Department of Civil Engineering

Course File

Repair and Rehabilitation of Structures

(Course Code: CE851PE)

IV B.Tech II Semester

2023-24

Dr.M.S.Siva kumar

Professor

ANURAG Anurag ENGINEERING COLLEGE

(An Autonomous Institution)

Ananthagiri, Kodad, Telangana 508 206, India.

REPAIR AND REHABILITATION OF STRUCTURES

Check List

Int. Marks:25 Ext. Marks:75 Total Marks:100

ANURAG ENGINEERING COLLEGE
(An Autonomous Institution)
IV Year B.Tech. II Semester

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3	0	0	3

(CE851PE) REPAIR AND REHABILITATION OF STRUCTURES

UNIT- I

MAINTENANCE AND REPAIR STRATEGIES

Maintenance, Facets of Maintenance, importance of Maintenance, various aspects of Inspection, Condition Assessment of a structure, Various methods of Condition assessment , NDT and NDE ,Repair Strategies , Repairs-Rehabilitation-Retrofitting- Strengthening-Upgradation of a Structure, Selection of Materials and Techniques for Repair

UNIT- II

REPAIRS TO MASONRY AND CONCRETE STRUCTURES

Methods of crack repair in masonry and concrete structures, routing and sealing of cracks, removal and surface preparation in masonry and concrete structures, reinforcement repair, anchorage, placement methods; Shot-creting and guniting, Grouting- Portland cement grouting, chemical grouting, Dry packing, polymer impregnation, Strengthening of structures flexural strengthening, Shear Strengthening, strengthening of columns- jacketing of Columns, strengthening by interior and external reinforcing, External Pre- stressing, Fiber wrapping, Corrosion Protection: surface treatment, joint sealants, cathodic protection

UNIT-III

REPAIRS TO TIMBER AND STEEL STRUCTURES

Testing of Timber Structures for rots, Creosote retention, Planning for repairs in Timber Structures- Repairs to Timber Structures, Dynamic Loading and Fatigue, welding technology, weldability, Cleaning and surface Preparation of Corroded Structural Steel, replacement and addition of new members, different Types of Steel and Composite Joints.

UNIT- IV

REPAIRS TO SPECIAL STRUCTURES AND SPECIAL REPAIRING TECHNIQUES

Repairs to Concrete Structures under water , Repairs to Bridges , Repairs to Water Tanks , Repairs to Tunnels , Repairs to Dams – At least one case study for each of these structures

UNIT- V

SEISMIC RETROFITTING OF STRUCTURES

Retrofit of Reinforced Concrete Buildings - Retrofit of Steel Buildings - Retrofit of Foundations - Base Isolation and Energy Dissipation - Retrofit Case Studies

TEXT BOOKS:

1. Den Campbell, Allen and Harold Roper, “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. Philip H. Perkins”Repair , Protection and Waterproofing of Concrete Structures”,Elsevier Applied Science Publisher, London,Newyark, 1986
4. P.C. Guha “ Maintenance and Repairs of Buildings “ , New Central Book Agency , Kolkata 2006.

REFERENCES:

1. 1. H.W.Kwon " Maintenance and Repair of Concrete under water" , 11th International Conference Proceedings ,Conclinic Co. Ltd., 2013
2. 2..CPWD " Handbook on Repair and Rehabilitation of RC buildings " , Director General of CPWD , New Delhi,2002
3. IITM & CPWD " Hand book on Seismic Retrofit of buildings " , Narosa Publishing House
4. American Wood Council " National Design Specification " , 2005

Department of Civil Engineering
Timetable

IV B.Tech. II Semester – R&RS

Day/Hour	9.30-10.20	10.20-11.10	11.20-12.10	12.10-01.00	01.40-2.25	2.25-3.10	3.15-04.00
Monday		R&RS					
Tuesday		R&RS					
Wednesday	R&RS						
Thursday			R&RS				
Friday	R&RS						
Saturday							

Department of Civil Engineering

Vision of the Institute
To be a premier Institute in the country and region for the study of Engineering, Technology and Management by maintaining high academic standards which promotes the analytical thinking and independent judgment among the prime stakeholders, enabling them to function responsibly in the globalized society.

Mission of the Institute
To be a world-class Institute, achieving excellence in teaching, research and consultancy in cutting-edge Technologies and be in the service of society in promoting continued education in Engineering, Technology and Management.

Quality Policy
To ensure high standards in imparting professional education by providing world-class infrastructure, top-quality-faculty and decent work culture to sculpt the students into Socially Responsible Professionals through creative team-work, innovation and research.

Vision of the Department
To impart knowledge, skill and excellence in civil engineering with a global perspective to enable the students as competent, qualitative & ethically strong engineers with an intuition to improve quality of life for the benefit of the society.

Mission of the Department

- To train the students in the civil engineering domain.
- To develop knowledge and skill to solve regional and global problems.
- To transform into qualitative and ethically strong professional engineers through research and
- Development.

Program Educational Objectives (B.Tech. – CE)

Graduates will be able to

PEO1: To provide knowledge in mathematics, science, and engineering principles for a successful Career in sectors of civil engineering and allied industry and/or higher education.

PEO2: To develop an ability to identify, formulate, solve problems along with adequate analysis, Design, synthesizing and interpretation skills in civil engineering systems.

PEO3: To exhibit professionalism, ethics, communication skills and team work in their profession and engaged in lifelong learning of contemporary civil engineering trends.

Department of Civil Engineering

Program Outcomes (B.Tech. – CE)

At the end of the Program, a graduate will have the ability to

PO 1: An ability to apply knowledge of mathematics, science, and engineering
PO 2: An ability to design and conduct experiments, as well as to analyze and interpret data
PO 3: An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability
PO 4: An ability to function on multidisciplinary teams
PO 5: An ability to identify, formulates, and solves engineering problems
PO 6: An understanding of professional and ethical responsibility
PO 7: An ability to communicate effectively
PO 8: The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
PO 9: A recognition of the need for, and an ability to engage in lifelong learning
PO 10: Knowledge of contemporary issues.
PO 11: An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice
PO 12: An ability to carry out research in different areas of Civil Engineering including latest technology like GIS/Remote Sensing resulting in design, development, analyze and journal publications and technology development.

Department of Civil Engineering

COURSE OBJECTIVES

On completion of this Subject/Course the student shall be able to:

S.No	Objectives
1	The importance of maintenance and to assess the condition of the structure.
2	The repair strategies required for Masonry and Concrete structures.
3	The repair strategies required for Timber and Steel structures.
4	The advanced technologies available in repairing of structures.
5	The seismic retrofitting of structures.

COURSE OUTCOMES

The expected outcomes of the Course/Subject are:

S.No	Outcomes
1.	Understand the behavior of existing structures
2.	Understand the main causes for structural failure and will be able to give the guidelines to their repairs and retrofitting of masonry and concrete structures.
3.	Understand the main causes for structural failure and will be able to give the guidelines to their repairs and retrofitting of steel structures.
4.	Understand the repairing of complicated and special structures using the new technologies available.
5.	Give the guidelines and retrofitting procedures required for seismic prone structures.

Signature of faculty

Note: Please refer to Bloom’s Taxonomy, to know the illustrative verbs that can be used to state the outcomes.

Department of Civil Engineering

GUIDELINES TO STUDY THE COURSE / SUBJECT

Course Design and Delivery System (CDD):

- The Course syllabus is written into number of learning objectives and outcomes.
- Every student will be given an assessment plan, criteria for assessment, scheme of evaluation and grading method.
- The Learning Process will be carried out through assessments of Knowledge, Skills and Attitude by various methods and the students will be given guidance to refer to the text books, reference books, journals, etc.

The faculty be able to –

- Understand the principles of Learning
- Understand the psychology of students
- Develop instructional objectives for a given topic
- Prepare course, unit and lesson plans
- Understand different methods of teaching and learning
- Use appropriate teaching and learning aids
- Plan and deliver lectures effectively
- Provide feedback to students using various methods of Assessments and tools of Evaluation
- Act as a guide, advisor, counselor, facilitator, motivator and not just as a teacher alone

Signature of HOD　　　　　　　　　　Signature of faculty

Date:　　　　　　　　　　Date:

Department of Civil Engineering

COURSE SCHEDULE

The Schedule for the whole Course / Subject is:

S. No.	Description	Duration (Date)		Total No. of Periods
		From	To	
1.	**UNIT - I** **MAINTENANCE AND REPAIR STRATEGIES** Maintenance, Facets of Maintenance, importance of Maintenance, various aspects of Inspection, Condition Assessment of a structure, Various methods of Condition assessment , NDT and NDE ,Repair Strategies , Repairs-Rehabilitation-Retrofitting-Strengthening-Upgradation of a Structure, Selection of Materials and Techniques for Repair	15.11.2023	05.12.2023	14
2.	**UNIT - II** **REPAIRS TO MASONRY AND CONCRETE STRUCTURES** Methods of crack repair in masonry and concrete structures, routing and sealing of cracks, removal and surface preparation in masonry and concrete structures, reinforcement repair, anchorage, placement methods; Shot-creting and guniting, Grouting- Portland cement grouting, chemical grouting, Dry packing, polymer impregnation, Strengthening of structures flexural strengthening, Shear Strengthening, strengthening of columns- jacketing of Columns, strengthening by interior and external reinforcing, External Pre-stressing, Fiber wrapping, Corrosion Protection: surface treatment, joint sealants, cathodic protection	06.12.2023	30.12.2023	17
3.	**UNIT - III** **REPAIRS TO TIMBER AND STEEL STRUCTURES** Testing of Timber Structures for rots, Creosote retention, Planning for repairs in Timber Structures-Repairs to Timber Structures, Dynamic Loading and Fatigue, welding technology, weldability, Cleaning and surface Preparation of Corroded Structural Steel, replacement and addition of new members, different Types of Steel and Composite Joints.	02.01.2024	19.01.2024	9

4.	**UNIT - IV** **REPAIRS TO SPECIAL STRUCTURES AND SPECIAL REPAIRING TECHNIQUES** Repairs to Concrete Structures under water , Repairs to Bridges , Repairs to Water Tanks , Repairs to Tunnels , Repairs to Dams – At least one case study for each of these structures	24.01.2024	13.02.2024	16
5.	**UNIT – V** **SEISMIC RETROFITTING OF STRUCTURES** Retrofit of Reinforced Concrete Buildings - Retrofit of Steel Buildings - Retrofit of Foundations - Base Isolation and Energy Dissipation - Retrofit Case Studies	14.02.2024	03.04.2024	14

Total No. of Instructional periods available for the course: 70 Hours

Department of Civil Engineering

SCHEDULE OF INSTRUCTIONS - COURSE PLAN

Unit No.	Lesson No.	Date	No. of Periods	Topics / Sub-Topics	Objectives & Outcomes Nos.	References (Textbook, Journal)
1.	1	15-11-2023 16-11-2023 17-11-2023	3	**Maintenance** Introduction to Maintenance Facets of Maintenance Importance of Maintenance	1 1	Maintenance and Repairs of Buildings by P.C. Guha
	2	20-11-2023	1	**Inspection** Various Aspects of Inspection	1 1	Maintenance and Repairs of Buildings by P.C. Guha
	3	21-11-2023 22-11-2023	2	**Condition Assessment** Condition Assessment of a Structure Various Methods of Condition Assessment	1 1	Maintenance and Repairs of Buildings by P.C. Guha
	4	23-11-2023 24-11-2023	2	**NDT and NDE** Introduction to Non-Destructive Testing (NDT) and Non-Destructive Evaluation (NDE) Techniques and Tools for NDT and NDE	1 1	Maintenance and Repairs of Buildings by P.C. Guha
	5	28-11-2023 29-11-2023 30-11-2023 01-12-2023 04-12-2023	5	**Repair Strategies** Introduction to Repair Strategies Repairs, Rehabilitation, Retrofitting, Strengthening, Upgradation Selection of Materials for Repair Techniques for Repair Case Studies of Repair Strategies	1 1	Maintenance and Repairs of Buildings by P.C. Guha
	6	05-12-2023	1	**Review and Wrap-Up** Review of Key Concepts Q&A Session Discussion on Real-World Applications	1 1	Maintenance and Repairs of Buildings by P.C. Guha
2.	1	06-12-2023 07-12-2023	2	**Introduction to Masonry and Concrete Structures** Overview of common issues and repair needs Importance of crack repair	2 2	Maintenance and Repairs of Buildings by P.C. Guha

				and reinforcement		
	2	08-12-2023 11-12-2023	2	**Crack Repair Methods** Routing and sealing of cracks Removal and surface preparation	2 2	Maintenance and Repairs of Buildings by P.C. Guha
	3	12-12-2023 13-12-2024	2	**Reinforcement Repair and Anchorage** Methods for reinforcement repair Techniques for anchorage and placement	2 2	Maintenance and Repairs of Buildings by P.C. Guha
	4	14-12-2024 15-12-2024	2	**Shot-Creating and Guniting** Principles and applications of shot-creting Techniques and advantages of guniting	2 2	Maintenance and Repairs of Buildings by P.C. Guha
	5	18-12-2024 19-12-2024	2	**Grouting Techniques** Portland cement grouting Chemical grouting Dry packing and polymer impregnation	2 2	Maintenance and Repairs of Buildings by P.C. Guha
	6	20-12-2024 21-12-2024	2	**Strengthening of Structures** Flexural strengthening methods Shear strengthening techniques	2 2	Maintenance and Repairs of Buildings by P.C. Guha
	7	22-12-2024 27-12-2024	2	**Strengthening of Columns** Jacketing of columns Interior and exterior reinforcing External pre-stressing and fiber wrapping	2 2	Maintenance and Repairs of Buildings by P.C. Guha
	8	28-12-2024 29-12-2024	2	**Corrosion Protection** Surface treatment methods Joint sealants Introduction to cathodic	2 2	Maintenance and Repairs of Buildings by P.C. Guha

				protection		
	9	30-12-2024	1	**Review and Wrap-Up** Review of Key Concepts Q&A Session Discussion on Real-World Applications	2 2	Maintenance and Repairs of Buildings by P.C. Guha
3.	1	02-01-2024	1	**Testing of Timber Structures** Methods for testing timber for rot and decay Assessment of creosote retention effectiveness	3 3	Maintenance and Repairs of Buildings by P.C. Guha
	2	03-01-2024	1	**Planning for Repairs in Timber Structures** Assessment and inspection techniques Strategic planning based on assessment findings	3 3	Maintenance and Repairs of Buildings by P.C. Guha
	3	04-01-2024	1	**Repairs to Timber Structures** Techniques for reinforcing and replacing timber components Application of preservation treatments	3 3	Maintenance and Repairs of Buildings by P.C. Guha
	4	05-01-2024	1	**Dynamic Loading and Fatigue in Steel Structures** Effects of dynamic loading on steel structures Fatigue failure mechanisms and prevention	3 3	Maintenance and Repairs of Buildings by P.C. Guha
	5	08-01-2024	1	**Welding Technology for Steel Structures** Overview of welding techniques used in steel repairs Factors influencing weldability of different steel types	3 3	Maintenance and Repairs of Buildings by P.C. Guha
	6	09-01-2024	1	**Cleaning and Surface**	3 3	Maintenance and Repairs of Buildings

				Preparation of Corroded Structural Steel Methods for cleaning corroded steel surfaces Importance of surface preparation before repair		by P.C. Guha
	7	17-01-2024	1	**Replacement and Addition of New Members** Procedures for replacing and adding new steel members Integration of new members into existing structures	3 3	Maintenance and Repairs of Buildings by P.C. Guha
	8	18-01-2024	1	**Different Types of Steel and Composite Joints** Overview of various types of steel used in construction Techniques and considerations for composite joints	3 3	Maintenance and Repairs of Buildings by P.C. Guha
	9	19-01-2024	1	**Review and Application** Recap of key concepts and techniques covered Practical exercises or case studies to apply knowledge	3 3	Maintenance and Repairs of Buildings by P.C. Guha
4	1	24-01-2024	1	**Introduction to Underwater Concrete Structures** Challenges and considerations in underwater repairs	4 4	Maintenance and Repairs of Buildings by P.C. Guha
	2	25-01-2024 29-01-2024	2	**Assessment and Inspection Techniques** Techniques for assessing underwater concrete conditions Methods for underwater inspection and assessment	4 4	Maintenance and Repairs of Buildings by P.C. Guha
	3	30-01-2024	1	**Repair Methods**	4	Maintenance and

				Materials and techniques used for repairs underwater	4	Repairs of Buildings by P.C. Guha
	4	31-01-2024	1	**Repairs to Bridges** Common issues requiring bridge repairs	4 4	Maintenance and Repairs of Buildings by P.C. Guha
	5	01-02-2024 02-02-2024	2	**Bridge Inspection and Assessment** Techniques for bridge inspection Methods for assessing bridge condition and safety	4 4	Maintenance and Repairs of Buildings by P.C. Guha
	6	05-02-2024	1	**Bridge Repair Methods** Approaches to repairing bridge components	4 4	Maintenance and Repairs of Buildings by P.C. Guha
	7	06-02-2024	1	**Repairs to Water Tanks** Types of water tanks and their structural challenges	4 4	Maintenance and Repairs of Buildings by P.C. Guha
	8	07-02-2024	1	**Structural Assessment and Evaluation** Techniques for assessing water tank integrity	4 4	Maintenance and Repairs of Buildings by P.C. Guha
	9	08-02-2024	1	**Repairs to Tunnels** Challenges and considerations in tunnel repairs	4 4	Maintenance and Repairs of Buildings by P.C. Guha
	10	09-02-2024 12-02-2024	2	**Tunnel Inspection and Assessment** Techniques for tunnel inspection Methods for inspecting tunnel conditions	4 4	Maintenance and Repairs of Buildings by P.C. Guha
	11	13-02-2024	1	**Tunnel Repair Methods** Approaches to repairing tunnel linings and structures	4 4	Maintenance and Repairs of Buildings by P.C. Guha
5	1	14-02-2024	1	**Introduction to Seismic Retrofitting** Introduction to seismic retrofitting and its importance in structural safety Overview of seismic forces	5 5	Maintenance and Repairs of Buildings by P.C. Guha

				and their impact on structures Objectives and benefits of seismic retrofitting		
	2	15-02-2024 16-02-2024 19-02-2024	3	**Retrofit of Reinforced Concrete Buildings** Techniques for assessing RC buildings for retrofitting needs Common vulnerabilities in RC buildings Methods for retrofitting RC buildings Strengthening techniques for beams, columns, and slabs Case study of a retrofitted RC building Analysis of techniques used and results achieved	5 5	Maintenance and Repairs of Buildings by P.C. Guha
	3	20-02-2024 21-02-2024 22-03-2024	3	**Retrofit of Steel Buildings** Techniques for assessing steel buildings for retrofitting needs Common vulnerabilities in steel buildings Methods for retrofitting steel buildings Strengthening techniques for steel frames and connections Case study of a retrofitted steel building Analysis of techniques used and results achieved	5 5	Maintenance and Repairs of Buildings by P.C. Guha
	4	23-03-2024 26-03-2024 27-03-2024	3	**Retrofit of Foundations** Techniques for assessing foundation vulnerabilities Common issues in foundations under seismic loads Methods for retrofitting foundations Strengthening techniques for shallow and deep foundations Case study of a retrofitted	5 5	Maintenance and Repairs of Buildings by P.C. Guha

				foundation Analysis of techniques used and results achieved		
	5	28-03-2024 01-04-2024	2	**Base Isolation and Energy Dissipation** Introduction to base isolation and its benefits Types of base isolators and their applications Introduction to energy dissipation devices and their benefits Types of energy dissipators and their applications	5 5	Maintenance and Repairs of Buildings by P.C. Guha
	6	02-04-2024 03-04-2024	2	**Retrofit Case Studies** Detailed case study of a major retrofitting project Overview of project scope and objectives Techniques and methods used in the retrofitting project - Analysis of outcomes and lessons learned	5 5	Maintenance and Repairs of Buildings by P.C. Guha
	7	04-04-2024	1	Revision of units I & II	1, 2 1, 2	Maintenance and Repairs of Buildings by P.C. Guha
	8	05-04-2024	1	Revision of units III & IV	3, 4 3, 4	Maintenance and Repairs of Buildings by P.C. Guha

Signature of HOD
Date:

Signature of faculty
Date:

Note:
1. Ensure that all topics specified in the course are mentioned.
2. Additional topics covered, if any, may also be specified in bold.
3. Mention the corresponding course objective and outcome numbers against each topic.

