 25 minutes has been found most economical and effective. Beyond 30 minutes very little reduction in water content has been observed.

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The formation of voids can be checked, if in addition to vacuum processing, intermittent vibration is also applied. By the application of vibration higher degree of consolidation is achieved and the amount of water withdrawn is almost double.

Advantages:
1. Vacuum processed concrete stiffens very rapidly hence the form work can be removed after 30 minutes of casting even on columns about 4.5 m high. It is of considerable economic value as the form work can be reused at frequent interval.
2. The surface of vacuum processed concrete is entirely free from pitting and the uppermost I mm surface is highly resistant to abrasion. This property is very useful in the construction of concrete work where the concrete surface is in constant contact with flowing water at a high velocity.
3. Vacuum proceed concrete bonds well with the old concrete hence it can be used for resurfacing road slabs and for other repair work.

Disadvantages:
Its main disadvantage is its high initial cost.

7. Colcrete:
It is grouted concrete obtained by penetrating or injecting the colgrout into the voids of preplaced coarse aggregates. Colgrout is the colloidal mix of cement, sand and water in requisite proportions produced by high speed mixing in a mixer known as colcrete mixer. Colcrete mixer is a double drum concrete mixer. The proportioning of the ingredients can be done either by weight or by volume.

The cement and water is mixed in the first drum of the mixer and the water/cement slurry produced in this drum is transferred into the second drum and sand is added to produce the cement, sand and water grout. The mixing cycle in each drum may be kept 1.5 minutes or more till a suitable grout is obtained.

Advantages of Colcrete:
In ordinary 1:2:4 mix, the surface area of coarse aggregate per cubic metre of concrete is found in the order of 68800 square metres. To wet and activate this area with a relatively small amount of water of a particular water cement ratio concrete in a short mixing period presents great difficulty. Cement particles tend to adhere closely which entrapped air, thus mixing of conventional concrete remains imperfect. To overcome this difficulty the constituents of the concrete are passed through a colloidal mill, where each solid particle surface is brought in contact with the liquid.

Colcrete Process:
After cleaning the surface and form work, a layer of big size boulders is placed in the form section and the voids of holders are packed by graded stones of diminishing sizes, the minimum size being 40 mm. The minimum size of 40 mm is chosen to enable the concrete grout to penetrate into the voids. Again a layer of big size boulders is spread and voids filled with graded diminishing size stone pieces. The height of each layer may vary from 22.5 cms to 30 cms. The process is repeated till the height of the lift is reached. Voids in the packed aggregate may vary from 33% to 40%.

Mixing of Colgrout:
The colgrout is mixed in double drum colcrete mixers to form colloidal grout of suitable consistency. The cement and water is mixed in the first drum of the mixer and water cement slurry produced is transferred to the second drum where sand is added to produce cement-sand grout. The mixing time in each drum of 1.5 minute is found sufficient.
Grout pipes of 7.5 cms to 10 cms in diameter can be used they may be inserted either at the time of packing boulders or inserted after the packing into the holes left for this purpose. The pipes are spaced at about 2 metres centre to

centre and the grout is injected at a velocity of about 30 cms per second. The pipes are taken from the bottom of the lift and are raised by about 5 to 10 cms before grout to clear the outlets.
The grouting should be done continuously and its fluidity should be maintained during the period of injection in the grout pipe. Grout should not be allowed to form air locks by flowing along surface of low penetration resistance, as along flat surfaces. After the grout has come to the surface, grout pipes are removed and surface leveled off by gravity grouting of the surface.

Characteristics of Colgrout:
1. The cement is thoroughly mixed with other constituents of the mix as each particle of the cement in the mix is completely wetted by the high speed shearing action of the mixer.
2. The colgrout has colloidal characteristics, resulting in the maximum gel formation of the cement. This prevents aggregation of sand resulting in the reduction of bleeding to a minimum.
3 As colgrout is quite fluid and stable, it can be pumped to considerable distances to the point of placement. It does not need any admixture, however for special purposes these may be used by high speed mixing.
4. The breaking up of aggregations and separations of the smaller particles of cement is achieved by high speed mixing, which results in greater fluidity.
5. Colgrout normally is composed of same ingredients of cement and sand in the proportion of 1 part of cement and upto 4 part of sand.

Special mortars:
The term mortar is used to indicate a paste prepared by adding required quantity of water to a mixture of binding material like cement or lime and fine aggregate like sand.
The above two components of mortar, namely, the binding material and fine aggregate are sometimes referred to as the matrix and adulterant respectively. The matrix binds the particles of the adulterant and as such, the durability, quality and strength of mortar will mainly depend on the quantity and quality of the matrix. The combined effect of the two components of mortar is that the mass is able to bind the bricks or stones firmly.
Following are the various types of special mortars which are used for certain conditions -
1. Fire-resistant mortar
2. Lightweight mortar
3. Packing mortar
4. Sound-absorbing mortar
5. X-ray shielding mortar

1. Fire-resistant mortar: This mortar is prepared by adding aluminous cement to the finely crushed powder of fire-bricks. The usual proportion is 1 part of aluminous cement to 2 parts of powder of fire-bricks. This mortar is fire-resistant and it is therefore used with fire-bricks for lining furnaces, fire places, ovens, etc.
2. Lightweight mortar: This mortar is prepared by adding materials such as saw dust, wood powder, etc. to the lime mortar or cement mortar. Other materials which may be added are asbestos fibers, jute fibers, coir, etc. This mortar is used in the sound-proof and heat-proof constructions.
3. Packing mortar: To pack oil wells, special mortars possessing the properties of high homogeneity, water resistance, predetermined setting time, ability to form solid water-proof plugs in cracks and voids of rocks, resistance to subsoil water pressure, etc. have to be formed. The varieties of packing mortars include cement-sand, cement-loam and cement-sand-loam. The composition of packing mortar is decided by taking into consideration the hydrogeologic conditions, packing methods and type of timbering.
4. Sound-absorbing mortar: To reduce the noise level, the sound-absorbing plaster is formed with the help of sound-absorbing mortar. The bulk density of such a mortar varies from 6 to 12 kN/m3 and the binding materials

employed in its composition may be Portland cement, lime, gypsum, slag, etc. The aggregates are selected from lightweight porous materials such as pumice, cinders, etc.

5. X-ray shielding mortar: This type of mortar is used for providing the plastering coat to walls and ceiling of X-ray cabinets. It is a heavy type of mortar with bulk density over 22 kN/m3. The aggregates are obtained from heavy rock and suitable admixtures are added to enhance the protective property of such a mortar.

Concrete Chemicals:

Concrete chemicals or admixtures are materials other than cement, aggregate and water that are added to concrete either before or during its mixing to alter its properties, such as workability, curing temperature range, set time or color. Some concrete admixtures have been in use for a very long time in concrete construction, such as calcium chloride to provide a cold-weather setting concrete.

Types of Concrete Chemicals (Admixtures):

Based on their functions, admixtures can be classified into the following five major categories -

1. Retarding admixtures
2. Accelerating admixtures
3. Superplasticizers
4. Water reducing admixtures
5. Air-entraining admixtures

Among other important admixtures that do not fit into these categories are admixtures whose functions include bonding, shrinkage reduction, damp proofing and coloring. The following paragraphs provides details on the above-mentioned categories of concrete admixtures.

1. Retarding Admixtures:

Retarding admixtures slow down the hydration of cement, lengthening set time. Retarders are beneficially used in hot weather conditions in order to overcome accelerating effects of higher temperatures and large masses of concrete on concrete setting time. Because most retarders also act as water reducers, they are frequently called water-reducing retarders. As per chemical admixture classification by ASTM-ASTM C 494, type B is simply a retarding admixture, while type D is both retarding and water reducing, resulting in concrete with greater compressive strength because of the lower water-cement ratio. Retarding admixtures consists of both organic and inorganic agents. Organic retardants include unrefined calcium, sodium, NH4, salts of lignosulfonic acids, hydroxycarboxylic acids, and carbohydrates. Inorganic retardants include oxides of lead and zinc, phosphates, magnesium salts, fluorates and borates. As an example of a retardant's effects on concrete properties, lignosulfonate acids and hydroxylated carboxylic acids slow the initial setting time by at least an hour and no more than three hours when used at 65 to 100 degrees Fahrenheit. The concrete contractor, however, need not memorize these chemical-specific results. Given the specific job requirements and goals, the concrete supplier should offer appropriate admixtures and concrete mixes from which to choose.

2. Accelerating admixtures:

Accelerators shorten the set time of concrete, allowing a cold-weather pour, early removal of forms, early surface finishing, and in some cases, early load application. Proper care must be taken while choosing the type and proportion of accelerators, as under most conditions, commonly used accelerators cause an increase in the drying shrinkage of concrete. Calcium chloride is a common accelerator, used to accelerate the time of set and the rate of strength gain. It should meet the requirements of ASTM D 98. Excessive amounts of calcium chloride in concrete mix may result in rapid stiffening, increase in drying shrinkage and corrosion of reinforcement. In colder climates, calcium chloride should not be used as an anti-freeze. Large amount of calcium chloride is required to lower the freezing point of the concrete, which may ruin the concrete.

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3. Superplasticizers:
Superplasticizers, also known as plasticizers, include water-reducing admixtures. Compared to what is commonly referred to as a "water reducer" or "mid-range water reducer", super plasticizers are "high-range water reducers". High range water reducers are admixtures that allow large water reduction or greater flowability (as defined by the manufacturers, concrete suppliers and industry standards) without substantially slowing set time or increasing air entrainment. Each type of super plasticizer has defined ranges for the required quantities of concrete mix ingredients, along with the corresponding effects. They can maintain a specific consistency and workability at a greatly reduced amount of water. Dosages needed vary by the particular concrete mix and type of superplasticizer used. They can also produce a high strength concrete. As with most types of admixtures, superplasticizers can affect other concrete properties as well. The specific effects, however, should be found from the manufacturer or concrete supplier.