Department of Civil Engineering

SCHEDULE OF INSTRUCTIONS – UNIT-I PLAN

Unit No.	Lesson No.	Date	No. of Periods	Topics / Sub-Topics	Objectives & Outcomes Nos.	References (Textbook, Journal)
1.	1	15-11-2023 16-11-2023 17-11-2023	3	**Maintenance** Introduction to Maintenance Facets of Maintenance Importance of Maintenance	1 1	Maintenance and Repairs of Buildings by P.C. Guha
	2	20-11-2023	1	**Inspection** Various aspects of inspection	1 1	Maintenance and Repairs of Buildings by P.C. Guha
	3	21-11-2023 22-11-2023	2	**Condition Assessment** Condition Assessment of a Structure Various Methods of Condition Assessment	1 1	Maintenance and Repairs of Buildings by P.C. Guha
	4	23-11-2023 24-11-2023	2	**NDT and NDE** Introduction to Non-Destructive Testing (NDT) and Non-Destructive Evaluation (NDE) Techniques and Tools for NDT and NDE	1 1	Maintenance and Repairs of Buildings by P.C. Guha
	5	28-11-2023 29-11-2023 30-11-2023 01-12-2023 04-12-2023	5	**Repair Strategies** Introduction to Repair Strategies Repairs, Rehabilitation, Retrofitting, Strengthening, Selection of Materials for Repair Techniques for Repair Case Studies of Repair Strategies	1 1	Maintenance and Repairs of Buildings by P.C. Guha
	6	05-12-2023	1	**Review and Wrap-Up** Review of Key Concepts Q&A Session Discussion on Real-World Applications	1 1	Maintenance and Repairs of Buildings by P.C. Guha

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Department of Civil Engineering

SCHEDULE OF INSTRUCTIONS – UNIT-II PLAN

2.	1	06-12-2023 07-12-2023	2	**Introduction to Masonry and Concrete Structures** Overview of common issues and repair needs Importance of crack repair and reinforcement	2 2	Maintenance and Repairs of Buildings by P.C. Guha
	2	08-12-2023 11-12-2023	2	**Crack Repair Methods** Routing and sealing of cracks Removal and surface preparation	2 2	Maintenance and Repairs of Buildings by P.C. Guha
	3	12-12-2023 13-12-2024	2	**Reinforcement Repair and Anchorage** Methods for reinforcement repair Techniques for anchorage and placement	2 2	Maintenance and Repairs of Buildings by P.C. Guha
	4	14-12-2024 15-12-2024	2	**Shot-Creating and Guniting** Principles and applications of shot-creting Techniques and advantages of guniting	2 2	Maintenance and Repairs of Buildings by P.C. Guha
	5	18-12-2024 19-12-2024	2	**Grouting Techniques** Portland cement grouting Chemical grouting Dry packing and polymer impregnation	2 2	Maintenance and Repairs of Buildings by P.C. Guha
	6	20-12-2024 21-12-2024	2	**Strengthening of Structures** Flexural strengthening methods Shear strengthening techniques	2 2	Maintenance and Repairs of Buildings by P.C. Guha
	7	22-12-2024 27-12-2024	2	**Strengthening of Columns** Jacketing of columns Interior and exterior	2 2	Maintenance and Repairs of Buildings by P.C. Guha

				reinforcing External pre-stressing and fiber wrapping		
	8	28-12-2024 29-12-2024	2	**Corrosion Protection** Surface treatment methods Joint sealants Introduction to cathodic protection	2 2	Maintenance and Repairs of Buildings by P.C. Guha
	9	30-12-2024	1	**Review and Wrap-Up** Review of Key Concepts Q&A Session Discussion on Real-World Applications	2 2	Maintenance and Repairs of Buildings by P.C. Guha

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Department of Civil Engineering

SCHEDULE OF INSTRUCTIONS – UNIT-III PLAN

3.	1	02-01-2024	1	**Testing of Timber Structures** Methods for testing timber for rot and decay Assessment of creosote retention effectiveness	3 3	Maintenance and Repairs of Buildings by P.C. Guha
	2	03-01-2024	1	**Planning for Repairs in Timber Structures** Assessment and inspection techniques Strategic planning based on assessment findings	3 3	Maintenance and Repairs of Buildings by P.C. Guha
	3	04-01-2024	1	**Repairs to Timber Structures** Techniques for reinforcing and replacing timber components Application of preservation treatments	3 3	Maintenance and Repairs of Buildings by P.C. Guha
	4	05-01-2024	1	**Dynamic Loading and Fatigue in Steel Structures** Effects of dynamic loading on steel structures Fatigue failure mechanisms and prevention	3 3	Maintenance and Repairs of Buildings by P.C. Guha
	5	08-01-2024	1	**Welding Technology for Steel Structures** Overview of welding techniques used in steel repairs Factors influencing weldability of different steel types	3 3	Maintenance and Repairs of Buildings by P.C. Guha
	6	09-01-2024	1	**Cleaning and Surface Preparation of Corroded Structural Steel** Methods for cleaning	3 3	Maintenance and Repairs of Buildings by P.C. Guha

				corroded steel surfaces Importance of surface preparation before repair		
	7	17-01-2024	1	**Replacement and Addition of New Members** Procedures for replacing and adding new steel members Integration of new members into existing structures	3 3	Maintenance and Repairs of Buildings by P.C. Guha
	8	18-01-2024	1	**Different Types of Steel and Composite Joints** Overview of various types of steel used in construction Techniques and considerations for composite joints	3 3	Maintenance and Repairs of Buildings by P.C. Guha
	9	19-01-2024	1	**Review and Application** Recap of key concepts and techniques covered Practical exercises or case studies to apply knowledge	3 3	Maintenance and Repairs of Buildings by P.C. Guha

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Department of Civil Engineering

SCHEDULE OF INSTRUCTIONS – UNIT-IV PLAN

4	1	24-01-2024	1	**Introduction to Underwater Concrete Structures** Challenges and considerations in underwater repairs	4 4	Maintenance and Repairs of Buildings by P.C. Guha
	2	25-01-2024 29-01-2024	2	**Assessment and Inspection Techniques** Techniques for assessing underwater concrete conditions Methods for underwater inspection and assessment	4 4	Maintenance and Repairs of Buildings by P.C. Guha
	3	30-01-2024	1	**Repair Methods** Materials and techniques used for repairs underwater	4 4	Maintenance and Repairs of Buildings by P.C. Guha
	4	31-01-2024	1	**Repairs to Bridges** Common issues requiring bridge repairs	4 4	Maintenance and Repairs of Buildings by P.C. Guha
	5	01-02-2024 02-02-2024	2	**Bridge Inspection and Assessment** Techniques for bridge inspection Methods for assessing bridge condition and safety	4 4	Maintenance and Repairs of Buildings by P.C. Guha
	6	05-02-2024	1	**Bridge Repair Methods** Approaches to repairing bridge components	4 4	Maintenance and Repairs of Buildings by P.C. Guha
	7	06-02-2024	1	**Repairs to Water Tanks** Types of water tanks and their structural challenges	4 4	Maintenance and Repairs of Buildings by P.C. Guha
	8	07-02-2024	1	**Structural Assessment and Evaluation** Techniques for assessing water tank integrity	4 4	Maintenance and Repairs of Buildings by P.C. Guha
	9	08-02-2024	1	**Repairs to Tunnels** Challenges and considerations in tunnel repairs	4 4	Maintenance and Repairs of Buildings by P.C. Guha
	10	09-02-2024	2	**Tunnel Inspection and**	4	Maintenance and

		12-02-2024		**Assessment** Techniques for tunnel inspection Methods for inspecting tunnel conditions	4	Repairs of Buildings by P.C. Guha
	11	13-02-2024	1	**Tunnel Repair Methods** Approaches to repairing tunnel linings and structures	4 4	Maintenance and Repairs of Buildings by P.C. Guha

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2. Additional topics covered, if any, may also be specified in bold.
3. Mention the corresponding course objective and outcome numbers against each topic.

Department of Civil Engineering

SCHEDULE OF INSTRUCTIONS – UNIT-IV PLAN

5	1	14-02-2024	1	**Introduction to Seismic Retrofitting** Introduction to seismic retrofitting and its importance in structural safety Overview of seismic forces and their impact on structures Objectives and benefits of seismic retrofitting	5 5	Maintenance and Repairs of Buildings by P.C. Guha
	2	15-02-2024 16-02-2024 19-02-2024	3	**Retrofit of Reinforced Concrete Buildings** Techniques for assessing RC buildings for retrofitting needs Common vulnerabilities in RC buildings Methods for retrofitting RC buildings Strengthening techniques for beams, columns, and slabs Case study of a retrofitted RC building Analysis of techniques used and results achieved	5 5	Maintenance and Repairs of Buildings by P.C. Guha
	3	20-02-2024 21-02-2024 22-03-2024	3	**Retrofit of Steel Buildings** Techniques for assessing steel buildings for retrofitting needs Common vulnerabilities in steel buildings Methods for retrofitting steel buildings Strengthening techniques for steel frames and connections Case study of a retrofitted steel building Analysis of techniques used and results achieved	5 5	Maintenance and Repairs of Buildings by P.C. Guha
	4	23-03-2024 26-03-2024	3	**Retrofit of Foundations**	5 5	Maintenance and

Department of Civil Engineering

		27-03-2024		Techniques for assessing foundation vulnerabilities Common issues in foundations under seismic loads Methods for retrofitting foundations Strengthening techniques for shallow and deep foundations Case study of a retrofitted foundation Analysis of techniques used and results achieved		Repairs of Buildings by P.C. Guha
	5	28-03-2024 01-04-2024	2	**Base Isolation and Energy Dissipation** Introduction to base isolation and its benefits Types of base isolators and their applications Introduction to energy dissipation devices and their benefits Types of energy dissipators and their applications	5 5	Maintenance and Repairs of Buildings by P.C. Guha
	6	02-04-2024 03-04-2024	2	**Retrofit Case Studies** Detailed case study of a major retrofitting project Overview of project scope and objectives Techniques and methods used in the retrofitting project - Analysis of outcomes and lessons learned	5 5	Maintenance and Repairs of Buildings by P.C. Guha

Signature of HOD
Date:

Signature of faculty
Date:

Note:

1. Ensure that all topics specified in the course are mentioned.
2. Additional topics covered, if any, may also be specified in bold.
3. Mention the corresponding course objective and outcome numbers against each topic.

Department of Civil Engineering

LESSON PLAN (U-I)

Lesson No: 01 Duration of Lesson: 2hrs30 min

Lesson Title: Maintenance

Instructional / Lesson Objectives:

- Understand the definition and scope of maintenance.
- Identify the different types of maintenance: preventive, predictive, corrective, and scheduled.
- Discuss the benefits of maintenance, including safety, longevity, cost savings, and reliability.
- Explain the role of maintenance in infrastructure management.
- Recognize the impact of maintenance on the overall lifecycle of a structure.

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

15 mins for taking attendance 120 min for the lecture delivery 15 min for doubts session

Assignment / Questions:
(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment – I & tutorial-I sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-I)

Lesson No: 02 Duration of Lesson: 50 min

Lesson Title: Inspection

Instructional / Lesson Objectives:

- Understand the various aspects of inspection, including visual and instrumental methods.
- Differentiate between types of inspections: visual inspection, instrumental inspection, and safety inspection.
- Explain the purpose and importance of regular inspections.
- Discuss the role of inspections in identifying maintenance needs.
- Learn the tools and techniques used in different types of inspections.

Teaching AIDS : PPTs, Digital Board

Time Management of Class :

5 mins for taking attendance
40 min for the lecture delivery
5 min for doubts session

Assignment / Questions:

(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment – I & tutorial-I sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-I)

Lesson No: 03 Duration of Lesson: 1hr 40 min

Lesson Title: Condition Assessment

Instructional / Lesson Objectives:

- Define condition assessment and its importance in structural integrity.
- Identify visual signs of structural issues and potential failure points.
- Explain methods of structural analysis and their applications.
- Discuss environmental factors affecting structures and their impact on condition.
- Review different methods of condition assessment and their advantages and limitations.
- Understand the role of condition assessment in maintenance planning.

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

10 mins for taking attendance
80 min for the lecture delivery
10 min for doubts session

Assignment / Questions:
(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment – I & tutorial-I sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-I)

Lesson No: 04 Duration of Lesson: 1hr 40 min

Lesson Title: NDT and NDE

Instructional / Lesson Objectives:

- Understand the principles and significance of Non-Destructive Testing (NDT) and Non-Destructive Evaluation (NDE).
- Describe various NDT and NDE techniques and their applications.
- Identify the tools and equipment used in NDT and NDE.
- Discuss the benefits of using NDT and NDE in maintenance and repair.
- Review the limitations and challenges associated with NDT and NDE.
- Analyze case studies demonstrating the use of NDT and NDE in real-world scenarios.

Teaching AIDS : PPTs, Digital Board

Time Management of Class :

10 mins for taking attendance 80 min for the lecture delivery 10min for doubts session

Assignment / Questions:

(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment – I & tutorial-I sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-I)

Lesson No: 5 Duration of Lesson: 4hr 10 min

Lesson Title: Repair Strategies

<u>Instructional / Lesson Objectives:</u>

Repair Strategies

- Define repair strategies and their importance in maintaining structural integrity.
- Differentiate between repairs, rehabilitation, retrofitting, strengthening, and upgradation.
- Identify factors influencing the choice of repair strategies.
- Discuss the criteria for selecting repair materials and techniques.
- Review common repair techniques and their applications.
- Analyze case studies of successful repair strategies and their outcomes.

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

25 mins for taking attendance
200 min for the lecture delivery
25min for doubts session

Assignment / Questions:
(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment – I & tutorial-I sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-II)

Lesson No: 01 Duration of Lesson: 1hr40 min

Lesson Title: Introduction to Masonry and Concrete Structures

Instructional / Lesson Objectives:

- Understand the basic components and construction techniques of masonry and concrete structures.
- Identify common structural issues such as cracks, spalling, and degradation.
- Recognize the importance of timely maintenance and repair in ensuring structural integrity.
- Appreciate the role of crack repair and reinforcement in extending the lifespan of masonry and concrete structures.

Teaching AIDS : PPTs, Digital Board

Time Management of Class :

10 mins for taking attendance 10 min for revision of previous class 65 min for lecture delivery 15 min for doubts session

Assignment / Questions:

(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment – II & tutorial-II sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-II)

Lesson No: 02 Duration of Lesson: 1hr40 min

Lesson Title: Crack Repair Methods

Instructional / Lesson Objectives:

- Explain the process of routing cracks to prepare them for repair.
- Demonstrate effective techniques for sealing cracks to prevent moisture ingress and further deterioration.
- Discuss the importance of thorough surface preparation before applying repair materials.
- Evaluate different materials and methods used in crack repair based on effectiveness and durability.

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

10 mins for taking attendance
10 min for revision of previous class
65 min for lecture delivery
15 min for doubts session

Assignment / Questions:
(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment – II & tutorial-II sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-II)

Lesson No: 03 Duration of Lesson: 1hr40 min

Lesson Title: Reinforcement Repair and Anchorage

Instructional / Lesson Objectives:

- Identify common types of reinforcement used in masonry and concrete structures.
- Describe methods for repairing damaged reinforcement bars and mesh.
- Explain techniques for securely anchoring reinforcement in existing concrete or masonry.
- Evaluate placement methods to ensure proper alignment and integration with existing structures.

Teaching AIDS : PPTs, Digital Board

Time Management of Class :

10 mins for taking attendance 10 min for revision of previous class 65 min for lecture delivery 15 min for doubts session

Assignment / Questions:

(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment – II & tutorial-II sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-II)

Lesson No: 04 Duration of Lesson: 1hr40 min

Lesson Title: Shot-Creating and Guniting
Instructional / Lesson Objectives:

- Understand the principles behind shot-creating and its application in repairing concrete structures.
- Compare and contrast shot-creating with traditional casting methods in terms of efficiency and cost-effectiveness.
- Analyze the advantages of guniting in repairing surfaces with complex geometries or hard-to-reach areas.
- Demonstrate the proper techniques for applying shotcrete and guniting materials to achieve desired structural repairs.

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

10 mins for taking attendance 10 min for revision of previous class 65 min for lecture delivery 15 min for doubts session

Assignment / Questions:
(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment – II & tutorial-II sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-II)

Lesson No: 05 Duration of Lesson: 1hr40 min

Lesson Title: Grouting Techniques
Instructional / Lesson Objectives:

- Explain the purpose and benefits of Portland cement grouting in structural repair.
- Discuss the chemical properties and applications of various grouting materials.
- Demonstrate the proper techniques for dry packing to fill voids and cracks in masonry structures.
- Evaluate the effectiveness of polymer impregnation in enhancing the durability and waterproofing of concrete surfaces.

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

10 mins for taking attendance 10 min for revision of previous class 65 min for lecture delivery 15 min for doubts session

Assignment / Questions:
(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment – II & tutorial-II sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-II)

Lesson No: 06 Duration of Lesson: 1hr40 min

Lesson Title: Strengthening of Structures
Instructional / Lesson Objectives:

- Identify structural deficiencies that can be addressed through flexural strengthening methods.
- Explain the principles behind shear strengthening techniques and their application in improving structural stability.
- Compare different materials and techniques used for strengthening existing structures against dynamic loads.
- Analyze case studies to understand the practical application and long-term benefits of structural strengthening techniques.

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

10 mins for taking attendance
10 min for revision of previous class
65 min for lecture delivery
15 min for doubts session

Assignment / Questions:
(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment – II & tutorial-II sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-II)

Lesson No: 07 Duration of Lesson: 1hr40 min

Lesson Title: Strengthening of Columns
Instructional / Lesson Objectives:

- Describe the process of jacketing columns to increase their load-carrying capacity and seismic resistance.
- Evaluate the effectiveness of interior and exterior reinforcing techniques in enhancing column strength.
- Discuss the principles and advantages of external pre-stressing for strengthening concrete columns.
- Demonstrate the application of fiber wrapping as a cost-effective method for strengthening columns against external forces.

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

10 mins for taking attendance
10 min for revision of previous class
65 min for lecture delivery
15 min for doubts session

Assignment / Questions:
(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment – II & tutorial-II sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-II)

Lesson No: 08 Duration of Lesson: 1hr40 min

Lesson Title: Corrosion Protection
Instructional / Lesson Objectives:

- Explain the importance of surface treatment methods in preventing corrosion of steel reinforcement.
- Discuss the selection criteria for joint sealants based on environmental conditions and structural requirements.
- Evaluate the principles and applications of cathodic protection in extending the service life of concrete structures.
- Demonstrate the proper installation and maintenance practices for corrosion protection systems in masonry and concrete.

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

10 mins for taking attendance 10 min for revision of previous class 65 min for lecture delivery 15 min for doubts session

Assignment / Questions:
(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment – II & tutorial-II sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-III)

Lesson No: 01 Duration of Lesson: 50 min

Lesson Title: Testing of Timber Structures
Instructional / Lesson Objectives:

- To make students learn about stress distribution of soils.
- To provide information to students about variation of vertical stress and horizontal stress.
- To make students understand the concept of compaction of soils.
- To provide information about various compaction equipment.

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

5 mins for taking attendance 5 min for revision of previous class 35 min for lecture delivery 5 min for doubts session

Assignment / Questions:
(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment – III & tutorial-III sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-III)

Lesson No: 02 Duration of Lesson: 50 min

Lesson Title: Planning for Repairs in Timber Structures
Instructional / Lesson Objectives:

- To make students learn about stress distribution of soils.
- To provide information to students about variation of vertical stress and horizontal stress.
- To make students understand the concept of compaction of soils.
- To provide information about various compaction equipment.

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

5 mins for taking attendance
5 min for revision of previous class
35 min for lecture delivery
5 min for doubts session

Assignment / Questions:
(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment – III & tutorial-III sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-III)

Lesson No: 03 Duration of Lesson: 50 min

Lesson Title: Repairs to Timber Structures
Instructional / Lesson Objectives:

- To make students learn about stress distribution of soils.
- To provide information to students about variation of vertical stress and horizontal stress.
- To make students understand the concept of compaction of soils.
- To provide information about various compaction equipment.

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

5 mins for taking attendance 5 min for revision of previous class 35 min for lecture delivery 5 min for doubts session

Assignment / Questions:
(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment – III & tutorial-III sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-III)

Lesson No: 4 Duration of Lesson: 50 min

Lesson Title: Dynamic Loading and Fatigue in Steel Structures.
Instructional / Lesson Objectives:

- To make students learn about stress distribution of soils.
- To provide information to students about variation of vertical stress and horizontal stress.
- To make students understand the concept of compaction of soils.
- To provide information about various compaction equipment.

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

5 mins for taking attendance 5 min for revision of previous class 35 min for lecture delivery 5 min for doubts session

Assignment / Questions:
(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment – III & tutorial-III sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-III)

Lesson No: 5 Duration of Lesson: 50 min

Lesson Title: Welding Technology for Steel Structures
Instructional / Lesson Objectives:

- To make students learn about stress distribution of soils.
- To provide information to students about variation of vertical stress and horizontal stress.
- To make students understand the concept of compaction of soils.
- To provide information about various compaction equipment.

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

5 mins for taking attendance
5 min for revision of previous class
35 min for lecture delivery
5 min for doubts session

Assignment / Questions:
(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment – III & tutorial-III sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-III)

Lesson No:6 Duration of Lesson: 50 min

Lesson Title: Cleaning and Surface Preparation of Corroded Structural Steel
Instructional / Lesson Objectives:

- To make students learn about stress distribution of soils.
- To provide information to students about variation of vertical stress and horizontal stress.
- To make students understand the concept of compaction of soils.
- To provide information about various compaction equipment.

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

5 mins for taking attendance
5 min for revision of previous class
35 min for lecture delivery
5 min for doubts session

Assignment / Questions:
(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment – III & tutorial-III sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-III)

Lesson No: 7 Duration of Lesson: 50 min

Lesson Title: Replacement and Addition of New Members
Instructional / Lesson Objectives:

- To make students learn about stress distribution of soils.
- To provide information to students about variation of vertical stress and horizontal stress.
- To make students understand the concept of compaction of soils.
- To provide information about various compaction equipment.

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

5 mins for taking attendance 5 min for revision of previous class 35 min for lecture delivery 5 min for doubts session

Assignment / Questions:
(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment – III & tutorial-III sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-III)

Lesson No: 8 Duration of Lesson: 50 min

Lesson Title: Different Types of Steel and Composite Joints
Instructional / Lesson Objectives:

- To make students learn about stress distribution of soils.
- To provide information to students about variation of vertical stress and horizontal stress.
- To make students understand the concept of compaction of soils.
- To provide information about various compaction equipment.

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

5 mins for taking attendance
5 min for revision of previous class
35 min for lecture delivery
5 min for doubts session

Assignment / Questions:
(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment – III & tutorial-III sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-III)

Lesson No: 9 Duration of Lesson: 3hrs 20 min

Lesson Title: Revision
Instructional / Lesson Objectives:

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

5 mins for taking attendance 45 min for revision

Assignment / Questions:
(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment – III & tutorial-III sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-IV)

Lesson No: 1 Duration of Lesson: 50 min

Lesson Title: Introduction to Underwater Concrete Structures
Instructional / Lesson Objectives:

- Understand the unique challenges posed by underwater environments on concrete structures.
- Recognize the common causes of deterioration in underwater concrete.
- Appreciate the importance of specialized repair techniques for underwater concrete structures.
- Identify the safety and logistical considerations in conducting underwater repairs.

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

5 mins for taking attendance 5 min for revision of previous class 35 min for lecture delivery 5 min for doubts session

Assignment / Questions:
(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment – IV & tutorial-IV sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-IV)

Lesson No: 2 Duration of Lesson: 1hrs 40 min

Lesson Title: Assessment and Inspection Techniques

Instructional / Lesson Objectives:

- Learn the various techniques for assessing the condition of underwater concrete structures.
- Develop skills in using underwater inspection tools and technologies.
- Interpret inspection data to determine the extent and nature of damage.
- Understand the protocols for conducting thorough underwater assessments.

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

5 mins for taking attendance 10 min for revision of previous class 125 min for lecture delivery 10 min for doubts session

Assignment / Questions:
(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment – IV & tutorial-IV sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-IV)

Lesson No: 3 Duration of Lesson: 50 min

Lesson Title: Repair Methods
Instructional / Lesson Objectives:

- Master the materials and techniques used in repairing underwater concrete structures.
- Evaluate the effectiveness of different repair methods for underwater applications.
- Learn the step-by-step process of executing underwater repairs.
- Understand the environmental considerations in choosing repair materials for underwater use.

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

5 mins for taking attendance
5 min for revision of previous class
35 min for lecture delivery
5 min for doubts session

Assignment / Questions:
(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment – IV & tutorial-IV sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-IV)

Lesson No: 4 Duration of Lesson: 50 min

Lesson Title: Repairs to Bridges

Instructional / Lesson Objectives:

- Identify common structural issues that necessitate repairs in bridges.
- Understand the types of bridges and their unique repair challenges.
- Appreciate the significance of timely repairs in ensuring bridge safety and longevity.
- Recognize the impact of environmental factors on bridge deterioration.

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

5 mins for taking attendance 5 min for revision of previous class 35 min for lecture delivery 5 min for doubts session

Assignment / Questions:
(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment – IV & tutorial-IV sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-IV)

Lesson No:5 Duration of Lesson: 1hrs 40 min

Lesson Title: Bridge Inspection and Assessment

Instructional / Lesson Objectives:

- Learn the techniques for conducting thorough bridge inspections.
- Develop skills in using inspection tools and interpreting assessment results.
- Understand the criteria for evaluating the structural integrity of bridges.
- Identify common signs of distress and damage in bridge components.

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

10 mins for taking attendance
10 min for revision of previous class
70 min for lecture delivery
10 min for doubts session

Assignment / Questions:
(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment – IV & tutorial-IV sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-IV)

Lesson No: 6 Duration of Lesson: 50 min

Lesson Title: Bridge Repair Methods

Instructional / Lesson Objectives:

- Master the various approaches to repairing different components of bridges.
- Evaluate the advantages and limitations of different bridge repair techniques.
- Learn the processes and materials used in bridge rehabilitation.
- Understand the importance of maintaining structural continuity and safety during repairs.

Teaching AIDS : PPTs, Digital Board

Time Management of Class :

5 mins for taking attendance
5 min for revision of previous class
35 min for lecture delivery
5 min for doubts session

Assignment / Questions:

(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment – IV & tutorial-IV sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-IV)

Lesson No: 7 Duration of Lesson: 50 min

Lesson Title: Repairs to Water Tanks

Instructional / Lesson Objectives:

- Recognize the different types of water tank structures and their uses.
- Understand the common structural challenges faced by water tanks.
- Appreciate the importance of regular maintenance and timely repairs in water tanks.
- Identify the factors contributing to the deterioration of water tanks.

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

5 mins for taking attendance
5 min for revision of previous class
35 min for lecture delivery
5 min for doubts session

Assignment / Questions:
(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment – IV & tutorial-IV sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-IV)

Lesson No: 8 Duration of Lesson: 50min

Lesson Title: Structural Assessment and Evaluation

Instructional / Lesson Objectives:

- Learn the techniques for assessing the structural integrity of water tanks.
- Develop skills in conducting thorough inspections of water tanks.
- Interpret assessment data to identify areas needing repair.
- Understand the protocols for ensuring safety during water tank inspections.

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

5 mins for taking attendance
5 min for revision of previous class
35 min for lecture delivery
5 min for doubts session

Assignment / Questions:
(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment – IV & tutorial-IV sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-IV)

Lesson No: 9 Duration of Lesson: 50 min

Lesson Title: Repairs to Tunnels

Instructional / Lesson Objectives:

- Understand the unique challenges in maintaining and repairing tunnel structures.
- Recognize the common causes of deterioration in tunnels.
- Appreciate the importance of specialized repair techniques for tunnels.
- Identify the safety and logistical considerations in conducting tunnel repairs.

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

5 mins for taking attendance 5 min for revision of previous class 35 min for lecture delivery 5 min for doubts session

Assignment / Questions:
(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment – IV & tutorial-IV sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-IV)

Lesson No: 10 Duration of Lesson: 1hr 40 min

Lesson Title: Tunnel Inspection and Assessment

Instructional / Lesson Objectives:

- Learn the techniques for conducting thorough inspections of tunnels.
- Develop skills in using inspection tools and interpreting assessment results.
- Understand the criteria for evaluating the structural integrity of tunnels.
- Identify common signs of distress and damage in tunnel components.

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

10 mins for taking attendance 10 min for revision of previous class 70 min for lecture delivery 10 min for doubts session

Assignment / Questions:
(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment – IV & tutorial-IV sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-IV)

Lesson No: 11 Duration of Lesson: 50 min

Lesson Title: Tunnel Repair Methods

Instructional / Lesson Objectives:

- Master the approaches to repairing different components of tunnels.
- Evaluate the advantages and limitations of various tunnel repair techniques.
- Learn the processes and materials used in tunnel rehabilitation.
- Understand the importance of maintaining structural continuity and safety during repairs.

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

5 mins for taking attendance
5 min for revision of previous class
35 min for lecture delivery
5 min for doubts session

Assignment / Questions:
(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment – IV & tutorial-IV sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-V)

Lesson No: 1 Duration of Lesson: 50 min

Lesson Title: Introduction to Seismic Retrofitting
Instructional / Lesson Objectives:

- Understand the necessity of seismic retrofitting for structural safety.
- Learn the basic principles of seismic forces and their effects on buildings.
- Identify the primary goals of seismic retrofitting.
- Recognize the benefits of implementing seismic retrofitting measures.

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

5 min for taking attendance
5 min for revision of previous class
30 min for lecture delivery
10 min for doubts session

Assignment / Questions:
(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment – V & tutorial-V sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-V)

Lesson No: 2 Duration of Lesson: 2hr 30 min

Lesson Title: Retrofit of Reinforced Concrete Buildings
Instructional / Lesson Objectives:

- Learn the methods for evaluating the need for retrofitting in RC buildings.
- Identify common weaknesses in RC structures.
- Learn specific techniques for strengthening beams, columns, and slabs.
- Apply knowledge to develop retrofitting strategies for RC structures.
- Analyze a real-world example of RC building retrofitting.

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

15 min for taking attendance
15 min for revision of previous class
100 min for lecture delivery
20 min for doubts session

Assignment / Questions:
(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment – V & tutorial-V sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-V)

Lesson No: 3 Duration of Lesson: 2hr 30 min

Lesson Title: Retrofit of Steel Buildings
Instructional / Lesson Objectives:

- Learn the methods for evaluating the need for retrofitting in steel buildings.
- Identify common weaknesses in steel structures.
- Learn specific techniques for strengthening steel frames and connections.
- Apply knowledge to develop retrofitting strategies for steel structures.
- Analyze a real-world example of steel building retrofitting.

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

15 min for taking attendance 15 min for revision of previous class 100 min for lecture delivery 20 min for doubts session

Assignment / Questions:
(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment –V & tutorial-V sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-V)

Lesson No: 4 Duration of Lesson: 2hr 30 min

Lesson Title: Retrofit of Foundations
Instructional / Lesson Objectives:

- Understand the common vulnerabilities of foundations under seismic loads.
- Learn methods for assessing foundation integrity.
- Identify signs of potential foundation failures during seismic events.
- Learn various retrofitting techniques for foundations.
- Analyze a real-world example of foundation retrofitting.

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

15 min for taking attendance 15 min for revision of previous class 100 min for lecture delivery 20 min for doubts session

Assignment / Questions:
(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment –V & tutorial- V sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-V)

Lesson No: 5 Duration of Lesson: 1hr 40 min

Lesson Title: Base Isolation and Energy Dissipation

Instructional / Lesson Objectives:

- Understand the concept and importance of base isolation.
- Learn about different types of base isolators and their applications.
- Evaluate the effectiveness of base isolation in seismic retrofitting.
- Apply base isolation techniques to enhance structural resilience.
- Understand the role of energy dissipation devices in seismic retrofitting.

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

10 mins for taking attendance
10 min for revision of previous class
70 min for lecture delivery
10 min for doubts session

Assignment / Questions:
(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment –V & tutorial- V sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-V)

Lesson No: 6 Duration of Lesson: 1hr 40 min

Lesson Title: Retrofit Case Studies
Instructional / Lesson Objectives:

- Gain in-depth knowledge of a significant retrofitting project.
- Understand the project scope, objectives, and challenges.
- Analyze the techniques and methods used in the retrofitting project.
- Learn from the outcomes and lessons of the project.
- Apply lessons learned from case studies to future projects.