4. Water reducing admixtures:
Water reducing admixtures require less water to make a concrete of equal slump, or increase the slump of concrete at the same water content. They can have the side effect of changing initial set time. Water reducers are mostly used for hot weather concrete placing and to aid pumping. A water-reducer plasticizer, however, is a hygroscopic powder, which can entrain air into the concrete mix via its effect on water's surface tension, thereby also, obtaining some of the benefits of air-entrainment (see below).

5. Air-entraining admixtures:
Air-entraining agents entrain small air bubbles in the concrete. The major benefit of this is enhanced durability in freeze-thaw cycles, especially relevant in cold climates. While some strength loss typically accompanies increased air in concrete, it generally can be overcome by reducing the water-cement ratio via improved workability (due to the air-entraining agent itself) or through the use of other appropriate admixtures. As always, admixtures should only be combined in a concrete mix by a competent professional because some of them can interact in undesirable ways.

6. Bonding admixtures:
Bonding admixtures including addition of compounds and materials such as polyvinyl chlorides and acetates, acrylics and butadiene-styrene co-polymers, can be used to assist in bonding new / fresh concrete with old / set concrete. Coloring agents have become more commonly used, especially for patios and walkways. Most are surface applied and often have the additional effect of surface hardening. Such surface applied coloring admixtures generally should not be used on air-entrained concrete. Integrally colored concrete is also available.

7. Waterproofing and damp proofing admixtures:
Water proofing and damp proofing admixtures including soaps, butyl stearate, mineral oil and asphalt emulsions, are used to decrease the amount of water penetration into the larger pores of concrete. Antifreeze" admixtures typically are accelerators used in very high doses, with a corresponding high price, to achieve a very fast set-time, though they do not have properties to protect against freezing on their own. However, in general, these are not used for residential work.

Expansive cement:

Expansive cement is special type of cement when mixed with water, which forms a paste that tends to increase in volume to a significantly greater degree than Portland cement paste after setting. The expansion of the cement mortar or concrete is compensated for the shrinkage losses. In this article we study about the manufacture, properties, types and uses of expansive cement.

Manufacture of Expansive Cement:

The process of manufacture if this type of cement is same as that of Portland cement, but the raw materials used for formation of clinkers are different. Firstly limestone and clay are heated together to a temperature of around 2,600 degrees Fahrenheit and clinkers are formed and in the next batch limestone, calcium sulphate and bauxite together at a temperature of about 2,300 degrees Fahrenheit, where sulfoaluminate clinkers are formed. These two clinkers are

grounded together to form expansive cement. when this cement is exposed or mixed with water, sulfo-aluminate expands in volume.

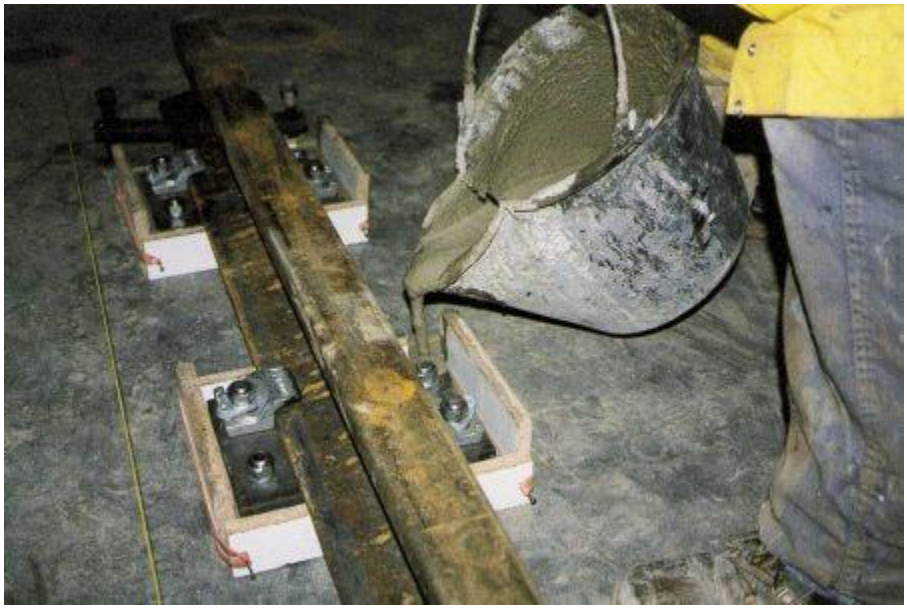

Fig.: Use of expansive cement mortar in grouting of anchor bolts.

Physical properties of Expansive Cement:

Table: Properties of expansive cement

Properties	Value
Setting Time	75 min
Air Content	12 %
7 Days expansion	
Min	0.04 %
Max	0.10 %
Compressive Strength	
7 Days	14.7 MPa
28 Days	24.5 MPa

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Types of Expansive Cement:
Depending upon the type of expansive compound used in the cement, expansive cement is divided into 3 types -
1. K Type expansive cement -
The raw material in this type of cement contains, portland cement, anhydrous tetracalcium trialuminate sulfate (C4A3S), calcium sulfate (CaSO4), and lime (CaO), which are grounded and expansive cement is formed.
2. M Type expansive cement -
The Portland cement clinkers are grounded with calcium sulfate.
3. S Type expansive cement -
In this type of expansive cement, a portland cement containing a high computed tricalcium aluminate (C3A) content and an amount of calcium sulfate above the usual amount found in portland cement.
Uses of Expansive Cement:

1. This cement is used in large, continuous floor slabs without joints.
2. It work well to fill holes in foundations and to create self-stressed concrete that is stronger than conventional portland cement concrete.
3. Pre-stressed concrete components for bridges and buildings are made using this material.
4. Used for construction of water retaining structures and also for repairing the damaged concrete surfaces.
5. Used in grouting of anchor bolts.

Sulphur Infiltrated Concrete:

In the past Attempts have been made to use sulphur instead of cement as a binding material. Sulphur is heated and melted then mix with coarse aggregate and fine aggregate and prepare concrete. This concrete gives good strength when cooled. It has good resistance against acid and chemical, but such concrete is more costly than ordinary cement concrete.

Modern studies show that lean porous concrete, Sulphur is forcefully added into concrete which is increase the strength of concrete and improved the properties of concrete. Approximately 100MPa strength obtained in just 2

days. Addition of sulphur in lean porous concrete reduces the sulphur amount in concrete and makes economical concrete.

Less than 100mm size coarse aggregate, Well graded fine aggregate and 99.9% purified sulphur used in this process.

Water/cement ratio is kept at 0.7 or more.

Two methods are adopted for making Sulphur Infiltrated Concrete.

Method-1:

- In this test the specimen is dried at 121°C in a heating cabinet for 24 hours after 24 hours of wet Curing.
- Then after the dry test samples are kept in a sulphur molten container at a temperature of 121°C for 3 hours.
- Then after remove the samples from the container, wipe the sulphur from the surface and keep specimen for cool at room the temperature for 1 hour.
- Then after the specimens are weighed, from which the weight of the entering sulphur is obtained.

Method -2:

- In this Method, the specimen of dry concrete is placed in an airtight container with a vacuum pressure of 2 mm mercury and kept for 2 hours.
- Then after the vacuum is removed, the specimens are immersed in the molten Sulphur for half an hour.
- Then after the specimens are taken out, the sulphur is wiped off the surface, and allowed to cool at room temperature.

During testing, the compressive strength of sulphur infiltrated concrete increases by 7 times and the tensile strength increase by 5 times.

Such concrete has -

- High resistance to freezing and thawing.
- Corrosion resistance is high.
- Permeability decreases of concrete.

Uses of Sulphur Infiltrated Concrete:

- For making Pre-cast roof elements, fencing posts, pig pipes
- For making Railway sleeper
- In industries where high corrosion resistance is required.
- Precast concrete is cheaper than commercial concrete.

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Ferro cement:

Ferrocement is a construction material consisting of wire meshes and cement mortar. Applications of ferrocement in construction are vast due to the low self weight, lack of skilled workers, no need of framework etc. It was developed by P.L. Nervi, an Italian architect in 1940. Quality of ferrocement works are assured because the components are manufactured on machinery set up and execution time at work site is less. Cost of maintenance is low. This material has come into widespread use only in construction in the last two decades.

Properties of Ferrocement:

- Highly versatile form of reinforced concrete.
- It's a type of thin reinforced concrete construction, in which large amount of small diameter wire meshes uniformly throughout the cross section.
- Mesh may be metal or suitable material.
- Instead of concrete Portland cement mortar is used.
- Strength depends on two factors quality of sand/cement mortar mix and quantity of reinforcing materials used.

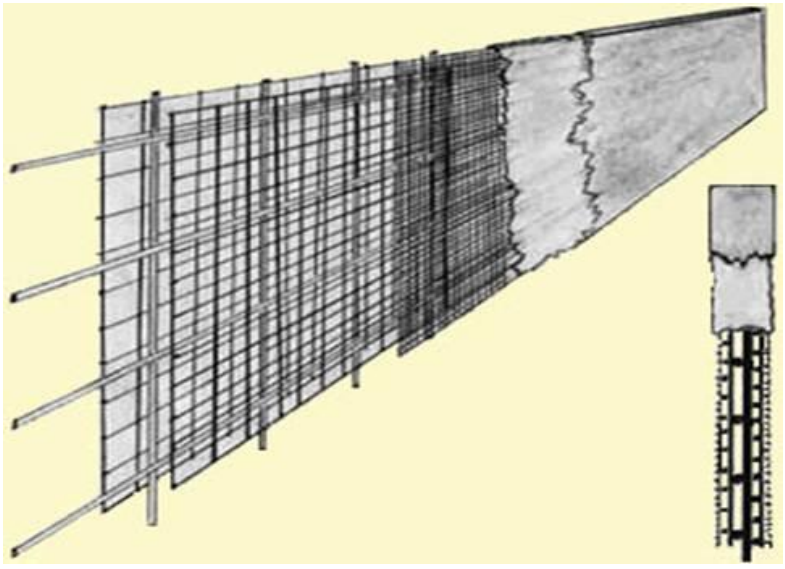

Fig.: Typical cross section of ferrocement structure.