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

10 mins for taking attendance
10 min for revision of previous class
70 min for lecture delivery
10 min for doubts session

Assignment / Questions:
(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment –V & tutorial- V sheets

Signature of faculty

Department of Civil Engineering

LESSON PLAN (U-V)

Lesson No: 7,8 Duration of Lesson: 1hr 40 min

Lesson Title: Revision
Instructional / Lesson Objectives:

- Understand the importance of maintenance and various facets involved in maintaining different types of structures.
- Learn comprehensive methods for inspecting and assessing the condition of structures, including NDT and NDE techniques.
- Gain knowledge on various repair strategies, including repairs, rehabilitation, retrofitting, strengthening, and upgrading, and how to select appropriate materials and techniques.
- Acquire skills for repairing masonry and concrete structures, including crack repair, reinforcement repair, shot-creting, grouting, and corrosion protection.
- Learn the methods for testing, assessing, and planning repairs for timber and steel structures, including dynamic loading, fatigue, welding technology, and surface preparation.
- Understand the techniques and strategies for repairing special structures such as underwater concrete structures, bridges, water tanks, tunnels, and dams, supported by case studies.

Teaching AIDS : PPTs, Digital Board
Time Management of Class :

10 mins for taking attendance 90 min for Revision

Assignment / Questions:
(Note: Mention for each question the relevant Objectives and Outcomes Nos.1,2,3,4 & 1,3..)

Refer assignment –V & tutorial- V sheets

Signature of faculty

Department of Civil Engineering

ASSIGNMENT – 1

This Assignment corresponds to Unit No. 1

Question No.	Question	Objective No.	Outcome No.
1	What is maintenance? Explain the importance of maintenance and facts of maintenance in a building	1	1
2	Explain in detail about NDT and NDE ,classification and Repair Strategies	1	1

Signature of HOD

Date:

Signature of faculty

Date:

Department of Civil Engineering

ASSIGNMENT – 2

This Assignment corresponds to Unit No. 2

Question No.	Question	Objective No.	Outcome No.
1	Write about Shot-creting and guniting, Grouting technique to repair a concrete structures	2	2
2	Describe with neat sketches how to do different methods of jacketing and strengthening to a column	2	2

Signature of HOD

Date:

Signature of faculty

Date:

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ASSIGNMENT – 3

This Assignment corresponds to Unit No. 3

Question No.	Question	Objective No.	Outcome No.
1	Illustrate the testing of timber structures for rots and creosote retention	3	3
2	Explain about cleaning technique and surface preparation of steel structures.	3	3

Signature of HOD

Date:

Signature of faculty

Date:

Department of Civil Engineering

ASSIGNMENT – 4

This Assignment corresponds to Unit No. 4

Question No.	Question	Objective No.	Outcome No.
1	Categorize the procedure of preplaced aggregate concrete pouring methods.	4	4
2	Describe a typical method used for repairing concrete structures underwater. Illustrate your answer with a brief case study.	4	4
3	Explain a typical repair technique for water tanks and provide a brief case study demonstrating this technique.	4	4

Signature of HOD

Date:

Signature of faculty

Date:

Department of Civil Engineering

ASSIGNMENT – 5

This Assignment corresponds to Unit No. 5

Question No.	Question	Objective No.	Outcome No.
1	What is base isolation in the context of retrofitting buildings, and how does it contribute to earthquake resilience?	5	5
2	Briefly describe one method used for retrofitting reinforced concrete buildings and provide an example of a case study where this method was applied.	5	5
3	Explain the seismic retrofitting technique of mass dampers methods	5	5

Signature of HOD

Date:

Signature of faculty

Date:

Department of Civil Engineering

TUTORIAL – 1

This tutorial corresponds to Unit No. 1 (Objective Nos.: 1, Outcome Nos.: 1)

Q1. Which of the following is NOT a facet of maintenance?
a) Preventive Maintenance b) Predictive Maintenance c) Decorative maintenance

Q2. What is the primary importance of maintenance in structures?
a) Increasing the lifespan of the structure b) Reducing insurance costs c) Improving the energy efficiency

Q3. Which of the following methods is commonly used for non-destructive testing (NDT) of concrete structures?
a) Ultrasonic pulse velocity test b) Core drilling c) Chemical analysis

Q4. Which strategy involves restoring a structure to its original design capacity or improving it beyond the original design?
a) Repair b) Rehabilitation c) Strengthening

Signature of HOD

Date:

Signature of faculty

Date:

Department of Civil Engineering

TUTORIAL – 2

This tutorial corresponds to Unit No. 2 (Objective Nos.: 2, Outcome Nos.: 2)

Q1. Which method involves injecting a sealant into a routed crack to prevent water and debris from entering?

a) Shot-creting
b) Routing and sealing
c) Dry packing
d) Fiber wrapping

Q2. What is the purpose of jacketing columns in concrete structures?

a) To enhance their aesthetic appearance
b) To increase their load-carrying capacity
c) To improve their thermal insulation
d) To reduce the weight of the structure

Q3. Which of the following is a method of corrosion protection for concrete structures?

a) Flexural strengthening
b) Shot-creting
c) Cathodic protection
d) Grouting

Q4. Which technique involves spraying a mixture of cement and sand onto a surface under high pressure?

a) Polymer impregnation
b) Shot-creting
c) Chemical grouting
d) External pre-stressing

Signature of HOD　　　　　　Signature of faculty

Date:　　　　　　Date:

Department of Civil Engineering

TUTORIAL SHEET – 3

This tutorial corresponds to Unit No. 3 (Objective Nos.: 3, Outcome Nos.: 3)

Q1. Which method is used to assess the condition of timber structures for the presence of rot?

a) Ultrasonic testing
b) Visual inspection
c) Magnetic particle testing
d) Dye penetrant testing

Q2. What is Creosote retention in the context of timber structures?

a) The ability of timber to resist fire
b) The absorption of a preservative to protect against rot and insects
c) The strength of timber to withstand dynamic loads
d) The aesthetic enhancement of timber

Q3. Which process is essential for preparing corroded structural steel for repairs?

a) Surface grinding
b) Sandblasting
c) Painting
d) Drilling

Q4. What is a key consideration in the weldability of steel structures?

a) The type of protective coating used
b) The chemical composition of the steel
c) The aesthetic appearance of the welds
d) The environmental conditions during welding

Signature of HOD

Date:

Signature of faculty

Date:

Department of Civil Engineering

TUTORIAL – 4

This tutorial corresponds to Unit No. 4 (Objective Nos.: 3, Outcome Nos.: 3)

Q1. What is a common method used for repairing concrete structures underwater?

a) Shot-creting
b) Dry packing
c) Underwater epoxy injection
d) Fiber wrapping

Q2. Which technique is often used for repairing bridges to address issues with expansion joints?

a) Polymer impregnation
b) Joint sealants
c) Jacketing
d) Shot-creting

Q3. Which method is typically used to repair leaks in water tanks?

a) Chemical grouting
b) Fiber wrapping
c) Surface grinding
d) Load testing

Q4. What is a common technique for repairing tunnels to ensure structural integrity and prevent water ingress?

a) Sandblasting
b) Shot-creting
c) External pre-stressing
d) Welding

Signature of HOD | Signature of faculty

Date: | Date:

Department of Civil Engineering

TUTORIAL SHEET – 5

This tutorial corresponds to Unit No. 5 (Objective Nos.: 5, Outcome Nos.: 5)

Q1. Which technique is commonly used for the seismic retrofitting of reinforced concrete buildings?

a) Chemical grouting
b) Fiber-reinforced polymer (FRP) wrapping
c) Sandblasting
d) Shot-creting

Q2. What is a key method used in the seismic retrofit of steel buildings?

a) Base isolation
b) Weld reinforcement
c) Joint sealants
d) Dry packing

Q3. Which method involves the installation of isolators between a building and its foundation to reduce seismic forces?

a) Chemical grouting
b) Base isolation
c) Fiber wrapping
d) External pre-stressing

Q4. What is an example of an energy dissipation device used in seismic retrofitting?

a) Shear walls
b) Dampers
c) Jacketing
d) Sandblasting

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Date: | Date:

Department of Civil Engineering

EVALUATION STRATEGY

Target (s)

a. Percentage of Pass : 90.7%

Assessment Method (s) (Maximum Marks for evaluation are defined in the Academic Regulations)

a. Daily Attendance
b. Assignments
c. Online Quiz (or) Seminars
d. Continuous Internal Assessment
e. Semester / End Examination

List out any new topic(s) or any innovation you would like to introduce in teaching the subjects in this semester

Case Study of any one existing application

Signature of HOD Signature of faculty

Date: Date:

Department of Civil Engineering

COURSE COMPLETION STATUS

Actual Date of Completion & Remarks if any

Units	Remarks	Objective No. Achieved	Outcome No. Achieved
Unit 1	Completed on 05-12-2023	1	1
Unit 2	Completed on 30-12-2023	2	2
Unit 3	Completed on 19-01-2024	3	3
Unit 4	Completed on 13-02-2024	4	4
Unit 5	Completed on 03-04-2024	5	5

Signature of HOD

Date:

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Date:

Department of Civil Engineering

Mappings

1. Course Objectives-Course Outcomes Relationship Matrix
(Indicate the relationships by mark "X")

Course-Outcomes / Course-Objectives	1	2	3	4	5
1	H		M		
2		H			
3			H		
4				H	
5					H

2. Course Outcomes-Program Outcomes (POs) & PSOs Relationship Matrix
(Indicate the relationships by mark "X")

P-Outcomes / C-Outcomes	a	b	c	d	e	f	g	h	i	j	k	l	PSO 1	PSO 2
1	H			H									H	
2		H	H			L		M		H			M	H
3		M			M			H	H		M			M
4	M		M			L	L						M	
5										M			H	

Department of Civil Engineering

Rubric for Evaluation

Performance Criteria	**Unsatisfactory**	**Developing**	**Satisfactory**	**Exemplary**
	1	**2**	**3**	**4**
Research & Gather Information	Does not collect any information that relates to the topic	Collects very little information some relates to the topic	Collects some basic Information most relates to the topic	Collects a great deal of Information all relates to the topic
Fulfill team role's duty	Does not perform any duties of assigned team role.	Performs very little duties.	Performs nearly all duties.	Performs all duties of assigned team role.
Share Equally	Always relies on others to do the work.	Rarely does the assigned work - often needs reminding.	Usually does the assigned work - rarely needs reminding.	Always does the assigned work without having to be reminded
Listen to other team mates	Is always talking—never allows anyone else to speak.	Usually doing most of the talking-- rarely allows others to speak.	Listens, but sometimes talks too much.	Listens and speaks a fair amount.

ANURAG Engineering College

(An Autonomous Institution)

Ananthagiri (V&M), Suryapet (Dt), Telangana – 508206.

IV B.Tech II Semester I MID Examinations, Jan 2024

Branch: CIVIL **Max. Marks: 20**

Date: 10.01.2024 AN **Subject: Repair and Rehabilitation of structures** **Time: 90 Min.**

PART-A

Answer all the questions **5 X 1M=5 Marks**

Q.NO	Question	Course Outcome	Bloom's Level
1.	What is rehabilitation?	CO1	L1
2.	Define the term preventive maintenance?	CO1	L2
3.	Define the different causes of cracks?	CO2	L1
4.	Illustrate about structural cracks?	CO2	L2
5.	What are the defect in the timber?	CO3	L1

PART-B

Answer the following **3 X 5M=15 Marks**

Q.NO	Question	Course Outcome	Bloom's Level
6.	Relate the various Facets of maintenance?	CO1	L2
	OR		
7.	Utilize ultrasonic pulse velocity test and write the working principle?	CO1	L3
8.	Explain the procedure for epoxy injection for crack filling methods?	CO2	L2
	OR		
9.	Build Reinforcement column jacketing methods?	CO2	L3
10.	Discuss in detail about various defects and cracks develop in timber structures?	CO3	L2
	OR		
11.	Express the repairing methods of timber structures?	CO3	L3

ANURAG Engineering College

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Ananthagiri (V&M), Suryapet (Dt), Telangana – 508206.

IV B.Tech II Semester II MID Examinations, April 2024

Branch: CIVIL **Max. Marks: 20**

Date: 08-04-2024 FN **Subject: REPAIR AND REHABILITATION OF STRUCTURES** **Time: 90 Min.**

PART-A

Answer all the questions **5 X 1M=5 Marks**

Q.NO	Question	Course Outcome	Bloom's Level
1.	Define the term about weldability?	CO3	L1
2.	What are the common causes of damage to bridges?	CO4	L2
3.	Illustrate about under water surface cleaning?	CO4	L1
4.	what seismic retrofitting?	CO5	L2
5.	Define the term infill wall method of seismic retrofitting?	CO5	L1

PART-B

Answer the following **3 X 5M=15 Marks**

Q.NO	Question	Course Outcome	Bloom's Level
6.	Describe in detail Environmental causes for deterioration in steel structures?	CO3	L3
	OR		
7.	Explain about cleaning technique and surface preparation of steel structures?	CO3	L4
8.	Illustrate the process of underwater repairs to piers to Bridges	CO4	L3
	OR		
9.	Categorize the procedure of Preplaced aggregate concrete pouring methods	CO4	L4
10.	Explain the seismic retrofitting technique of mass dampers methods	CO5	L3
	OR		
11.	Evaluate the seismic retrofitting technique for foundation by base isolation and energy dissipation methods	CO5	L4

First Internal Examination Marks

Programme**: BTech** Year: **IV** Course: **Theory** **A.Y: 2023-24**

Course:Repair & Rehabilitation of Structures Section: A Faculty Name: Dr. M.S.Siva Kumar

S. No	Roll No	Objective Marks (5)	Subjective Marks (15)	Total Marks (20)
1	19C11A0117	5	18	23
2	20C11A0101	4	17	21
3	20C11A0102	4	17	21
4	20C11A0103	4	13	17
5	20C11A0104	5	15	20
6	20C11A0105	4	11	15
7	20C11A0107	4	9	13
8	20C11A0108	4	17	21
9	20C11A0109	4	12	16
10	20C11A0111	4	9	13
11	20C11A0112	4	10	14
12	20C11A0113	5	12	17
13	20C11A0114	4	17	21
14	20C11A0115	AB	11	11
15	20C11A0116	5	13	18
16	20C11A0117	4	14	18
17	20C11A0118	4	14	18
18	20C11A0119	4	13	17
19	20C11A0120	4	8	12
20	20C11A0121	5	17	22
21	20C11A0122	5	17	22
22	20C11A0124	4	11	15
23	20C11A0125	4	18	22
24	20C11A0126	4	9	13
25	20C11A0127	5	18	23
26	21C15A0101	5	16	21
27	21C15A0102	4	13	17
28	21C15A0103	5	20	25
29	21C15A0104	4	18	22
30	21C15A0105	4	18	22
31	21C15A0106	4	18	22
32	21C15A0107	5	19	24
33	21C15A0108	5	17	22
34	21C15A0109	5	18	23
35	21C15A0110	4	18	22
36	21C15A0111	4	15	19
37	21C15A0112	4	11	15

38	21C15A0113	4	15	19
39	21C15A0114	4	12	16
40	21C15A0115	4	14	18
41	21C15A0116	4	17	21
42	21C15A0117	5	19	24
43	21C15A0120	5	19	24
44	21C15A0121	4	13	17

No. of Absentees: **Nil**

Total Strength: **44**

Signature of Faculty

: **Signature of HoD**

Second Internal Examination Marks

Programme**: BTech** Year: **IV** Course: **Theory** **A.Y: 2023-24**

Course:Repair & Rehabilitation of Structures Section: A Faculty Name: Dr. M.S.Siva Kumar

S. No	**Roll No**	**Objective Marks (5)**	**Subjective Marks (15)**	**Total Marks (20)**
1	19C11A0117	4	17	21
2	20C11A0101	5	13	18
3	20C11A0102	4	17	21
4	20C11A0103	4	13	17
5	20C11A0104	5	19	24
6	20C11A0105	4	14	18
7	20C11A0107	4	7	11
8	20C11A0108	4	15	19
9	20C11A0109	AB	7	7
10	20C11A0111	AB	7	7
11	20C11A0112	4	11	15
12	20C11A0113	4	17	21
13	20C11A0114	4	16	20
14	20C11A0115	4	11	15
15	20C11A0116	5	17	22
16	20C11A0117	4	12	16
17	20C11A0118	4	10	14
18	20C11A0119	4	13	17
19	20C11A0120	AB	7	7
20	20C11A0121	5	19	24
21	20C11A0122	5	16	21
22	20C11A0124	AB	AB	0
23	20C11A0125	5	16	21
24	20C11A0126	4	11	15
25	20C11A0127	5	17	22
26	21C15A0101	4	15	19
27	21C15A0102	4	12	16
28	21C15A0103	5	20	25
29	21C15A0104	4	17	21
30	21C15A0105	4	18	22
31	21C15A0106	5	16	21
32	21C15A0107	5	19	24
33	21C15A0108	5	17	22
34	21C15A0109	4	17	21
35	21C15A0110	4	18	22
36	21C15A0111	4	16	20
37	21C15A0112	4	11	15

38	21C15A0113	5	16	21
39	21C15A0114	5	16	21
40	21C15A0115	4	14	18
41	21C15A0116	4	14	18
42	21C15A0117	5	19	24
43	21C15A0120	5	19	24
44	21C15A0121	4	10	14

No. of Absentees: 01

Total Strength: 43

Signature of Faculty

: **Signature of HoD**

(CE851PE) REPAIR AND REHABILITATION OF STRUCTURES

UNIT- I

MAINTENANCE AND REPAIR STRATEGIES

Maintenance, Facets of Maintenance, importance of Maintenance, various aspects of Inspection, Condition Assessment of a structure, Various methods of Condition assessment , NDT and NDE ,Repair Strategies , Repairs-Rehabilitation-Retrofitting-Strengthening-Upgradation of a Structure, Selection of Materials and Techniques for Repair

- MAINTENANCE :
- Maintenance is an important aspect of building construction system and maintenance includes many services and their proper running for a long time.