Constituent Materials for Ferrocement:

1. Cement
2. Fine Aggregate
3. Water
4. Admixture
5. Mortar Mix
6. Reinforcing mesh
7. Skeletal Steel
8. Coating

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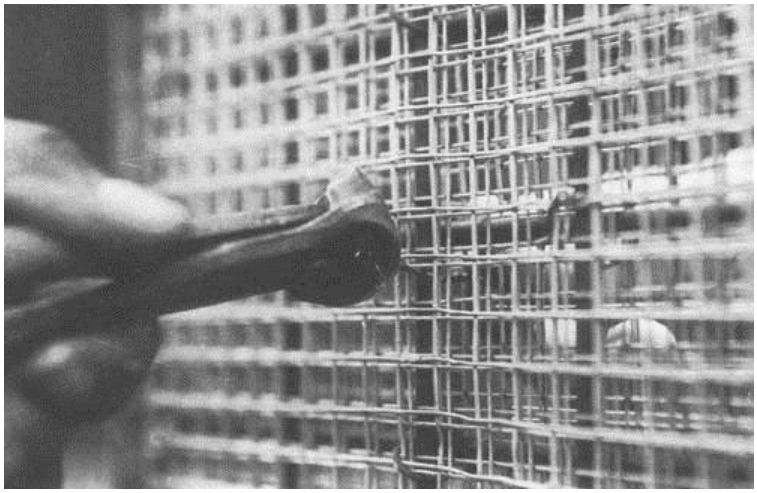

Fig.: Reinforcing Mesh

Advantages and Disadvantages of Ferrocement:

Advantages -

- Basic raw materials are readily available in most countries.
- Fabricated into any desired shape.
- Low labour skill required.
- Ease of construction, low weight and long lifetime.
- Low construction material cost.
- Doesn't need heavy plant or machinery.
- Better resistance against earthquake.

Disadvantages -

- Structures made of it can be punctured by collision with pointed objects.
- Corrosion of the reinforcing materials due to the incomplete coverage of metal by mortar.
- It is difficult to fasten to Ferrocement with bolts, screws, welding and nail etc.
- Large no of labors required.
- Cost of semi-skilled and unskilled labors is high.
- Tying rods and mesh together is especially tedious and time consuming.

Process of Ferrocement Construction:

- Fabricating the skeletal framing system.
- Applying rods and meshes.
- Plastering.
- Curing

Applications of Ferrocements in Construction:

- Housing
- Marine
- Agricultural
- Rural Energy
- Anticorrosive Membrane Treatment
- Miscellaneous.

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Rust eliminators and polymers coating for rebar during repair:

Rust eliminators:

Cement paste normally provides a highly alkaline environment that projects embedded steel against corrosion. Concrete with a low water/cement ratio, well compacted and well cured, has a low permeability and hence minimizes the penetration of atmospheric moisture as well as other components such as oxygen, chloride ion, carbon dioxide and water, which encourage corrosion of steel bar.

In very aggressive environments, the bars may be coated with special materials developed for this purpose. Coating on reinforcing steel, therefore, serves as a means of isolating the steel from the surrounding environment. Common metallic coatings contain galvanizing zinc. High chloride concentration around the embedded steel corrodes the zinc coating, followed by corrosion of steel.

Hence, this treatment is used for moderately aggressive environments. For high corrosive atmospheres caused by chloride ions from the de-icing salts applied to protect against sodium chloride and calcium chloride, usually near seashores, epoxy coating is applied to protect steel reinforcing bars from corrosion. Such bars have acceptable bond and creep characteristics. The coat normally applied is 150 um thick. The reinforcement is epoxied in the factory itself, where the steel rods are manufactured. Such reinforcement are known as fusion-bonded epoxy coated steel. Steel manufacturers also manufacture CTD (Cold Twisted Deformed) bars with better corrosion resistance, termed as Corrosion Resistance Steel (CRS). The performance of the CRS CTD bars is better in resisting corrosion compared to plain CTD bars. However, the use of CRS CTD bars will only delay the process of corrosion. It will not prevent corrosion once for all.

Polymer Resin based Coating:

These are generally of two types –

1. Resins blended with organic solvents, and
2. Solvent free coating.

Solvent-based coatings are subdivided into single and two component coatings. The coatings on drying produce a smooth dense continuous film that provides a barrier to moisture and mild chemical attack of the concrete. Because of the resistance to moisture penetration, staining, and ease of cleaning, they are preferred for locations of high humidity and those in which a lot of soiling occurs.

Most products are low solids content materials which require multiple coats to produce a continuous film over concrete, since the materials are thermoplastic, and have a significant degree of extensibility they are capable of bridging minor cracks which may develop in the concrete surface if they are applied in sufficient thickness. The number of coats required depends on the surface texture, porosity and the targeted dry film thickness. Although some of the newer products have some moisture tolerance, enabling them to be applied over damp surfaces, in normal usage they should be applied over dry surfaces. Due to their relative in permeability to water vapour, they could blister when applied to concrete surfaces with high moisture content or where the opposite surface of the concrete is in constant contact with moisture. Careful control of wet film thickness is therefore necessary during application.

Two component polymer coatings consist of a solution of a compounded polymer with or without solvent and a reactive chemical component called the curing agent hardener or catalyst. The materials are usually mixed just prior to use in accordance with the manufacturer's instructions. When using two components polymer based coatings the following items are of importance to the application of the materials –

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1. Most produces are supplied as a kit containing the two components in the required proportions. Therefore, in order to realize the full potential of the product the correct mix ratio of the two components must be used.

2. To ensure a complete reaction of the two components they must be mixed thoroughly.

3. Some two component material require an induction period of 15 to 40 min after mixing. Therefore, such products cannot be used immediately after mixing.

4. Viscosity reduction by the use of thinners should be resorted to only after the manufacturers are consulted.

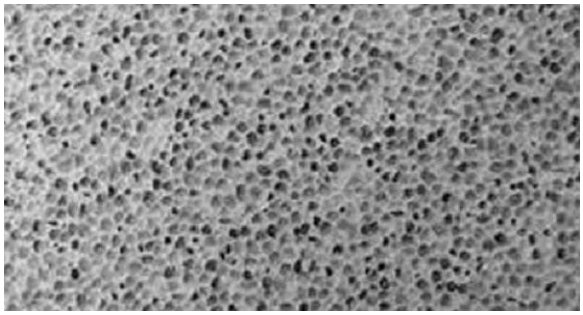
5. The storage temperature of solvent based coatings is not critical. They should be stored are a temperature 16 to 32°C just prior to use.

Foamed concrete:

Foamed concrete is a highly aerated mortar/paste, typically containing 30 to 80% air bubbles by volume . It comprises Portland cement (fast setting non-Portland cements are also available), water, fine aggregate/filler (usually omitted for densities below 1000 kg/m³) and mechanically produced (preformed) foam. It has high workability, which allows it to flow and compact under its own weight.

Typical plastic densities of foamed concrete are from 400 to 1600 kg/m³ (i.e. they are generally lighter than controlled low strength mortar and lightweight aggregate concrete). Final dry densities are between 100 and 300 kg/m³ lower than ´normal concrete´ depending on the prevailing conditions.

Compressive strengths, determined from sealed cubes, range from 0.5 to 5 N/mm². However, strengths of around 25 to 30 N/mm² are feasible for foamed concretes with higher densities.Typically, low strengths are sought for void and trench filling applications and the higher strengths are used for load-bearing applications such as house foundations and slabs.



Foamed concrete is a type of lightweight concrete that is manufactured from cement, sand or fly ash, water, and the foam. Foam concrete is in the form of foamed grout or foamed mortar. Foam concrete can be defined as a cementitious material that consists of minimum 20 percent of foam, that is mechanically entrained into the plastic mortar. The dry density of foamed concrete may vary from 300 to 1600 kg/m3. The compressive strength of foam concrete determined at 28 days, ranges from 0.2 to 10N/mm^2 or can go higher.

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Foam concrete is differentiated from air entrained concrete in terms of the volume of air that is entrained. The air entrained concrete takes in the air of 3 to 8 percent. It also differs from the retarded mortar and aerated concrete for the same reason of percentage of air entrained. In the case of retarded mortar systems, it is 15 to 22 percent. The bubbles are chemically formed in the case of an aerated concrete.

Production of Foamed Concrete:
The production of foamed concrete involves the dilution of surfactant in water, which is passed through a foam generator that will produce foam of stable form. The foam produced in mixed with the cementitious mortar or the grout, so that foamed quantity of required density is produced. These surfactants are also used in the manufacture of low density fills. These are also called as controlled low strength Material (CLSM). Here, to obtain an air content of 15 to 25 percent, the foam is added directly to a mix of low cement content and rich sand. It must be kept in mind that low density fillers are supplied as foamed concrete by some manufacturers, so misleading must be taken care.

Two main methods are used for production of foamed concrete -

- Inline Method and
- Pre-foam Method

Inline Method of Foam Concrete Production:
The base mix of cement and sand is added to a unit. In this unit, the mix is blended with foam thoroughly. The process of mixing is carried out with proper control. This will help in mixing of larger quantities. The inline method comprises two processes -

- Wet Method- Inline System
- Dry Method -Inline System

Wet Method of Inline System - The materials used in the wet method will be wetter in nature. With the help of a series of static inline mixers, the base material and the foam are fed and mixed together. The continual on board density monitor is used to check the blending of the whole mix. The output volume is dependent on the density of the foamed concrete and not on the ready mixed truck. That is one $8m^3$ base material delivery would produce $35m^3$ of a foamed concrete of $500kg/m^3$ density.

Dry Method of Inline System - Here the dry materials are used. They are taken into the onboard silos. From here they are weighed properly and mixed with the help of on- board mixers. The mixed base materials are then pumped to a mixing chamber. In wet method of foam concrete production, foam is added and mixed. This method employs a large amount of water for mixing. 130 cubic meters of foamed concrete can be produced from a single delivery of cement or fly ash blend.