- OBJECTIVE OF MAINTENANCE :
- To preserve in good condition buildings and services.
- To extend the usual life of the buildings and prevent premature capital outlay for replacement.
- To satisfy lender/ insurer requirement to provide a safe, secure and efficient working and living environment and to avoid deterioration of physical assets.
- To maximize the aesthetic and economic values of a building as well as increase the health and safety of the occupants.

- When deterioration occurs due to any reason it is inevitable to restore it to its original standards.

- To make improvements whenever required.
- To sustain utility value

Maintenance work is classified as

- Preventive maintenance
- Remedial maintenance
- Routine maintenance
- Special maintenance

The maintenance work done before the defects occurred in the structure is called preventive structure

Remedial maintenance

It is the maintenance done after the defects in the structure. It involves the following basic steps.

- Finding the deterioration
- Determining the cause
- Evaluating the strength of the existing structures
- Evaluating the need of the structures
- Selecting and implanting the repair procedure

Routine maintenance

It is the service maintenance attended to the structure periodically. It is depends upon specifications and materials of structure, purpose, intensity and condition of use.

Special maintenance

It is the work done under special condition and requires sanction and performed to rectify heavy damage.

Importance of Maintenance various aspects of Inspection

- Improves the life of structure
- Improved life period gives better return on investment
- Better appearance and aesthetically appealing
- Leads to quicker detection of defects and hence remedial measures
- Prevents major deterioration that leads to collapse
- Ensures safely to occupants
- Ensures feeling of confidence by 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

VARIOUS ASPECTS INSPECTION:

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.
- ✓ Helps 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

b)Weekly Routine Maintenance:

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

c) Monthly Routine 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 Routine Maintenance:
- ✓ Attending to small repairs and white washing
- ✓ Painting of steel components exposed to weather
- ✓ Check of displacements and remedial measures

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
- Check on proper function of sewer, water lines, wash basins, sinks etc
- Check on drain pipes from roof, during rainy season

Weekly Routine Maintenance

Electrical Accessories
Flushing sewer line
Leakage of water line

Monthly Routine Maintenance

Cleaning Doors, windows, etc

- Checking Septic Tank/Sewer
- Observation for cracks in the elements
- Cleaning of overhead tanks

Yearly Routine Maintenance

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

FACETS OF MAINTENANCE: Maintenance operations have many facets such as Emergency maintenance: Necessitated by unforeseen breakdown drainage or damage caused by natural calamity like fire, floods, cyclone earthquake etc.

Condition Based maintenance: Work initiated after due inspection

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

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

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

Day-to-Day care and maintenance Shut down maintenance: Thorough overhaul and maintenance after closing a facility.

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

Necessity of maintenance: The causes which necessitate the maintenance effects the service and durability of the structure as follows:

a) Atmospheric agencies

b) Normal wear and tear

c) Failure of structure

a) Atmospheric agencies

Rain: It is the important source of water, which affects the structure in the following ways;

Physical:

Expansion and contraction – The materials is subjected to repetitive expansion and contraction while they become wet and dry and develops the stresses.

Expansion of water – The variation of temperature causes the expansion and contraction absorbed water and affects the micro-structures of the materials.

Erosion – Transportation, attrition and abrasion of the materials is quite evident effect of the water.

Chemical: The water available in nature contains acids and alkaline and other compound

Wind: It is the agent, which transports the abrasive material and assists the physical weathering Its action is aggravated during rains and, When it is moving with high speed, it may contains acidic gases like CO_2 fumes which may act over the material and penetrates quite deeply in materials and structure.

Temperature: The seasonal and annual variation of the temperature, difference

b) Normal Wear and tear: During the use of structure it is subjected to abrasion and thereby it loses appearance and serviceability.

c) Failure of structure: Failure is defined as the behavior of structure not in agreement with expected condition of stability or lacking freedom from necessary repair or non-compliance with desired use of and occupancy of the completed structure. In field it may result in visual collapse of the structure or even suspension of the services e.g. the collapse of towers, sliding
or over turning of dam, settlement of foundation, crushing of columns etc.

The causes of failure may be broadly grouped as:

Improper Design: Due to incorrect, insufficient data regarding use, loading and environmental conditions, selection of material and poor detailing.

Defective Construction: Poor materials, poor workmanship, lack of quality.

Assessment Procedure for Evaluating Damages in Structure and Repair techniques:

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.

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.

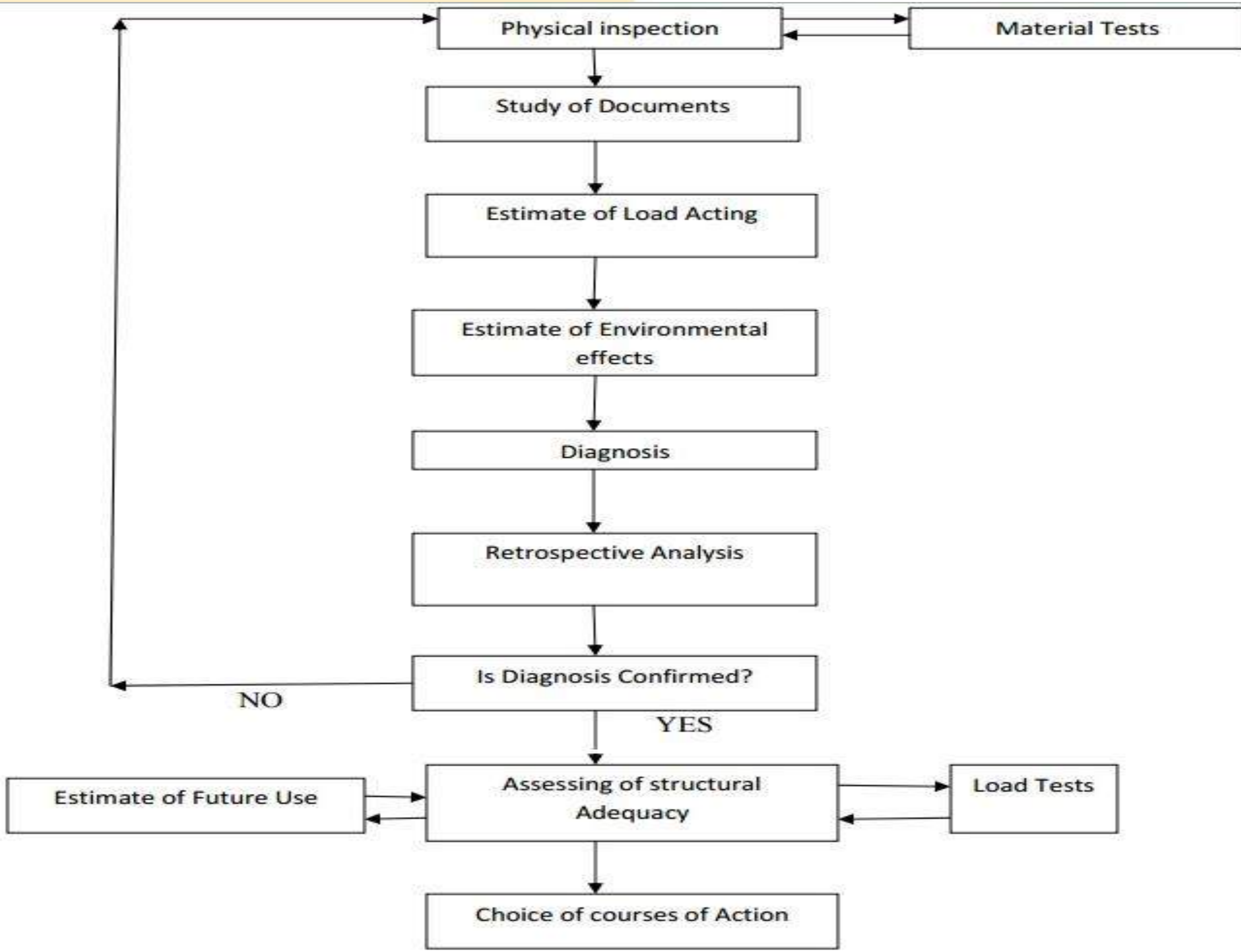
11) Estimation of future use.

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


Physical inspection
Material Tests
Study of Documents
Estimate of Load Acting
Estimate of Environmental effects
Diagnosis
Retrospective Analysis
Is Diagnosis Confirmed?
NO
YES
Estimate of Future Use
Assessing of structural Adequacy
Load Tests
Choice of courses of Action

PHYSICAL INSPECTION OF DAMAGED STRUCTURE.

- Some of the use full in formation may be obtained from the
- physical inspection of damaged structure, like nature of distress, type of distress, extent damage and its classification etc,
- their causes preparing and documenting the damages,
- collecting the samples for laboratory testing and analysis, planning for in situ testing,
- special environmental effects which have not been considered at the design stage and
- information on the loads acting on the existing structure at the time of damage may be, obtained.
- To stop further damages, preventive measure necessary may be planned which may warrent urgent execution.

THE CAUSES OF DETERIORATION

- i) Deterioration due to corrosion
- ii) Environmental effects
- iii) Poor quality material used
- iv) Quality of supervision
- v) Design and construction flaws

DESIGN AND CONSTRUCTION FLAWS

- Design of concrete structures governs the performance of concrete structures.
- Well designed and detailed concrete structure will show less deterioration in comparison with poorly designed and detailed concrete, in the similar condition.
- The beam-column joints are particularly prone to defective concrete, if detailing and placing of reinforcement is not done properly.
- Inadequate concrete cover may lead to carbonation depth reaching up to the reinforcement, thus, increasing the risk of corrosion of the reinforcement.

ENVIRONMENTAL EFFECTS

- Micro-cracks present in the concrete are the sources of ingress of moistures atmospheric carbon di-oxide into the concrete which attack reinforcement and with various ingredients of concrete.
- In aggressive environment concrete structure will be severely reduces.

POOR QUALITY MATERIAL USED

- Quality of materials, to be used in construction, should be ensured by means various tests as specified in the IS codes.
- Alkali-aggregate reaction and sulphate attack results in early deterioration.
- Clayey materials in the fine aggregates weaken the mortar aggregate bond and reduce the strength.
- Salinity causes corrosion of reinforcing bars as well as deterioration of concrete.

QUALITY OF SUPERVISION

- Construction work should be carried out as per the laid down specification.
- Adherence to specified water-cement ratio controls strength, permeability durability of concrete.
- Insufficient vibration may result in porous and honey combined concrete, whereas excess vibration may cause segregation.

DETERIORATION DUE TO CORROSION

- Spelling of concrete cover
- Cracks parallel to the reinforcement
- Spelling at edges
- Swelling of concrete
- Dislocation
- Internal cracking and reduction in area of steel reinforcement.

What is NDT?

- **Nondestructive testing** or **non-destructive testing** (**NDT**) is a wide group of analysis techniques used in science and technology industry to evaluate the properties of a material, component or system without causing damage.
- The terms **nondestructive examination** (**NDE**), **nondestructive inspection** (**NDI**), and **nondestructive evaluation** (**NDE**) are also commonly used to describe this technology.

TESTING SYSTEM OF HARDENED CONCRETE

- (a) Non – Destructive Testing System (NDTS)
- (b) Partially Destructive Testing System (PDTS)
- (c) Destructive Testing System (DTS)

Non–destructive Testing Methods

- Surface Hardness Method
- Ultrasonic Pulse Velocity Method
- Resonant Frequency Method
- Dynamic or vibration method
- Pulse Attenuation Method
- Pulse Echo Method
- Radioactive Method
- Nuclear Methods
- Magnetic Methods
- Electro magnetic methods
- Electrical Methods
- Acoustic Emission Technique
- Radar Technique
- Radiography Methods

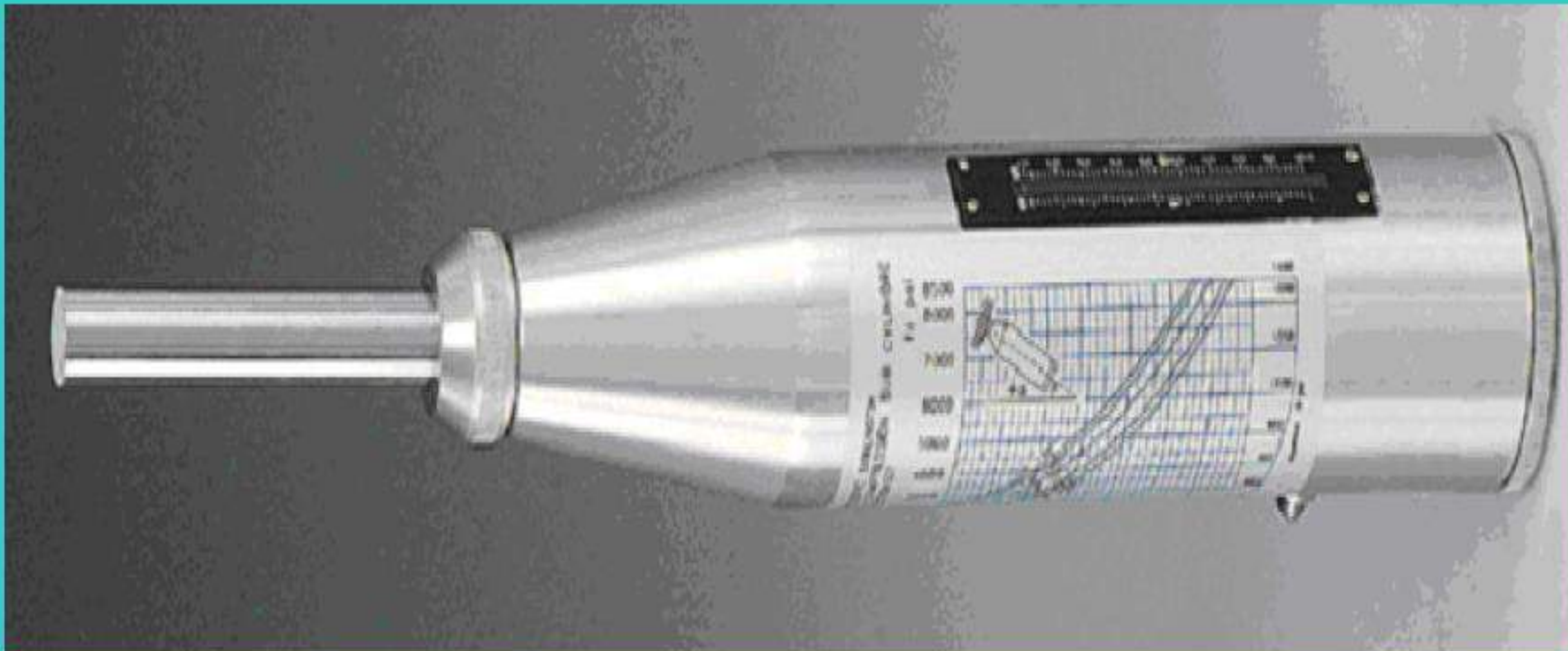
Semi-Destructive Testing Systems

- Penetration Techniques
- Pull-out and Pull-off Tests
- Core sampling and testing
- Break off test
- Permeability Test
- Half–cell potential survey
- Resistivity survey
- Carbonation and pH value test
- Chloride content test
- Abrasion resistance test.

Testing For Mechanical Properties

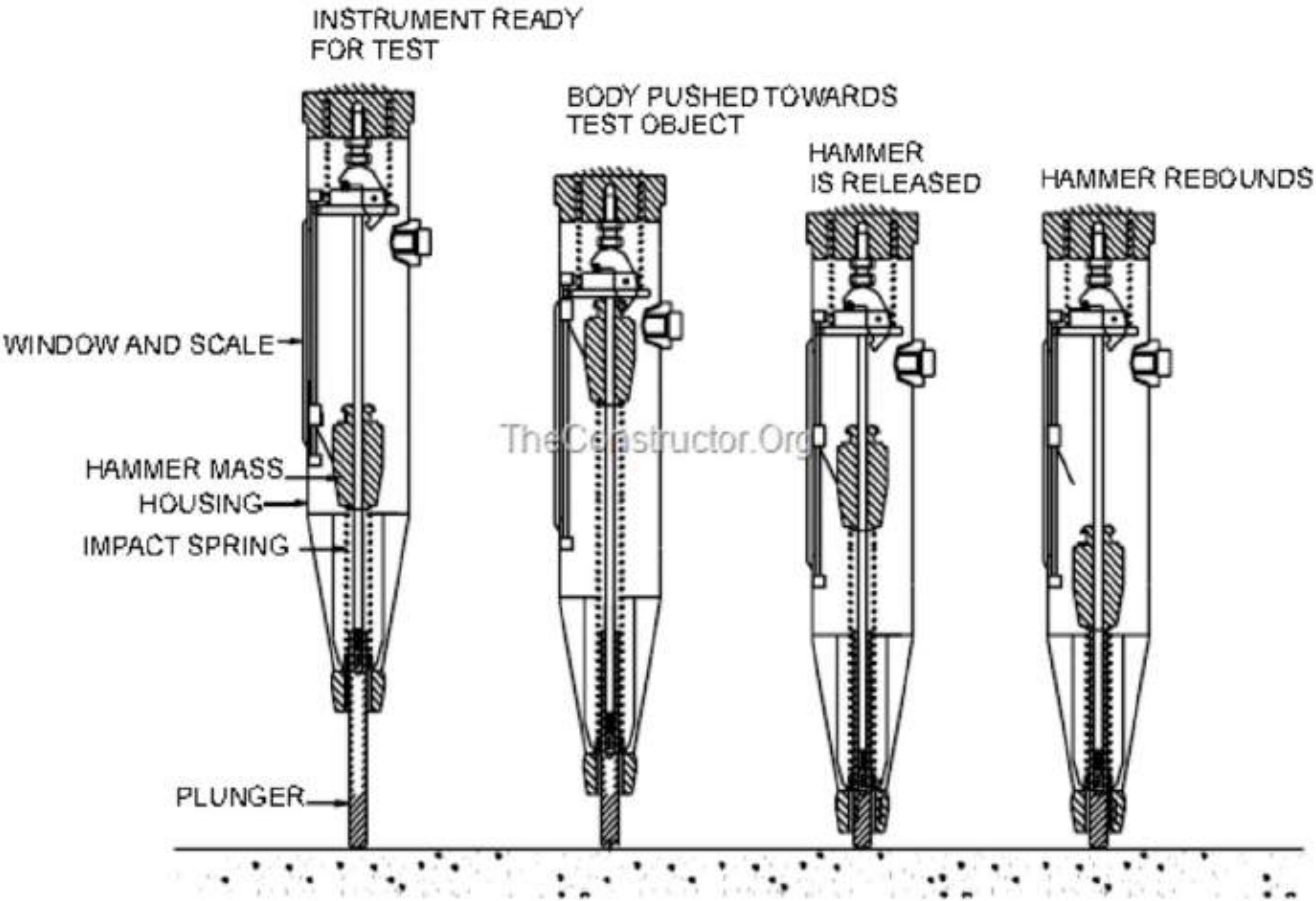
Compressive Strength	Core testing, Windsor probe test, Rebound hammer test, Pull-out test
Quality of Concrete	Ultrasonic Pulse Velocity test
Tensile Strength	Pull off test, Splitting tensile test
Flexural Strength	Centre-point & third-point load test
Abrasion Resistance	Sand blasting test
Bond Strength	Pull off testing

Surface Hardness Test



A Typical Rebound Hammer

Rebound Hammer Test :



Rebound hammer test, or Schmidt Hammer Test, is a simple method to estimate the in situ concrete strength. The hammer measures the rebound of a spring loaded mass impacting against the surface of the concrete. The rebound hammer has an arbitrary scale ranging from 10 to 100. Emperor kal correlation was established between concrete strength and the rebound number. It should be noted that the surface for testing should be grinded flat and smooth. When conducting test, the Hammer should be held at right angles to the surface, because the rebound reading can be affected by the orientation of the hammer. When used on the underside of a suspended slab, gravity will increase is the rebound distance of mass. It rebound hammer should be calibrated before use.