Pre- Foam Method of Foam Concrete Production:
Here, the ready-mix truck brings the base material to the site. Through the other end of the truck, the pre- formed foam is injected into the truck, while the mixer is rotating. So, small quantities of foam concrete can be produced for small works, like for grouting or trench fill works. This method would provide foam concrete with densities ranging from 300 to 1200 kg/m^3. The foam input will be from 20 to 60 percentage air. The final volume of the foam can be calculated by reducing the amount of other base material. As this is carried out in the truck, control of stable air and density is difficult for this method. So, a degree of under and over yield must be specified and allowed. When the

foam is formed, it is combined with a cement mortar mix having water cement ratio of 0.4 to 0.6. If the mortar is wet, the foam becomes unstable. If it is too dry, the pre-foam is difficult to blend.

Composition of Foamed Concrete:

Foamed concrete composition varies with the density that is demand. Generally, the foamed concrete that has densities lesser than 600kg/m^3 will have cement, foam, water also some addition of fly ash or limestone dust. To achieve higher densities for foamed concrete, sand can be employed. The base mix is 1:1 to 1:3 for heavier foamed concrete, which is filler to portland cement ratio (CEM I). For more densities, say greater than 1500kg/m^3 more filler and medium sand is employed. To reduce the density, the filler amount should be reduced. It is recommended to eliminate the foam concrete with density lesser than 600kg/m^3.

Materials for Foamed Concrete:

Cement for Foam Concrete -

Ordinary Portland cement is commonly used, but rapid hardening cement can also be used if necessary. Foam concrete can incorporate a wide range of cement and other combination, for example, 30 percent of cement, 60 percent of fly ash and limestone in 10 percent. The content of cement range from 300 to 400 kg/m3.

Sand for Foam Concrete -

The maximum size of sand used can be 5mm. Use of finer sands up to 2mm with amount passing through 600 micron sieve range from 60 to 95%.

Pozzolanas -

The supplementary cementitious materials like fly ash and ground granulated blast furnace slag have been used widely in the manufacture of foam concrete. The amount of fly ash used ranges from 30 to 70 percent. White GGBFS range from 10 to 50%. This reduces the amount of cement used and economical. Silica fume can be added to increase the strength; at an amount of 10 percentage by mass.

Foam -

The hydrolyzed proteins or the synthetic surfactants are the most common forms based on which foams are made. The synthetic based foam agents are easier to handle and are cheap. They can be stored for a longer period. Lesser energy is required to produce these foams. The protein based foam are costly but have high strength and performance. The foam can be of two types: wet foam and dry foam. Wet foams with densities lesser than 100 kg/m3 are not recommended for the manufacture of foam concrete. They have a very loosely place large bubble structure. To a fine mesh, the agent and the water are being sprayed. This process produces foam that has bubbles with size ranging from 2 to 5mm. Dry foam is highly stable in nature. A solution of water and the foaming agent is forced by restrictions into a mixing chamber by compressor air. The produced foam have bubble size which is smaller than the wet foam. That is less than 1mm. These give a structure of bubbles, which are evenly arranged. (BS 8443:2005 covers the foaming admixtures)

Other Materials and Aggregates for Foam Concrete -

The coarse aggregate or other replacement for coarse aggregates cannot be used. This is because these materials would sink in the lightweight foam.

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Mix Details of Foam Concrete -
The foam concrete properties depend upon the following factors -

- The volume of the foam
- The cement content in the mix
- The filler material
- The age

The influence of water cement ratio has a very little influence on the properties of the foam concrete, unlike foam and the cement content.

Properties of Foamed Concrete:

The foam concrete properties in its fresh and hardened state are explained below -

Visual Appearance of Foamed Concrete -
The exact comparison for the foam that is manufactured to produce foam concrete resembles the shaving foam. When this is mixed with the mortar of standard specification, the final mix will resemble the consistency of yogurt or in the form of a milkshake.

Fresh Properties of Foamed Concrete -
The workability of foamed concrete is very high and have a slump value of 150mm to collapse. These have a strong plasticizing effect. This property of foam concrete makes it highly demanded in most of the applications. Once the flow of the mix has remained static for a longer period, it is very difficult to restart its original state. Foam concrete in the fresh state is thixotropic in nature. The chances of bleeding in foamed concrete are reduced due to high air content. When the mix temperature increases, good filling, and contacts are carried out due to the expansion of air. If the amount of sand used is higher or coarse aggregates is used other than the standard specifications, there are chances for segregation. This can also lead to the collapse of the bubble, which would reduce the total volume and the foam structure. It is fine to carry out pumping of fresh foam concrete with care. Free fall of foam concrete at the end with turbulence, may result in the collapse of the bubble structure.

Hardened Properties of Foamed Concrete -
The physical properties of the foam concrete are clearly related to the dry density. The variation is seen in the tabulation given in the table below.

Table: Typical Properties of Foamed Concrete in its Hardened State

Dry Density Kg/m^3	Compressive Strength N/mm^2	Tensile Strength N/mm^2	Water Absorption Kg/m^2
400	0.5 - 1	0.05-0.1	75
600	1-1.5	0.2-0.3	33
800	1.5 -2	0.3-0.4	15

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1000	2.5 -3	0.4-0.6	7
1200	4.5-5.5	0.6-1.1	5
1400	6-8	0.8-1.2	5
16 00	7.5-10	1-1.6	5

The thermal conductivity of foam concrete ranges from 0.1W/mK to 0.7W/mK. The drying shrinkage ranges from 0.3 to 0.07% at 400 and 1600kg/m^3 respectively. The foamed concrete does not possess an equivalent strength similar to an autoclaved block with similar density. Under the action of load, there is internal hydraulic pressure created within the structure, which would cause the deformation of the foam concrete. The hardened foam concrete has good resistance against freezing and thawing. It was observed that the application of foamed concrete in an area of temperature ranging from -18 degree Celsius to +25 degree Celsius showed no signs of damage. The density of foamed concrete employed here range from 400to 1400kg/m^3.

Advantages of Foamed Concrete:

- The foam concrete mix does not settle. Hence it does not need any compaction
- The dead weight is reduced as it is light weight concrete
- The foamed concrete under its fresh state has freely flowing consistency. This property will help in completely filling the voids.
- The foam concrete structure has excellent load spreading and distributing capability
- Foamed Concrete Does not impose significant lateral loads
- The Water absorption property
- The foam concrete batches are easy to produce, so quality check and control are easily done
- The foam concrete has higher resistance to freezing and thawing
- Non-hazardous and faster work completion
- Cost effective, less maintenance

Disadvantages of Foamed Concrete:

- Presence of water in the mixed material make the foam concrete very sensitive
- Difficulty in finishing
- Time of mixing longer
- With the increase in density, the compressive strength and flexural strength decreases.

Mortar and dry pack:

Dry packing is the hand placement if a low w/c ratio mortar which is subsequently rammed in to place to produce a dense mortar plugs having tight contact to the existing concrete. Because of the low w/c ratio, there is e patch remains little shrinkage and the patch remains tight, with good durability, strength and water tightness. Dry pack should be used for filling holes having a depth equal to, or greater than, the least surface dimension of the repair area; for cone

belt, she bolt, core holes and grout-insert holes; for holes left by the removal of form ties; and for narrow slots cut for repair of cracks. Dry pack should not be used for relatively shallow depressions where lateral restraint cannot be obtained, for filling behind reinforcement, or for filling holes that extend completely through a concrete section. For the dry pack method of concrete pair, holes should be sharp and square at the surface edges, but corners within the holes should be rounded, especially when water tightness is required. The interior surfaces of holes left by cone bolts and she bolts should be roughened to develop and effective bond; this can be done with a rough stub of 7/8 inch steel wire rope, a notched tapered reamer, or a star drill. Other holes should be undercut slightly in several places around the perimeter. Holes for dry pack should have a minimum depth of 1 inch.

Dry pack mortar, which is also called deck mud or floor mud, is a mixture of sand, cement, and water. It is used to repair small spots, creating thick bed mortar for tile and brick placement, and bed shower installation.

The proportion of the mixture is one part of cement to four part of sand, and adequate water to produce mortar that stick together when it is molded into a ball with hands as illustrated in following Figure.

Added to that, the ball shall not crumble as a result of low water and should not slump due to high-water proportion. This mixture is claimed to yield a compressive strength of 21 MPa.

Fig.: Adequate amount of Water added

Mixture Proportion:

It is reported that one part of cement to four part of sand, preferably sharp clean sand, is adequate. However, mix proportions like one to two and half, and one to five or even six are reported. With regard to quantity of water, it depends on the moisture content of used sand. If moisture of sand is low, greater quantity of water would be needed compare with case where moisture content is high.

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Fig.: Dry Pack Mortar before adding Water

Fig.: Dry Pack Mortar Ready for Utilization

Applications of Dry Pack Mortar:

1. Used to prepare ordinary thick mortar beds.
2. Employed to level concrete surfaces up to 51 mm thick.
3. Used for floating shower bases.
4. It can be directly bonded or used as a detached floating mortar bed over a cleavage membrane or waterproofing membrane.
5. Use in both residential and commercial applications in dry and wet areas.
6. Dry pack mortar is used to fill deep holes in a concrete wall. As the dry pack mortar components are mixed, it should be placed in layers of 10mm and then compacted with hammer, stick, or hardwood dowel. It is recommended to employ metal stick to compact dry pack mortar rather than wooden stick. This is because metal stick yields better compaction and ensure greater bond. Additionally, it is advised to apply direct tamping at an angle to the sides of the hole to ensure good compaction at the sides of the hole.

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Fig. 4: Setting Bed for Installation of Bricks

Fig. 5: Creating Bed for Shower installation

Advantages of Dry Pack Mortar:

1. Used for Interior and Exterior applications.
2. Jobsite mixing of sand and cement is no longer needed.

3. It can be tamped, compacted, and sloped easily.
4. It guarantees a consistent mix on large jobs.

Vacuum concrete:

It is well known that high water/cement ratio is harmful to the overall quality of concrete, whereas low water/cement ratio does not give enough workability for concrete to be compacted hundred percentages. Generally, higher workability and higher strength or very low workability and higher strength do not go hand in hand. Vacuum process of concreting enables to meet this conflicting demand. This process helps a high workable concrete to get high strength.