The major drawback of rebound hammer test is the Limited accuracy. Even for calibrated Hammers, the error of test could be about 15% there as for uncalibrated hammers, the accuracy is much worse and error can reach 30%. this is the direct way of measuring actual strength of concrete.concrete cores are cut by means of a Rotary cutting tools with diamond bits.in this manner, a cylindrical specimen is obtained. The core is then soaked in waters, capped with molten sulphur to make its ends plane and parallel.The core is then tested in compression. In this way, we get the compressive strength of the concrete used in the structure which gives the idea about the quality of concrete.

Apparatus:

Rebound Hammer- a spring loaded steel hammer which will release when strikes a steel plunger to concrete surface

Test Anvil- a 6 inch diameter × 6 inch long high carbon steel cylinder hardened to Rockwell 65-67C

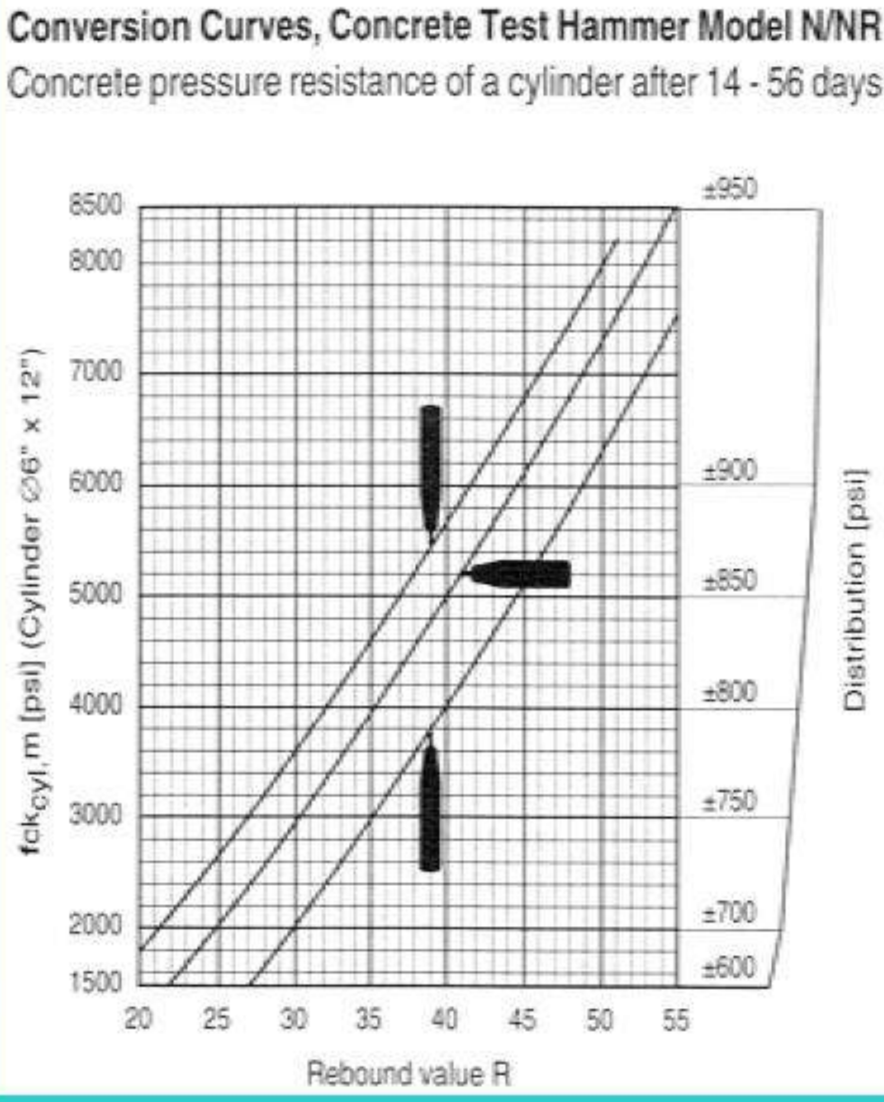
1. **Before commencement of the test, the rebound hammer has been tested against the test anvil, to get reliable results, for which the manufacturer of the rebound hammer indicates the range of readings on the anvil suitable for different types of rebound hammer.**
2. **Apply light pressure on the plunger. It will be released from the locked position and allow it to extend to the ready position to the test.**
3. **All the points of concrete structure selected for testing are to be in dry condition.**
4. **Press the plunger against the surface of the concrete keeping the**

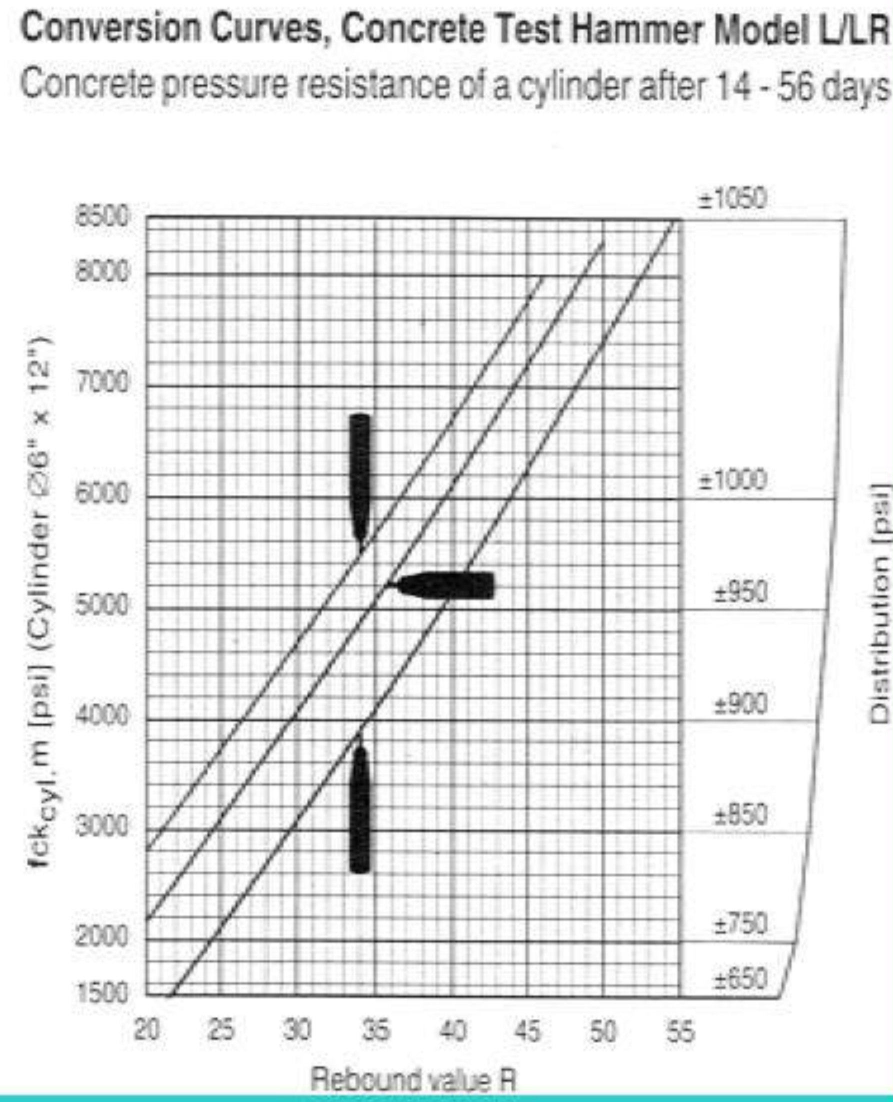
5. Apply a gradual increase in pressure until the hammer impacts. After impact, record the rebound number to the nearest whole number.
6. Average of about 6 readings is taken at each location.
7. The compressive strength is then determined by taking average of rebound reading.
8. Compressive strength of concrete can be determined from the relationship between the rebound number and the strength given by the compressive strength curves.

Quality of Cover Concrete from Rebound Number

Average rebound number	*Quality of concrete*
Greater than 40	very good hard layer
30 to 40	good layer
20 to 30	fair
less than 20	poor concrete
0	delaminated

Typical Calibration Curves





RBH

ADVANTAGE

- Simple to use. No special experience is needed to conduct the test.
- Establishes uniformity of properties.
- Equipment is inexpensive and is readily available.
- A wide variety of concrete test hammers is available with an operational range of M10 to M70.
- For rehabilitation of old Monuments..

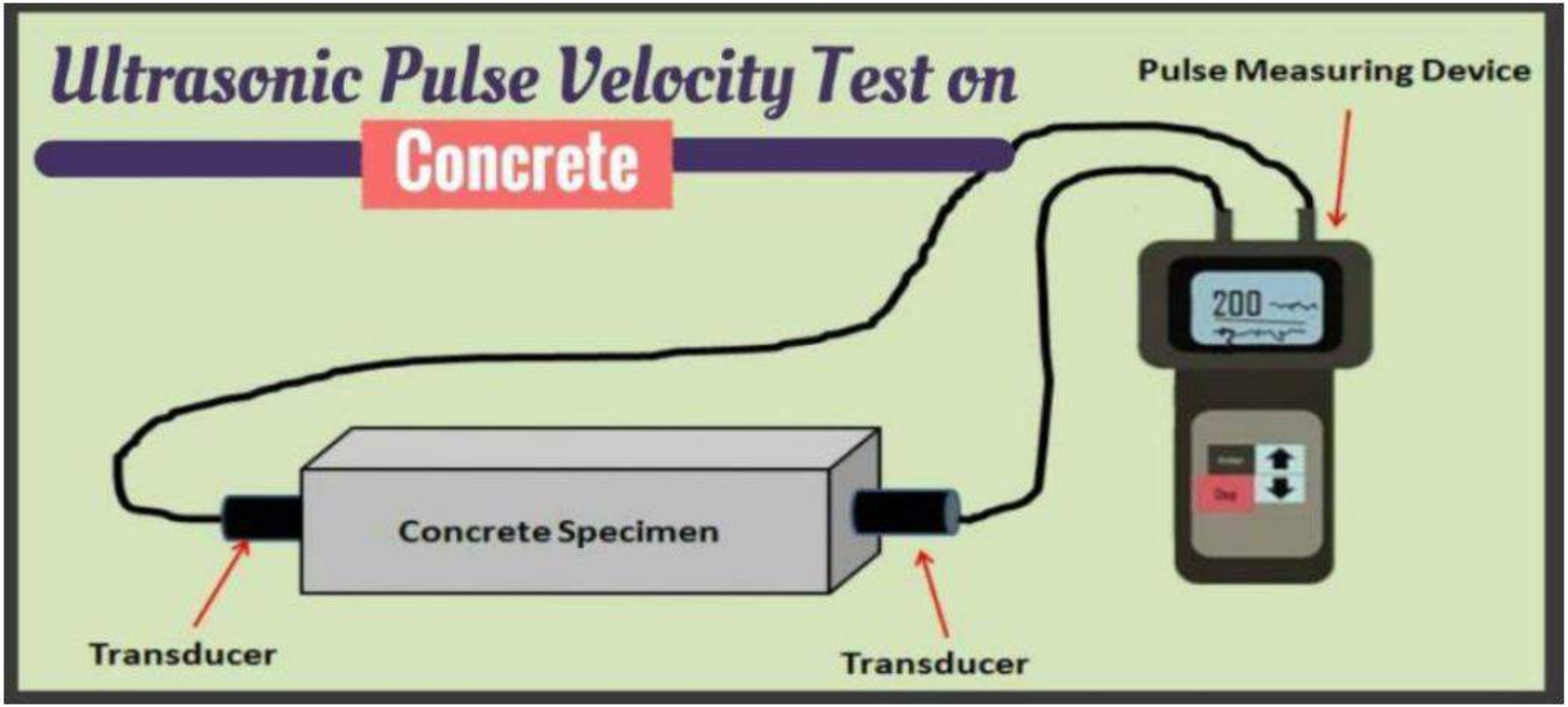
DISADVANTAGE

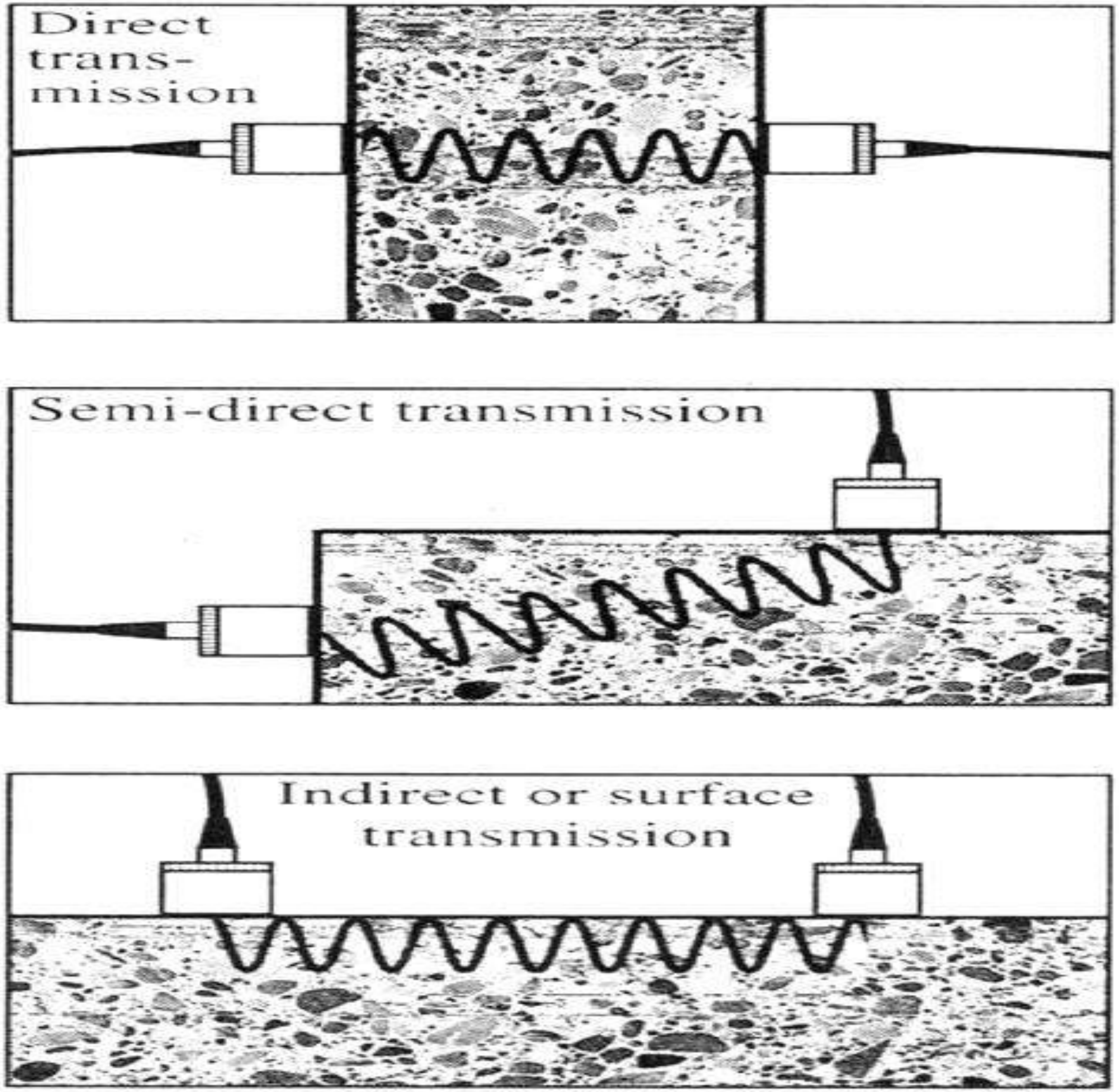
- Evaluates only the local point and layer of masonry to which it is applied.
- No direct relationship to strength or deformation properties.
- Unreliable for the detection of flaws.
- Cleaning maintenance of probe and spring mechanism

VARIOUS TEST USING NDT TECHNIQUES:

- ✓ Determination of concrete strength, presence of cracks, voids and honeycombing.
- ✓ Determination of depth of concrete cover, bar diameter and spacing.
- ✓ Determination of extent of corrosion of reinforcement.
- ✓ Determination of chemical attack on concrete.
- ✓ Determination of permeability.
- ✓ Determination of defects in matters and welded joints.