In this process, excess water used for higher workability, not required for hydration and harmful in many ways to the hardened concrete is withdrawn by means of vacuum pump, subsequent to the placing of the concrete. The process when properly applied produces concrete of quality. It also permits removal of formwork at an early age to be used in other repetitive work.

It essentially consists of a vacuum pump, water separator and filtering mat. The filtering consists of a backing piece with a rubber seal all round the periphery. A sheet of expanded metal and then a sheet of wire gauge also form part of the filtering mat. The top of the suction mat is connected to the vacuum pump. When the vacuum pump operates, suction is created within the boundary of the suction mat and the excess of water is sucked from the concrete through the fine wire gauge or muslin cloth. At least one face of the concrete must be open to the atmosphere to create difference of pressure. The contraction of concrete caused by loss of water must be vibrated.

The vacuum processing can be carried out either from the top surface or from the side surface. There will be only nominal difference in the efficiency of top processing or side processing. It has been seen that the size of the mat should not be less than 90cm X 60cm. smaller mat was not found to be effective.

Gunite and Shotcrete:

Gunite can be defined as mortar conveyed through a hose and pneumatically projected at a high velocity onto a surface. Recently this method has been further developed by the introduction of small sized coarse aggregate into the mix deposited to obtain considerably greater thickness in one operation and to make the process economical by reducing the cement content. Normally fresh material with zero slump can support itself without sagging or peeling off. The force of the jet impacting on the surface compacts the material. Sometimes use of set accelerators to assist overhead placing is practiced. The newly developed “Redi-set cement” can also be used for shotcreting process.

There is not much difference between guniting and shotcreting. Gunite was first used in the early 1900 and this process is mostly used for pneumatical application of mortar of less thickness, whereas shotcrete is a recent development on the similar principle of guniting for achieving greater thickness with small coarse aggregates.

There are two different processes in use, namely the “Wet-mix” process and the “dry-mix” process. The dry mix process is more successful and generally used.

Dry-mix Process:

The dry mix process consists of number of stages and calls for some specialized plan.

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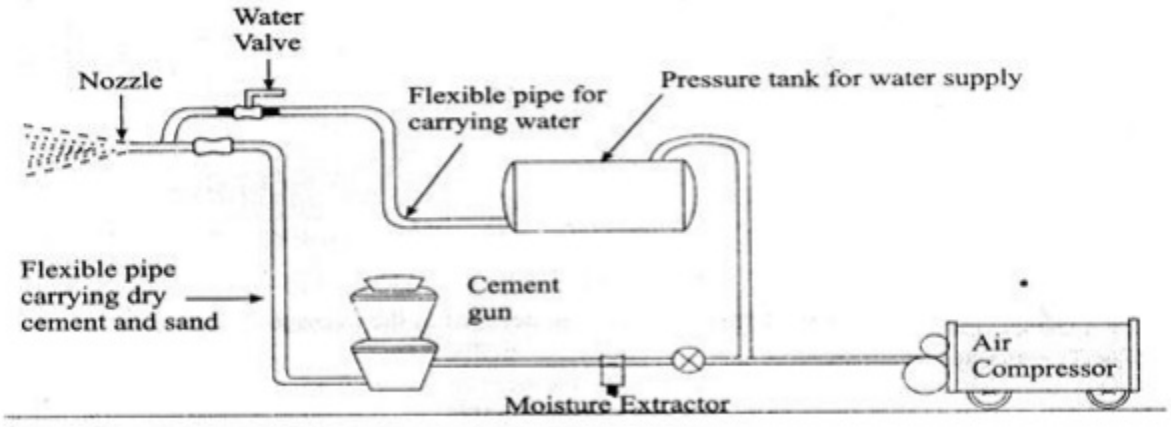
- This material is carried by compressed air through the delivery hose to a special nozzle. The nozzle is fitted inside with a perforated manifold through which water is sprayed under pressure and intimately mixed with the sand/cement jet.
- The wet mortar is jetted from the nozzle at high velocity onto the surface to gunited.

Wet-mix process:

In the wet-mix process the concrete is mixed with water as for ordinary concrete before conveying through the delivery pipe line to the nozzle, at which point it is jetted by a compressed air, onto the work in the same way, as that of dry-mix process.

The wet-mix process has been generally discarded in favour of dry-mix process, owing to the greater success of the latter.

The dry-mix method makes use of high velocity or low velocity system fully. The high velocity gunite is produced by using the small nozzle and a high air pressure to produce a high nozzle velocity of about 90 to 120 meters/sec. This results in exceptional good compaction. The lower velocity gunite is produced using large diameter hose for large output. The compaction will not be very high.



General arrangement of apparatus in gunite system.

Advantages of Wet and Dry process:

Some of the advantages and disadvantages of the wet and dry processes is discussed below. Although it is possible to obtain more accurate control of the water/cement ratio with the wet process the fact that this ratio can be kept very low with the dry process largely overcomes the objection of the lack of accurate control.

The difficulty of pumping light-weight aggregate concrete makes dry process more suitable when this type of aggregate is used. The dry process on the other hand, is vey sensitive to the water content of the sand, too wet a sand causes difficulties through blockade of the delivery pipeline, a difficulty which does not arise with the wet process.

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The lower water/cement ratio obtained with the dry process probably accounts for the lesser creep and greater durability of concrete produced in this way compared with concrete deposited by the wet process, but air-entraining agents can be use to improve the durability of concrete deposited by the latter means. Admixtures generally can be used more easily with the wet process except for accelerators.

Pockets of lean mix and of rebound can occur with the dry process. It is necessary for the nozzelman to have an area where he can dump unsatisfactory shotcrete obtained when he is adjusting the water supply or when he is having trouble with the equipment.
These troubles and the dust hazard are less with the wet process, but wet process does not normally give such a dense concrete as the dry process. Work can be continued in more windly weather with the wet process than with the dry process. Owing to the high capacities obtainable with concrete pumps, a higher rate of laying of concrete can probably be achieved in the wet process than with the dry process.

General use of Shotcrete:

1. It is useful where considerable savings and peculiar adaptability is needed and it is more suitable than conventional placing methods.
2. Shuttering and formwork need be erected only on side of the work and hence there will be considerable saving in the shuttering costs.
3. It can be conveyed over a considerable diameter pipe, makes this process suitable for sites where access is difficult.
4. The maximum rate of deposition is about 15 m^3 hr for the dry process but this can be exceeded with the wet process.
5. The low water-cement ratio, the thinness of the section deposited and the fact that normally only one side of the concrete is covered, necessitates careful attention to curing more than with normal concrete.
6. The normal specifications with respect to cement, aggregate and water, also apply for shotcrete, but it is desirable that the aggregate should be harder to allow for attrition.
7. Admixtures can be used in shotcrete to produce the same effects as in ordinary concrete.
8. The drying shrinkage will depend on the water content and may, therefore, be expected to be fairly low for the dry process. The creep of the dry shotcrete is similar to that of high quality normally placed concrete but shrinkage and creep of wet shotcrete is likely to be high.
9. The durability or resistance to frost action and other agencies of dry shotcrete is good.
10. About half of the entrained air is likely to be lost while spraying.

Epoxy injection:

The Injection of polymer under pressure will ensure that the sealant penetrates to the full depth of the crack. The technique in general consists of drilling hole at close intervals along the length of cracks and injecting the epoxy under pressure in each hole in turn until it starts to flow out of the next one. The hole in use is then sealed off and injection is started at the next hole and so on until full length of the crack has been treated. Before injecting the sealant, it is necessary to seal the crack at surface between the holes with rapid curing resin.

For repairs of cracks in massive structures, a series of holes (Usually 20mm in diameter and 20mm deep spaced at 150 to 300mm interval) intercepting the crack at a number of location are drilled. Epoxy injection can be used to bond the cracks as narrow as 0.05mm. It has been successfully used in the repair of cracks in buildings, bridges, dams and other similar structures. However, unless the cause of cracking is removed, cracks will probably recur possibly somewhere else in the structure. Moreover, in general this technique is not very effective if the cracks are actively leaking and cannot be dried out.

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Epoxy injection is a highly specialized job requiring a high degree of skill for satisfactory execution. The general steps involved are as follows –

1. Preparation of the surface - The contaminated cracks are cleaned by removing all oil, grease, dirt and fine particles of concrete which prevent the epoxy penetration and bonding. The contaminants should preferably be removed by flushing the surface with water or a solvent. The solvent is then blown out using compressed air, or by air drying. The surface cracks should be sealed to keep the epoxy from leaking out before it has cured or gelled. A surface can be sealed by brushing an epoxy along, the surface of cracks and allowing it to harden. If extremely high injection pressures are needed, the crack should be routed to a depth of about 12mm and width of about 20mm in V-shape, filled with an epoxy, and stuck off flush with the surface.

2. Installation of entry ports - The entry port or nipple is an opening to allow the injection of adhesive directly into the crack without leaking. The spacing of injection ports depends upon a number of factors such as depth of crack, width or crack and its variation with depth, viscosity of epoxy, injection pressure etc. and choice must be based on experience. In case of V-grooving of the cracks, a hole of 20mm dia and 12 to25mm below the apex of V-grooved section, is drilled into the crack. A tire-calue stren is bonded with an epoxy adhesive in the hole. In case the cracks are not V-grooved, the entry port is provided by bonding a fitting, having a hat-like croos-section with an opening at the top for adhesive to enter, flush with the concrete face over the crack.

3. Mixing of epoxy - The mixing can be done either by batch or continuous methods. In batch mixing, the adhesive components are premixed in specified proportions with a mechanical stirrer, in amounts that can be used prior to the commencement of curing of the material. With the curing of material, pressure injection becomes more and more difficult. In the continuous mixing system, the two liquid adhesive components pass through metering and driving pumps prior to passing through an automatic mixing head. The continuous mixing system allows the use of fast-setting adhesives that have short working life.

4. Injection of epoxy - In its simplest form, the injection equipment consists of a small reservoir or funnel attached to a length of flexible tubing, so as to provide a gravity head. For small quantities of repair material small hand-held guns are usually the most economical. They can maintain a steady pressure which reduces chances of damage to the surface seal. For big jobs power-driven pumps are often used for injection. The pressure used for injection must be carefully selected, as the use excessive pressure can propagate the existing cracks, causing additional damage. The injection pressures are governed by the width and depth of cracks and the viscosity of resin and seldom exceed 0.10 MPa. It is preferable to inject fine cracks under low pressure in order to allow the material to be drawn into the concrete by capillary action and it is a common practice to increase the injection pressure during the course of work to overcome the increase in resistance against flow as crack is filled with material. For relatively wide cracks gravity head of few hundred millimeters may be enough.

5. Removal of surface seal - After the injected epoxy has occurred; the surface seal may be removed by grinding or other means as appropriate. Fittings and holes at the entry ports should be painted with an epoxy patching compound.

Mortar repair for cracks:

Portland cement mortar may be used for repairing defects on surfaces not prominently exposed. where the defects are too wide for dry-pack filling or where the defects are too shallow for concrete filling, and no deeper than the far side of the reinforcement that is nearest the surface. repairs may be made either by use of shotcrete or by hand application methods, although hand application methods are generally recommended for areas subject to public view in historic preservation applications.

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Replacement mortar can be used to make shallow, small-size repairs to new or green concrete, provided that the repairs are performed within 24 hours of removing the concrete forms. Accomplishing successful mortar repairs to old concrete without the use of a bonding resin is unlikely or extremely difficult. Evaporative loss of water from the surface of the repair mortar, combined with capillary water loss to the old concrete, results in unhydrated or poorly hydrated cement in the mortar.

Additionally, repair mortar bond strength development proceeds at a slower rate than compressive strength development. This causes workers to mistakenly abandon curing procedure prematurely, when the mortar seems strong. Once the mortar dries, bond strength development stops, and bond failure of the mortar patch results. For these reasons using cement mortar without a resin bond coat to repair old concrete is discouraged. A Portland cement mortar patch is usually darker than the surrounding concrete unless precautions are taken to match colours. A leaner mix will usually produce a lighter colour patch.

Preparation and materials:

Concrete to repaired with replacement mortar should first have all the deteriorated or unsound areas removed. After preparation, the areas should be cleaned, roughened if necessary and surface-dried to a saturated surface condition. The mortar should be applied immediately thereafter. Replacement mortar contains water, Portland cement and sand. The water and sand should be suitable for use in concrete, and the same should pass through a no.16 sieves. Only enough water should be added to the cement sand mixture to permit placing.

Curing:

Failure to cure properly is the most common cause of failure of replacement mortar. It is essential that mortar repairs receive a through water cure starting immediately after initial set and continuing for 14 days. In no event should the mortar be allowed to become dry during the 14 day period following placement. Following the 14 day water cure and while the mortar is still saturated, the surface of the mortar should be coated with two coats of a wax-base curing compound meeting reclamation specifications.

Applications:

The success of this method depends on complete removal of all defective and affected concrete, good bonding of the mortar to the concrete, elimination of shrinkage of the patch after placement, and thorough curing. Replacement mortar repairs can be made using an epoxy bonding agent; this technique is highly recommended.

<u>Shoring and underpinning:</u>

The arrangement employed to prevent a damaged structure, due to either foundation settlement or other reasons from collapse, is called shoring. It is also used for providing temporary support to a structure which is being remodelled. The shores are of following types -

- **Racking Shores -** In this type, notches are cut in the walls of the building and inclined posts are property, while demolishing the building, are called horizontal or flying shores.

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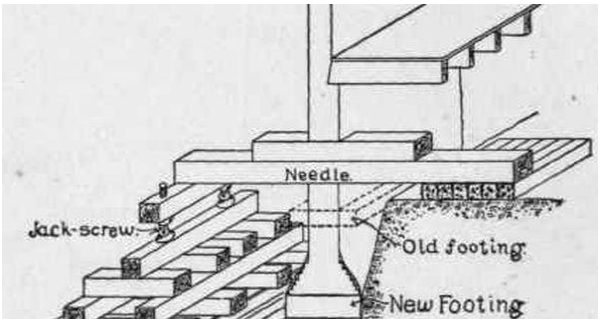
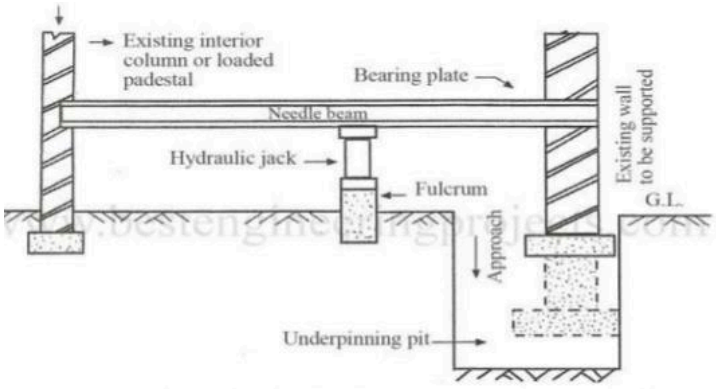
- **Horizontal of Flying Shores -** The shores, which are employed to support the walls of adjoining property, while demolishing the building are called horizontal or flying shores.

- **Vertical Dead Shores -** The vertical shores used to support walls temporally are called vertical or dead shores.





Underpinning is the operation of providing new permanent foundation. The underpining may be done by the following methods -

- **Pit Underpinning -** In this method, a pit is dug to expose the foundation to b remodelled and the old foundation is either removed completely or strengthened suitably.

- **Pier Underpinning -** In this method of underpinning, piers under foundations of structures are installed, filled with concrete and wedged up to transfer the load to a new pier. This method is most suitable in dry ground. In pier underpinning, proper care must be taken to prevent loss of ground installing the sheeting, otherwise the building structure mar sink.

  The least size of the underpinning pits to provide working place, for workers is 1m x 1.3m. The pits are sunk to a stratum strong enough.

  In this method piles are jacked into the ground with case for underpinning building, where underlying ground has water bearing strata.

Year: I
Semester: II

6. Name of the Faculty: Sayanta Sikdar Course Code: CEM21017
7. Course : Maintenance and Rehabilitation of Structures L: 3
8. Program : M.Tech (CEM) T: 0
9. Target : 60% P: 0
C: 3

UNIT – V: DEMOLITION TECHNIQUES

Refer to Annexure 1.

Internal Assessment – Class Test 1

Course: M. Tech (CEM) Semester: 2nd Maximum Marks: 20

Total No of questions: 5 Time duration: 1 hour

PAPER TITLE: Maintenance and Rehabilitation of Structures
PAPER CODE: CEM21017
Date: June 04, 2021

Class Test 1 – CEM21017 – Unit III

(Answer all questions – 4 X 5)

1. Write down any four facets of maintenance.
2. Define the following terms – Repair, Retrofit, Rehabilitation, Restoration.
3. Explain any four causes of deterioration of concrete structures.
4. Discuss about physical inspection of damaged structures and about the factors influencing maintenance of concrete structures.
5. Discuss about the load test method used for determining the strength of an existing structure. What are the possible decisions that can be made after evaluating the strength of a structure?

Year: I
Semester: II

6. Name of the Faculty: Sayanta Sikdar Course Code: CEM21017
7. Course : Maintenance and Rehabilitation of Structures L: 3
8. Program : M.Tech (CEM) T: 0
9. Target : 60% P: 0
C: 3

Class Test 1 Answer Script - Annexure 2

Internal Assessment – Class Test 2

Course: M. Tech (CEM) Semester: 2nd Maximum Marks: 20

Total No of questions: 4 Time duration: 1 hour

PAPER TITLE: Maintenance and Rehabilitation of Structures
PAPER CODE: CEM21017
Date: July 12, 2021

Class Test 2 – CEM21017 – Unit IV and V

(Answer all questions – 4 X 5)

1. Discuss about various types of special mortars.
2. Explain different fibres used for Fibre Reinforced Concrete.
3. Write a short note on mechanical demolition technique.
4. Differentiate between demolition by hand and mechanical demolition technique.

Year: I
Semester: II

6. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**
7. Course : Maintenance and Rehabilitation of Structures **L: 3**
8. Program : M.Tech (CEM) **T: 0**
9. Target : 60% **P: 0**
C: 3

Class Test 2 Answer Script - Annexure 3

Internal Assessment – Assisgnment 1

Assisgnment 1 – CEM21017 – Unit I and Unit II

Date of submission: 26.05.2021

Question 1. Identify the measures to control cracks in a concrete structure after site inspection and plan accordingly to solve the cracking issue. (CO1)

Question 2. Explain briefly the methods commonly used for corrosion protection. (CO2)

(6+6)

Assignment 1 Answer Script - Annexure 4

Internal Assessment – Assisgnment 2

Assisgnment 2 – CEM21017 – Unit III

Date of submission: 15.06.2021

Question. Explain about different testing techniques related to maintenance and repairing of structures in details. (CO3)

(6)

Assignment 2 Answer Script - Annexure 5

Year: I
Semester: II

6. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**
7. Course : Maintenance and Rehabilitation of Structures **L: 3**
8. Program : M.Tech (CEM) **T: 0**
9. Target : 60% **P: 0**
C: 3

Internal Assessment – Assisgnment 3

Assisgnment 3 – CEM21017 – Unit IV and Unit V

Date of submission: 27.07.2021

Question 1. Discuss briefly about Mortar repair for cracks. (CO4)

Question 2. Write down a recent case study on engineered demolition in your own words. (CO5)

(6+6)

Assignment 3 Answer Script - Annexure 6

	ADAMAS UNIVERSITY **MID-SEMESTER EXAMINATION** (Academic Session: 2020 – 21)		
Name of the Program:	M.Tech. (Construction Engineering & Management)	**Semester:**	II
Paper Title:	Maintenance and Rehabilitation of Structures	**Paper Code:**	CEM21017
Maximum Marks:	20	**Time Duration:**	2 Hrs
Total No. of Questions:	11	**Total No of Pages:**	01

Year: I
Semester: II

6. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**
7. Course : Maintenance and Rehabilitation of Structures **L: 3**
8. Program : M.Tech (CEM) **T: 0**
9. Target : 60% **P: 0**
C: 3

(Any other information for the student may be mentioned here)	1. At top sheet, clearly mention Name, Univ. Roll No., Enrolment No., Paper Name & Code, Date of Exam. 2. All parts of a Question should be answered consecutively. Each Answer should start from a fresh page. 3. Assumptions made if any, should be stated clearly at the beginning of your answer.