Ultrasonic Pulse Velocity Method :





Direct
trans-
mission
Semi-direct transmission
Indirect or surface
transmission

UPV Transducers

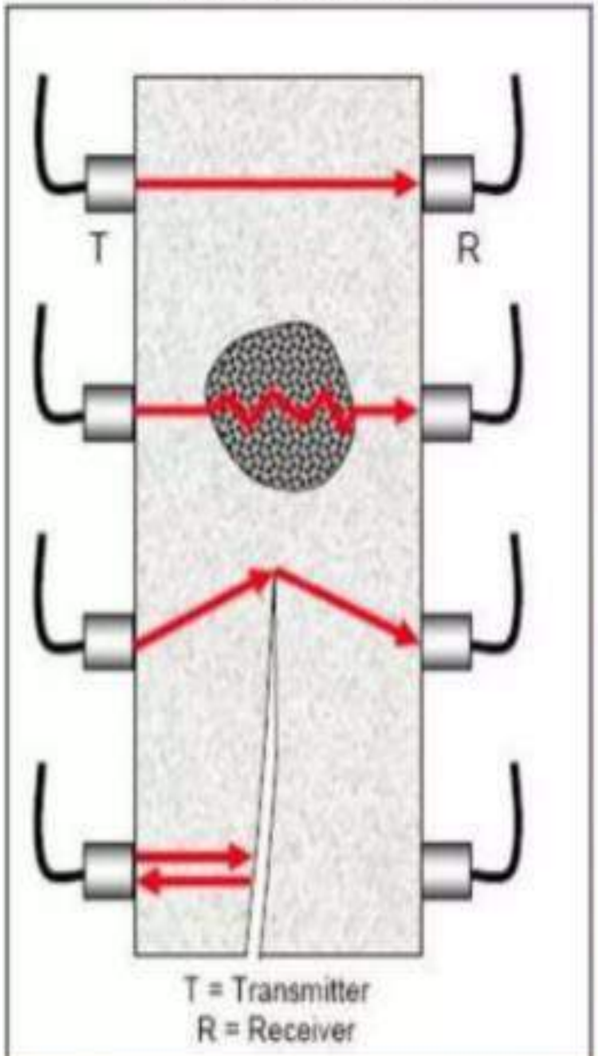


Table 2 Velocity Criterion for Concrete Quality Grading

Sl No.	Pulse Velocity by Cross Probing (km/sec)	Concrete Quality Grading
1.	Above 4·5	Excellent
2.	3·5 to 4·5	Good
3.	3·0 to 3·5	Medium
4.	Below 3·0	Doubtful

Note — In case of "doubtful" quality it may be necessary to carry out further tests.

In the ultrasonic pulse velocity test, the time of travel of an ultrasonic pulse through the concrete structure is measured and the pulse velocity is determined by the relation :

pulse velocity is equal to distance by time. As void and defects in the concrete prevent direct passage of ultrasonic pulse moving to the existence of concrete air interface is, the ultrasonic test can reveal internal defects of concrete such as the presence of honeycombing and the interiors. Besides, as there is positive relationship between wave velocity and elastic modulus, as well as between elastic modulus and strength, the ultrasonic velocity is able to reflect the concrete strength.

ADVANTAGES & LIMITATIONS

- Thickness and lengths up to 30 ft can be tested
- Position, size and type of defect can be determined
- Instant test results
- Portable
- Capable of being fully automated
- Access to only one side necessary

- The operator can decide whether the test piece is defective or not while the test is in progress.
- Considerable degree of skill necessary to obtain the fullest information from the test.
- Very thin sections can prove difficult.

Electrochemical Activity

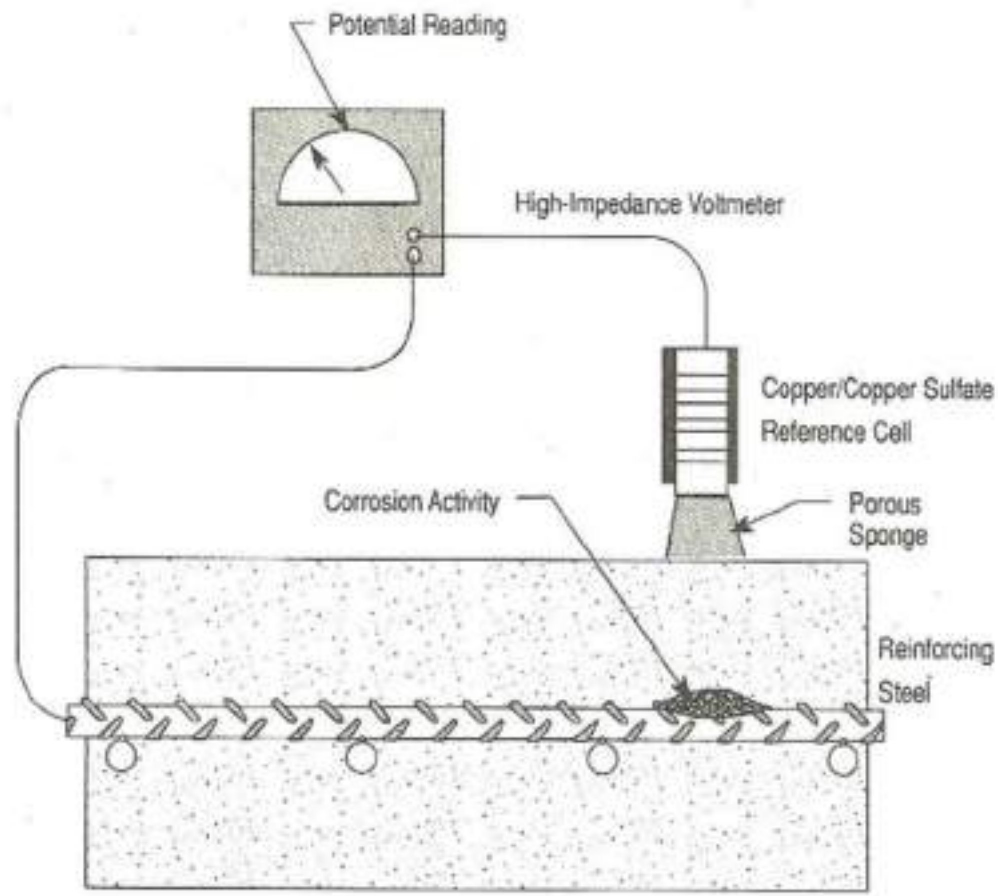
I. Half Cell Potential Method

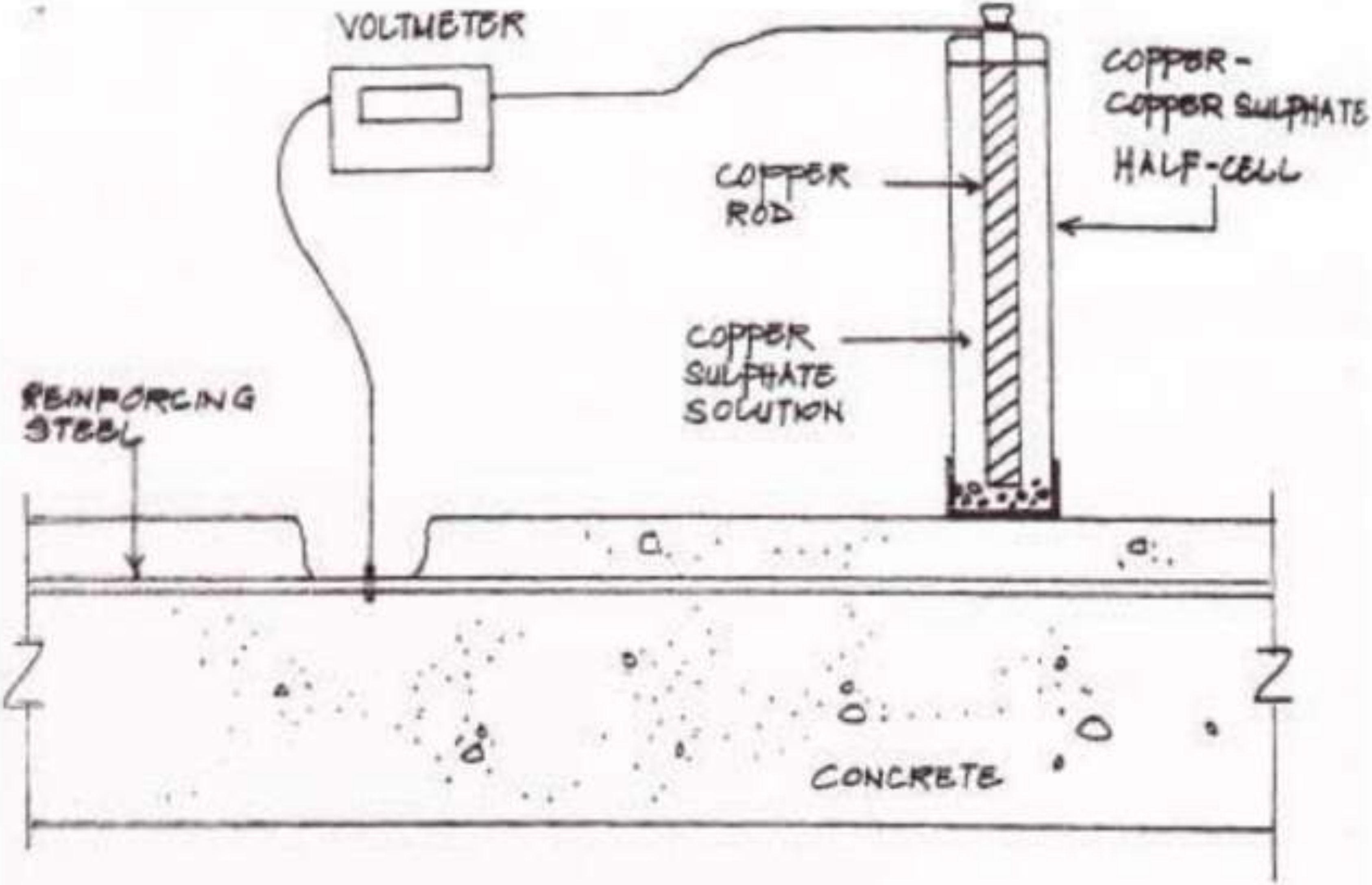
(also called Open-Circuit Potential Measurement Technique)

The half-cell is usually a copper/copper sulphate or silver/silver chloride cell.

The concrete functions as an electrolyte.

The risk of corrosion of the reinforcement in the immediate region of the test location is related empirically to the measured potential difference.

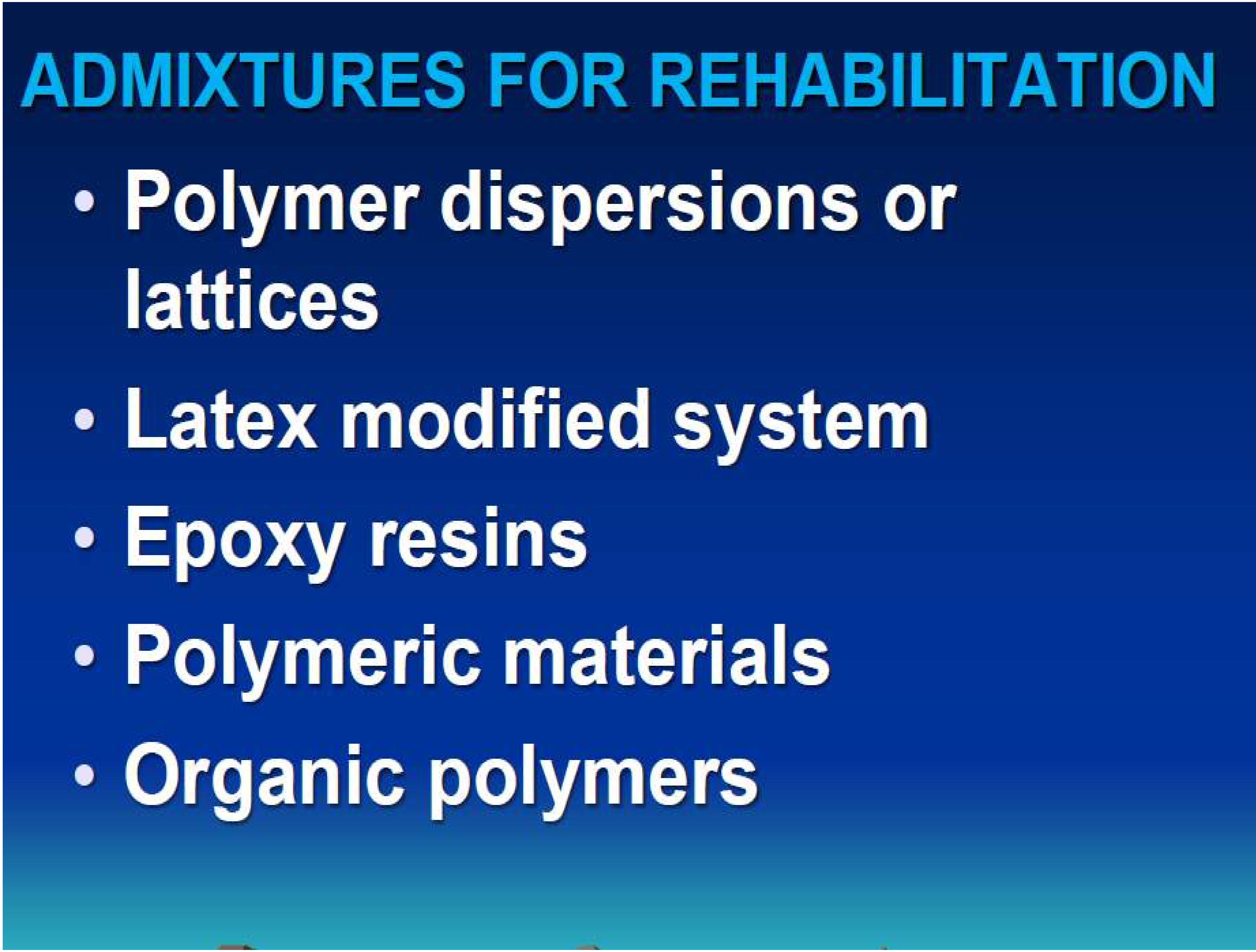




COPPER - COPPER SULPHATE
HALF - CELL CIRCUITRY

Classification of Repair Material

- Patch Repair Materials
- Injection Grouts
- Bonding Aids
- Resurfacing Materials
- Other Repair Materials


ADMIXTURES FOR REHABILITATION
• Polymer dispersions or lattices
• Latex modified system
• Epoxy resins
• Polymeric materials
• Organic polymers

MATERIAL REQUIREMENTS

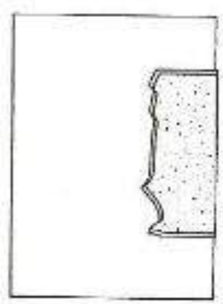
DESIRED PROPERTIES OF REPAIR MATERIALS

1. **Engineered materials with high performance, high durability and low maintenance**
   - Composites
   - Polymers
   - High performance concrete
2. **Materials must be easy to use, have high productivity and reduce construction cycle time**
   - High flow self-levelling concrete/mortar
   - Setting time controlling materials
   - Materials with wide applicability for varied substrate and environmental conditions
3. **Safe for the workers and users, environment friendly: which do emanate toxics or irritating fumes during application or service**
4. **Materials that do not add to the dead weight of the repaired component or the structure**

Selection of the Repair Material is guided by

- Type of the structure
- Type of the service conditions and environment
- Nature of the deterioration
- Extent of the deterioration
- Appearance
- Economic considerations

Load-Carrying Properties

Goal (performance requirements)	Results if the wrong material is selected (undesirable response)	Look for these properties	Avoid these!
Bond to substrate	 Loss of bond, delamination, detachment of repair from substrate	Tensile bond, low internal stress	High internal stress caused by thermal incompatibility, drying shrinkage*

MATERIAL TYPES

GENERAL CLASSIFICATION OF REPAIR MATERIALS

1. Portland cement based materials
2. Polymer modified concrete
3. Resin based mixtures
4. Substitute materials/Recent products

Crack repair Material

1. Cement slurry
2. Cement mortar
3. Epoxy resins
4. Poly vinyl acetate
5. Polymer resins
6. Acrylics
7. Fibber
8. Parma bond(bonding agent)
9. Parma master bond-base(epoxy concrete bonding agent)
10. Parma crack fill(crack repair)

Selection Criteria for Repair Materials

- Ease of application
- Cost
- Available labor skills and equipment
- Shelf life of the material
- Pot life of the material
- Type of damage
- Compatibility of the repair material with damaged concrete
- Appearance of finished surface
- Co-efficient of thermal expansion of the material
- Co-efficient of permeability of the material
- Corrosion resistance property of the material
- Durability of such concrete repair material
- Speed of concrete repair

1. PORTLAND CEMENT BASED MATERIALS

1. **Portland cement mortar**
2. **Portland cement concrete**

- The commonly used cement mortar or concrete with similar properties as the substrate.
- General observation is that problems such as shrinkage, cracking or even eventual failure of the repair work occurs

2. POLYMER MODIFIED CONCRETE PRODUCTS

1. Polymer modified cement
2. Polymer modified mortar
3. Polymer modified concrete
   - also called Latex Modified Concrete (LMC)
4. Polymer and fibre-modified mortar
5. Polymer mortar
6. Polymer concrete (PC)
7. Polymer impregnated concrete (PIC)

2. POLYMER MODIFIED CONCRETE PRODUCTS

- Polymer products have better durability under long-term exposure to UV radiation.
- In cement mortar or concrete, the polymer can be used as a second binder to the mix.
- Polymer mortars form matrix with cement in two-phase systems
    1. In the cementitious water phase, fine polymer particles of 0.1 – 0.2 μm are dispersed
    2. With cement, polymer particles join to form chain link reinforcement matrix increasing the tensile and flexural strength.