Group A **Answer All the Questions (5 x 1 = 5)**			
Q. No.	**Question**	**Knowledge Level**	**Course Outcome**
1	What are the tests for assessing the frost damage in concrete structures? Write any two.	Remember	**CO1**
2	What are the factors affecting Chemical attack on concrete?	Remember	**CO1**
3	Define corrosion.	Remember	**CO2**
4	Define effective cover and corrosion inhibitor.	Remember	**CO2**
5	List out some coating for reinforcement to prevent corrosion.	Remember	**CO2**
Group B **Answer All the Questions (3 x 5 = 15)**			
6 a)	What are the causes and types of cracking in concrete?	Remember	**CO1**
	(OR)		
6 b)	Explain the thermal properties of concrete in brief.	Understand	**CO1**
7 a)	Explain the functions of Quality assurance and needs for Quality assurance for concrete construction.	Understand	**CO1**
	(OR)		
7 b)	Explain the various components of Quality assurance for concrete in brief.	Understand	**CO1**
8 a)	Illustrate the mechanism behind corrosion.	Understand	**CO2**
	(OR)		
8 b)	Explain about Design and construction errors briefly.	Understand	**CO2**

Year: I
Semester: II

6. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**
7. Course : Maintenance and Rehabilitation of Structures **L: 3**
8. Program : M.Tech (CEM) **T: 0**
9. Target : 60% **P: 0**
C: 3

Mid Semester Answer Script – Annexure 7

Evaluation Sheet – Internal Assessment

Roll Number	Registration Number	Name of the Student	Internal Assessment (30)				
			Assignment (10)	Class Test (20)	Case Study	etc.	Total
PG/02/MTCOEM/2020/001	AU/2020/0004499	ANINDYA GHOSH	10	16	Nil	NA	26

Signature of HOD/Dean

Date: 26.08.2021

Signature of Faculty

Date: 26.08.2021

Year: I
Semester: II

6. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**
7. Course : Maintenance and Rehabilitation of Structures **L: 3**
8. Program : M.Tech (CEM) **T: 0**
9. Target : 60% **P: 0**
C: 3

Evaluation Sheet – Mid Semester

Roll Number	Registration Number	Name of the Student	Marks (20)
PG/02/MTCOEM/2020/001	AU/2020/0004499	ANINDYA GHOSH	18

Signature of HOD/Dean

Date: 26.08.2021

Signature of Faculty

Date: 26.08.2021

Year: I
Semester: II

6. Name of the Faculty: Sayanta Sikdar Course Code: CEM21017
7. Course : Maintenance and Rehabilitation of Structures L: 3
8. Program : M.Tech (CEM) T: 0
9. Target : 60% P: 0
C: 3

Planning for Remedial Classes – Mid Semester

Sl. No.	Name of Student	Roll No.	Reg. No.	Mid Sem Marks	Remedial Classes Held							Class test on the basis of Remedial Classes	End Sem Marks	Improvement (Y/N)
					Date									
					Venue									
					Time									
1.	Nil	Nil	Nil	Nil	Nil	Nil	Nil					Nil	Nil	NA

Signature of HOD/ Dean Signature of Faculty

Year: I
Semester: II

6. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**
7. Course : Maintenance and Rehabilitation of Structures **L: 3**
8. Program : M.Tech (CEM) **T: 0**
9. Target : 60% **P: 0**
C: 3

Date: 26.08.2021 **Date: 26.08.2021**

COURSE END SURVEY

INDIRECT ASSESSMENT

Sample format for Indirect Assessment of Course outcomes:

NAME: **ANINDYA GHOSH**
ROLL NO.: **PG/02/MTCOEM/2020/001**
REG. NO..: **AU/2020/0004499**
COURSE: **Maintenance and Rehabilitation of Structures (CEM21017)**
PROGRAM: **M.Tech (CEM)**

Please rate the following aspects of course outcomes of "Maintenance and Rehabilitation of Structures".

Use the scale 1-5 (Poor – Excellent)

Course Outcomes	Statement	1	2	3	4	5
CO1	Can you Explain the basic principles related to quality assurance of construction materials and weathering effects on concrete?				4	
CO2	Are you able to Predict construction error in concrete due to corrosion and improve design specification for protective measure?				4	
CO3	Do you Understand maintenance and repair strategies?				4	
CO4	Can you Select repair materials and techniques depending on damages occur in structures?				4	
CO5	Will you be able to Explain various demolition techniques and other case studies?				4	

Year: I
Semester: II

6. Name of the Faculty: Sayanta Sikdar — Course Code: CEM21017
7. Course : Maintenance and Rehabilitation of Structures — L: 3
8. Program : M.Tech (CEM) — T: 0
9. Target : 60% — P: 0
C: 3

INDIRECT ASSESSMENT CONSOLIDATION

ADAMAS UNIVERSITY, KOLKATA
SCHOOL OF
DEPARTMENT OF
CO Indirect Assessment

Programme: M.Tech (CEM) **Academic Year:2020-21** **Batch: 2020-22**

Course Code & Name: CEM21017 & Maintenance and Rehabilitation of Structures

Course Outcome	Students Feed Back (5)	Attainment (100)
CO1	4	80
CO2	4	80
CO3	4	80
CO4	4	80
CO5	4	80
etc.		

Signature of HOD/Dean
Date: 26.08.2021

Signature of Faculty
Date: 26.08.2021

Year: I
Semester: II

6. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**
7. Course : Maintenance and Rehabilitation of Structures **L: 3**
8. Program : M.Tech (CEM) **T: 0**
9. Target : 60% **P: 0**
C: 3

	ADAMAS UNIVERSITY **END SEMESTER EXAMINATION** (Academic Session: 2020 – 21)		
Name of the Program:	M.Tech. (Construction Engineering & Management)	**Semester:**	II
Paper Title:	Maintenance and Rehabilitation of Structures	**Paper Code:**	CEM21017
Maximum Marks:	50	**Time Duration:**	3 Hrs
Total No. of Questions:	17	**Total No of Pages:**	02
(Any other information for the student may be mentioned here)	**1.** At top sheet, clearly mention Name, Univ. Roll No., Enrolment No., Paper Name & Code, Date of Exam. **2.** All parts of a Question should be answered consecutively. Each Answer should start from a fresh page. **3.** Assumptions made if any, should be stated clearly at the beginning of your answer.		

Group A **Answer All the Questions (5 x 1 = 5)**			
		Knowledge Level	
1	How can the effect of freezing and thawing be prevented in concrete?	**R**	**CO1**
2	Why concrete cover is required?	**R**	**CO2**
3	What are the main objectives of maintenance of structure?	**R**	**CO3**
4	List out various types of special mortars.	**R**	**CO4**
5	Classify demolition techniques.	**U**	**CO5**
Group B			

Year: I
Semester: II

6. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**
7. Course : Maintenance and Rehabilitation of Structures **L: 3**
8. Program : M.Tech (CEM) **T: 0**
9. Target : 60% **P: 0**
C: 3

Answer All the Questions (5 x 2 = 10)			
6 a)	What is Quality audit of concrete construction?	**R**	**CO1**
(OR)			
6 b)	Explain Plastic shrinkage cracks in concrete.	**U**	**CO1**
7 a)	Illustrate about Alloyed steel or Stainless steel used for corrosion protection.	**U**	**CO2**
(OR)			
7 b)	Explain Cathodic protection to prevent corrosion.	**U**	**CO2**
8 a)	What are the general considerations to be taken into account for assessment of damage of a structure?	**R**	**CO3**
(OR)			
8 b)	What aspects are covered in Daily routine inspection or maintenance?	**R**	**CO3**
9 a)	Explain the necessity for developing Polymer concrete.	**U**	**CO4**
(OR)			
9 b)	Illustrate about Saw dust concrete as a special concrete.	**U**	**CO4**
10 a)	List out the preliminary aspects to be considered prior to site demolition work.	**R**	**CO5**
(OR)			
10 b)	Identify the process of preliminary investigation to be done before placing a contract for demolition work.	**Ap**	**CO5**
Group C **Answer All the Questions (7 x 5 = 35)**			
11 a)	What are the effects due to chemicals on concrete?	**R**	**CO1**
(OR)			
11 b)	Illustrate about permeability as a property of concrete.	**U**	**CO1**
12 a)	Explain the effects of corrosion on concrete structures.	**U**	**CO2**
(OR)			
12 b)	Illustrate about the construction errors for concrete constructions.	**U**	**CO2**
13 a)	Classify the maintenance involved in civil engineering works and discuss in brief.	**U**	**CO3**
(OR)			
13 b)	Identify the importance of maintenance work for structures.	**Ap**	**CO3**
14 a)	Illustrate about Ferro cement.	**U**	**CO4**
(OR)			
14 b)	What is Shotcrete? Discuss briefly.	**R**	**CO4**
15 a)	Identify the types and uses of Expansive cement.	**Ap**	**CO4**
(OR)			

Year: I
Semester: II

6. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**
7. Course : Maintenance and Rehabilitation of Structures **L: 3**
8. Program : M.Tech (CEM) **T: 0**
9. Target : 60% **P: 0**
C: 3

15 b)	Explain briefly about Sulphur infiltrated concrete.	**U**	**CO4**
16 a)	Identify the good practices to be followed for mechanical demolition technique.	**Ap**	**CO5**
(OR)			
16 b)	Explain the application criteria of Wrecking ball for demolition work.	**U**	**CO5**
17 a)	Explain Piecemeal demolition or demolition by hand.	**U**	**CO5**
(OR)			
17 b)	Illustrate about Hydraulic pusher arm machine used for demolition work.	**U**	**CO5**

End Semester Answer Script – Annexure 8

Evaluation Sheet (End Semester)

Roll Number	Registration Number	Name of the Student	Marks (50)
PG/02/MTCOEM/2020/001	AU/2020/0004499	ANINDYA GHOSH	47

Signature of HOD/Dean **Signature of Faculty**

Date: 26.08.2021 **Date: 26.08.2021**

Year: I
Semester: II

6. Name of the Faculty: Sayanta Sikdar Course Code: CEM21017
7. Course : Maintenance and Rehabilitation of Structures L: 3
8. Program : M.Tech (CEM) T: 0
9. Target : 60% P: 0
C: 3

Planning for Remedial Classes – End Semester

Sl. No.	Name of Student	Roll No.	Reg. No.	End Sem Marks	Remedial Classes Held							Class test on the basis of Remedial Classes	Supple Exam Marks	Improvement (Y/N)
					Date									
					Venue									
					Time									
1.	Nil	Nil	Nil	Nil	Nil	Nil	Nil					Nil	Nil	NA

Year: I
Semester: II

6. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**
7. Course : Maintenance and Rehabilitation of Structures **L: 3**
8. Program : M.Tech (CEM) **T: 0**
9. Target : 60% **P: 0**
C: 3

Signature of HOD/ Dean **Signature of Faculty**

Date: 26.08.2021 **Date: 26.08.2021**

Content beyond Syllabus

Papercrete, Self-healing concrete and Light-weight concrete

Refer Annexure 9, 10 and 11.

Consolidated Mark Statement

Roll Number	Registration Number	Name of the Student	Total Marks			
			Mid Semester (20)	Internal Assessment (30)	End Semester (50)	Total (100)
PG/02/MTCOEM/2020/001	AU/2020/0004499	ANINDYA GHOSH	18	26	47	91

Signature of Dean/HOD **Signature of Faculty**

Date: 26.08.2021 **Date: 26.08.2021**

Year: I
Semester: II

6. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**

7. Course : Maintenance and Rehabilitation of Structures **L: 3**

8. Program : M.Tech (CEM) **T: 0**

9. Target : 60% **P: 0**

C: 3

Year: I
Semester: II

6. Name of the Faculty: Sayanta Sikdar Course Code: CEM21017
7. Course : Maintenance and Rehabilitation of Structures L: 3
8. Program : M.Tech (CEM) T: 0
9. Target : 60% P: 0
C: 3

CO ATTAINMENT – GAP ANALYSIS & REMEDIAL MEASURES

ADAMAS UNIVERSITY, KOLKATA
SCHOOL OF
DEPARTMENT OF
CO ATTAINMENT - GAP ANALYSIS & REMEDIAL MEASURES

Batch :	2020-22		Academic Year: 2020-21
Course Code & Name		Name of the Coordinator	Year & Semester
CEM21017 & Maintenance and Rehabilitation of Structures		Sayanta Sikdar	I & II

CO	Direct Assessment	Indirect Assessment	CO Attainment	Target	CO Attainment Gaps	Action for Bridge the Gap	Target Modification
CO1	100	80	96	**70**	-26		**90**
CO2	100	80	96	**70**	-26		**90**
CO3	100	80	96	**70**	-26		**90**
CO4	100	80	96	**70**	-26		**90**
CO5	100	80	96	**70**	-26		**90**

Signature of HOD/Dean **Signature of Faculty**

Date: **Date:**

Year: I
Semester: II

6. Name of the Faculty: Sayanta Sikdar Course Code: CEM21017
7. Course : Maintenance and Rehabilitation of Structures L: 3
8. Program : M.Tech (CEM) T: 0
9. Target : 60% P: 0
C: 3

CO-PO ATTAINMENT

ADAMAS UNIVERSITY, KOLKATA
SCHOOL OF
DEPARTMENT OF
CO-PO ATTAINMENT

Programme : M.Tech (CEM)	Year & Sem: I & II	Academic Year: 2020-21	Batch:2020-22

Course Code	Course Name	CO-PO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CEM21017	Maintenance and Rehabilitation of Structures	Relationship	CO1, CO2, CO3, CO4, CO5	CO1, CO2, CO3, CO4, CO5		CO1, CO2, CO4, CO5	CO1, CO2, CO3, CO4, CO5		CO5	CO1, CO2, CO3, CO4, CO5		CO1, CO2, CO3, CO4, CO5
		Mapping Value	3	3		2	3		1	3		3
		Attainment	2.88	2.88	-	1.92	2.88	-	0.96	2.88	-	2.88

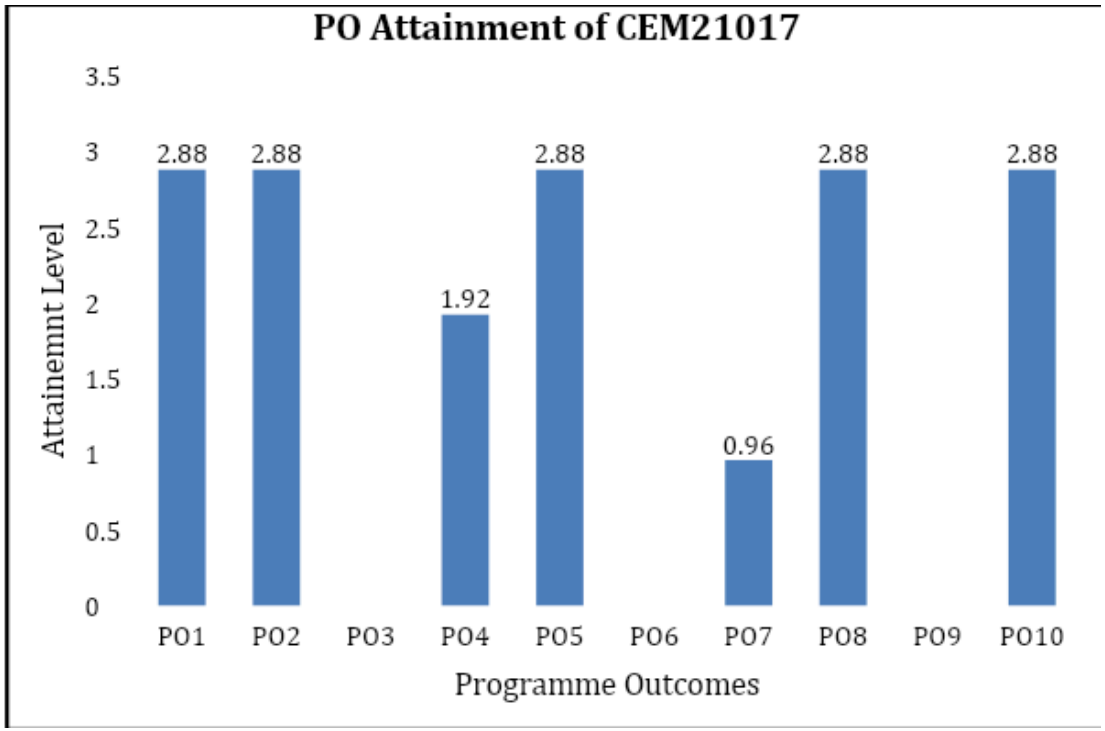
Signature of HOD/Dean Signature of Faculty

Year: I
Semester: II

6. Name of the Faculty: Sayanta Sikdar Course Code: CEM21017
7. Course : Maintenance and Rehabilitation of Structures L: 3
8. Program : M.Tech (CEM) T: 0
9. Target : 60% P: 0
C: 3

Date: **Date:**

PO ATTAINMENT OF THE COURSE



Signature of HOD/Dean **Signature of Faculty**

Year: I
Semester: II

6. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**

7. Course : Maintenance and Rehabilitation of Structures **L: 3**

8. Program : M.Tech (CEM) **T: 0**

9. Target : 60% **P: 0**

C: 3

Date: **Date:**

Year: I
Semester: II

6. Name of the Faculty: Sayanta Sikdar **Course Code: CEM21017**
7. Course : Maintenance and Rehabilitation of Structures **L: 3**
8. Program : M.Tech (CEM) **T: 0**
9. Target : 60% **P: 0**
C: 3

INSTRUCTIONS FOR FACULTY

Instructions for Faculty

- Faculty should keep track of the students with low attendance and counsel them regularly.
- Course coordinator will arrange to communicate the short attendance (as per University policy) cases to the students and their parents monthly.
- Topics covered in each class should be recorded in the table of RECORD OF CLASS TEACHING (Suggested Format).
- Internal assessment marks should be communicated to the students twice in a semester.
- The file will be audited by respective Academic Monitoring and Review Committee (AMRC) members for theory as well as for lab as per AMRC schedule.
- The faculty is required to maintain these files for a period of at least three years.
- This register should be handed over to the head of department, whenever the faculty member goes on long leave or leaves the Colleges/University.
- For labs, continuous evaluation format (break-up given in the guidelines for result preparation in the same file) should be followed.
- Department should monitor the actual execution of the components of continuous lab evaluation regularly.
- Instructor should maintain record of experiments conducted by the students in the lab weekly.
- Instructor should promote students for self-study and to make concept diary, due weightage in the internal should be given under faculty assessment for the same.
- Course outcome assessment: To assess the fulfilment of course outcomes two different approaches have been decided. Degree of fulfillment of course outcomes will be assessed in different ways through direct assessment and indirect assessment. In Direct Assessment, it is measured through quizzes, tests, assignment, Mid-term and/or End-term examinations. It is suggested that each examination is designed in such a way that it can address one or two outcomes (depending upon the course completion). Indirect assessment is done through the student survey which needs to be designed by the faculty (sample format is given below) and it shall be conducted towards the end of course completion. The evaluation of the achievement of the Course Outcomes shall be done by analyzing the inputs received through Direct and Indirect Assessments and then corrective actions suggested for further improvement.
- **Submission Targets of Course Contents:**
  - **S. No. 1 to 8 : Before Starting the Course**
  - **S. No. 9 & 10 : After Mid Semester Examination**
  - **S. No. 11 to 18 : Immediately After End Semester Examination**
  - **S. No. 19 to 22 :After Declaration of Result of the Course**