Matrix achieves greater plasticity and reduces shrinkage stress.

(CE851PE) REPAIR AND REHABILITATION OF STRUCTURES

UNIT- II

REPAIRS TO MASONRY AND CONCRETE STRUCTURES Methods of crack repair in masonry and concrete structures, routing and sealing of cracks, removal and surface preparation in masonry and concrete structures, reinforcement repair, anchorage, placement methods; Shot-creting and guniting, Grouting- Portland cement grouting, chemical grouting, Dry packing, polymer impregnation, Strengthening of structures flexural strengthening, Shear Strengthening, strengthening of columnsjacketing of Columns, strengthening by interior and external reinforcing, External Prestressing, Fiber wrapping, Corrosion Protection: surface treatment, joint sealants, cathodic protection

1. INTRODUCTION

- 3 Basic symptoms of distress in a concrete structure
- Cracking, Spalling and Disintegration
- Reasons for their development may be poor materials, poor design, poor construction practice, poor supervision or a combination

- repair of cracks usually does not involve strengthening

- repair of a structure showing spalling and disintegration, it is usual to find that there have been substantial losses of section and/or pronounced corrosion of the reinforcement

2. Repairing cracks

- In order to determine whether the cracks are active or dormant, periodic observations are done utilizing various types of telltales

- by placing a mark at the end of the crack

- a pin or a toothpick is lightly wedged into the crack and it falls out if there is any extension of the defect

- A strip of notched tape works similarly :

  Movement is indicated by tearing of the tape

- The device using a typical vernier caliper is the most satisfactory of all.

  Both extension and compression are indicated

- If more accurate readings are desired, extensometers can be used

- Where extreme accuracy is required resistance strain gauges can be glued across the crack

TYPES OF CRACKS IN MASONRY STRUCTURES:

1.Vertical cracks in sidewalls at corner

2.Vertical cracks around balconies

3.Vertical cracks below the openings in line with the window jambs.

4.Vertical cracks at the junction of RCC column and masonry wall.

5. Vertical cracks in the top most stories at corners of structures having RCC slab.

6.Horizontal cracks at window lintel or sill level in the top most story.

7.Horizontal cracks in the top most story below the RCC slab level.

8. Horizontal cracks at eaves level in the buildings having pitched roof with wooden joists and purlins.

9. Random cracks in all directions involving both external and internal walls.

10. Diagonal cracks over RCC lintels spanning large openings.

11. Shrinkage cracks.

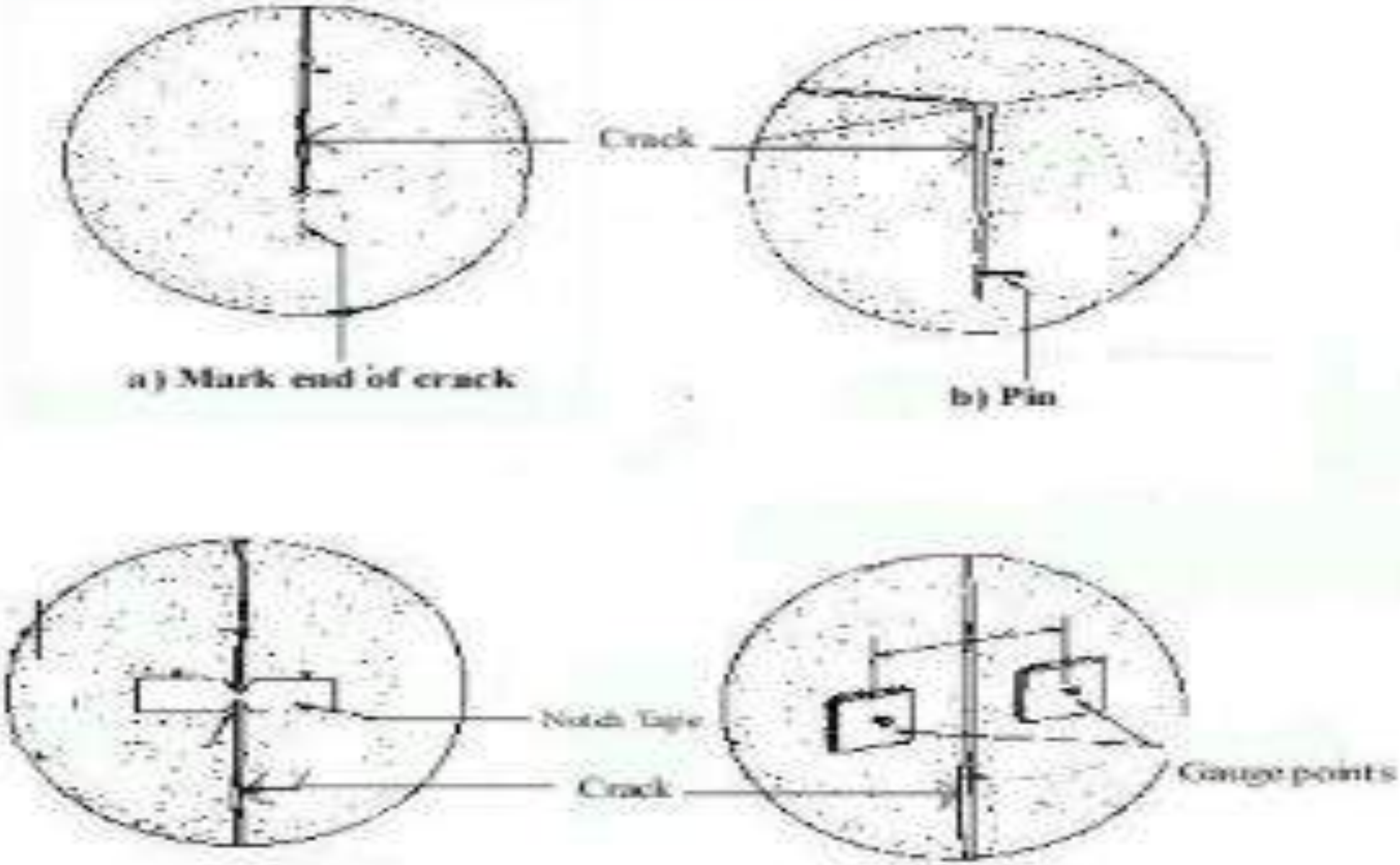
HOW DAMAGE OCCURS IN BRICK-MASONRY STRUCTURES:

- Effect of Aging on Brick-Work:
  - Rain Exposure
  - Temperature
  - Moisture Absorption
  - Chemical Alteration
  - Continuous Exposure to Chemicals

- Construction Error:
  - Eccentrically Loaded Walls gives overturning effect (Decorative Panels on one side, Support of Working platforms on one side)
  - Usage of Poor quality of materials
  - Error due to saving in economy

GENERAL CAUSES TO DEVELOP THE CRACKS:

- Poor quality of bricks.
- For masonry work,use the porous stones.
- Absence of grading in before the use of fine aggregate fine mortar.
- If percentage of clay and silt in fine aggregate exceed 3 percent.
- Due to the excessive amount of soluble sulphate.
- Plumb alignment.
- The position of the element in the structure.
- Differential loading.
- Weak mortar.
- Insufficient bond.
- Improper curing.
- Entered dampness from ground, roof and exterior faces.
- High daily temperature variations.
- Atmospheric pollutions.
- Lack of strength at corner and at junction of walls.
- Improper binding of thick walls.



a) Mark end of crack

b) Pin

c) Notched tape

d) Gauge points

Fig. 1 Tell Tales

2.1 Types of cracks

- active cracks and dormant cracks
- the proper differentiation between active and dormant cracks is one of magnitude of movement, and the telltales are a measure of the difference

- If the magnitude of the movement, measured over a reasonable period of time (say 6 months or 1 year), is sufficient to displace or show significantly on the telltales, we can treat the crack as an active one.

- If the movements are smaller, the crack may be considered as dormant.

- Cracks can also be divided into solitary or isolated cracks and pattern cracks
- Generally, a solitary crack is due to a positive overstressing of the concrete either due to load or shrinkage
- Overload cracks are fairly easily identified because they follow the lines demonstrated in laboratory load tests

- In a long retaining wall or long channel, the regular formation of cracks indicates faults in the design rather than the construction, but an irregular distribution of solitary cracks may indicate poor construction as well as poor design

- Regular patterns of cracks may occur in the surfacing of concrete and in thin slabs. These are called pattern cracks

Repair of structure

- The success of repair activity depends on the identification of the root cause of the deterioration of the concrete structures.
- If this cause is properly identified, satisfactory repairs can be done for the improvement of strength and durability, thus extending the life of the structure, is not difficult to achieve.

General procedure for repair

- Support the structural members properly as required.
- Remove all cracked, spalled and loose concrete.
- Clean the exposed concrete surfaces and steel reinforcement.

Crack repair Material

1. Cement slurry
2. Cement mortar
3. Epoxy resins
4. Poly vinyl acetate
5. Polymer resins
6. Acrylics
7. Fibber
8. Parma bond(bonding agent)
9. Parma master bond-base(epoxy concrete bonding agent)
10. Parma crack fill(crack repair)

Materials for Repair of Concrete

Repair Operation	Material	Comments
Sealing of fine cracks	Epoxy resins	- Good bonding properties even in the presence of moisture
Sealing of large cracks and joints	Portland cement Mortar Polymer mortar Putties and caulks	- Well – compacted - Good bonding properties - Based on synthetic polymers and tars
General sealing of surface	Synthetic polymers and asphalt coatings	
Localized patching of surfaces	- Concrete or mortar using Portland cement - Rapid-setting cements - Polymer resins; epoxies; polyesters	- Calcium aluminate and regulated-set cements - Good bonding

2. THE COMPOSITES USING POLYMER CAN BE

1. **Polymer concrete (PC)**, when the binder is a polymer that replaces the cement paste

2. **Polymer modified concrete (PMC)** ,when the polymer is mixed along with cement

3. **Polymer impregnated concrete (PIC)**, when the cement concrete is treated by soaking and polymerization.

4. Partially Impregnated And Surface coated polymer concrete.

2.3. Polymer-Impregnated Concrete (PIC)

- Polymer-Impregnated Concrete (PIC) is generally, a precast and hydrated portland cement concrete, which has been cleaned, dried (eventually evacuated) and impregnated with a low viscosity monomer (eventually soaked under pressure) before being polymerized.

- The unique feature of impregnating concrete is that a large part of the **voids volume** in the capillary pores is filled with the **polymer** and forms a continuous internal reinforcing structure which is thus responsible for the remarkable improvement in strength and durability.

3. PROPERTIES

- The mechanical and chemical resistant properties
- Porosity of the conventional cement mortar is greatly reduced increasing its durability.
- Seals the voids formed during the cement hydration.
- Compressive strength increases and is different for different composition and on type of polymers used.
- Tensile strength increases and is different for different composition and on type of polymers used.

MERITS

- It reduces freeze thaw deterioration, corrosion
- Increase in tensile strength
- Increase in compressive strength
- Increase in modulus of elasticity
- Resistance to acid attack
- It improves the durability of concrete
- Less pores

APPLICATIONS

- Structural floors
- Swimming pools
- Pipes
- Storage tanks for distilled water
- Anti-abrasive surface
- Marine structures
- Tunnel liners
- Telephone cable ducts

- Nuclear power plants.
- Kerbstones.
- Prefabricated structural element.
- Precast slabs for bridge decks.
- Roads.
- Marine Works.
- Prestressed concrete.

- Provide additional reinforcing bars, if the loss in reinforcement is more than 10%
- Apply shortcreting/polymer concrete for patch repair work and grouting for porous/honeycombed concrete.
- Apply protective coatings over the exposed/repaired surface.

Repair for cracks:

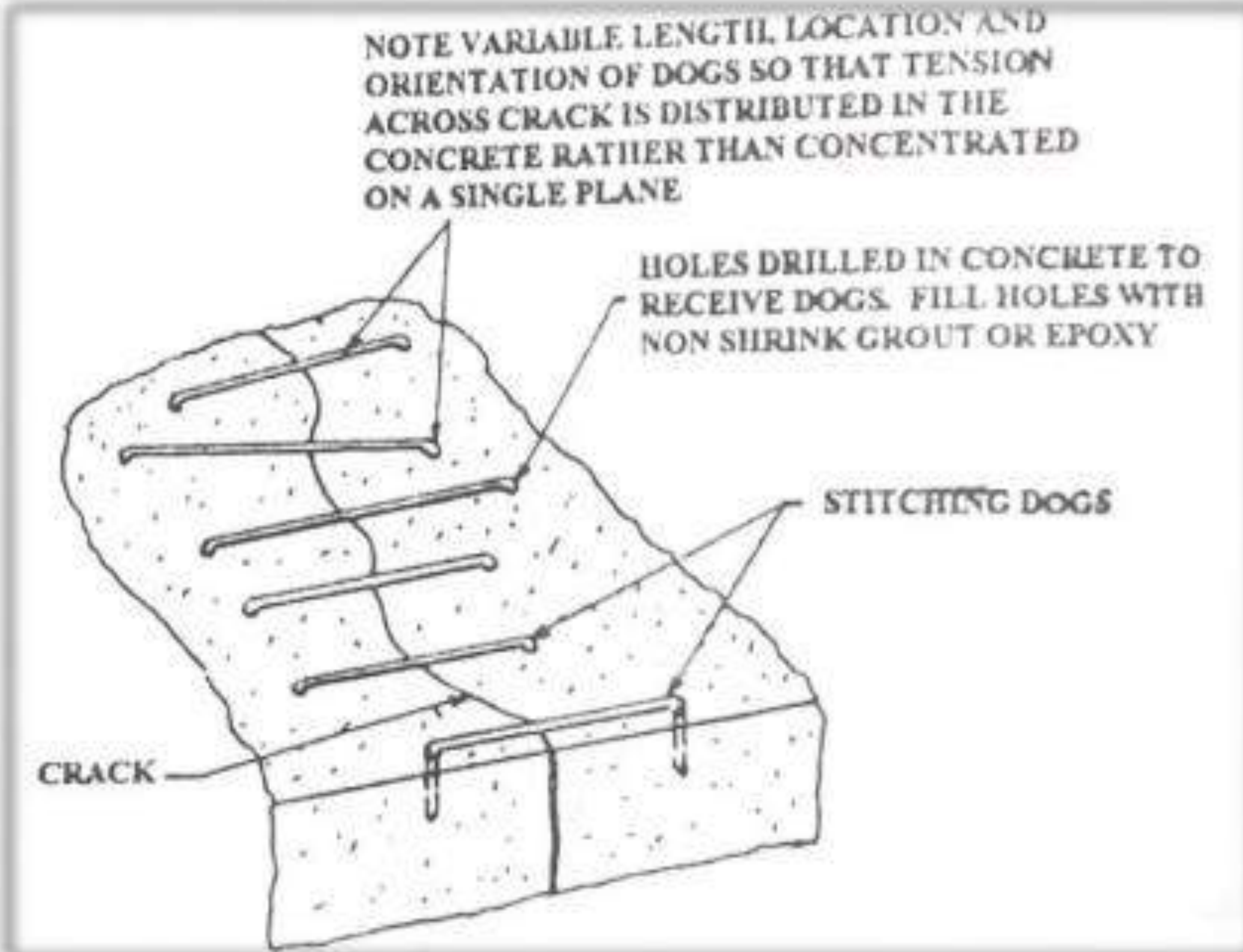
- Stitching
- Routing and sealing
- Resin injection

Stitching

- In this technique, the crack is bridged with U-shaped metal units called stitching dogs before being repaired with a rigid resin material.
- A non- shrink grout or an epoxy resin based adhesive should be used to anchor the legs of the dogs.
- Stitching dogs should be of variable length and orientation.

3. Stitching

- Concrete can be stitched by iron or steel dogs
- A series of stitches of different lengths should be used
- bend bars into the shape of a broad flat bottomed letter U between 1 foot and 3 feet long and with ends about 6 inches long
- The stitching should be on the side, which is opening up first


NOTE VARIABLE LENGTH, LOCATION AND ORIENTATION OF DOGS SO THAT TENSION ACROSS CRACK IS DISTRIBUTED IN THE CONCRETE RATHER THAN CONCENTRATED ON A SINGLE PLANE
HOLES DRILLED IN CONCRETE TO RECEIVE DOGS. FILL HOLES WITH NON SHRINK GROUT OR EPOXY
STITCHING DOGS
CRACK

Routing and sealing

- It can be executed with relatively unskilled labor and can be used to seal both fine pattern cracks and larger isolated cracks.
- This involves enlarging the crack along its exposed face and sealing it with crack fillers.

2. Routing and sealing

- This method involves enlarging the crack along its exposed face and filling and sealing it with a suitable material

- The routing operation
- placing the sealant
- This is a method where thorough water tightness of the joint is not required and where appearance is not important

REPAIR BY ROUTING AND SEALING

- This is a common technique for crack treatment and is relatively simple in comparison to the procedures and the training required for epoxy injection. The procedure is most applicable to flat horizontal surfaces such as floors and pavements. However, this method can be accomplished on vertical surfaces as well as on curved surfaces.
- This method is used to repair both fine pattern cracks and larger, isolated cracks. A common and effective use is for waterproofing by sealing cracks on the concrete surface where water stands, or where hydrostatic pressure is applied.

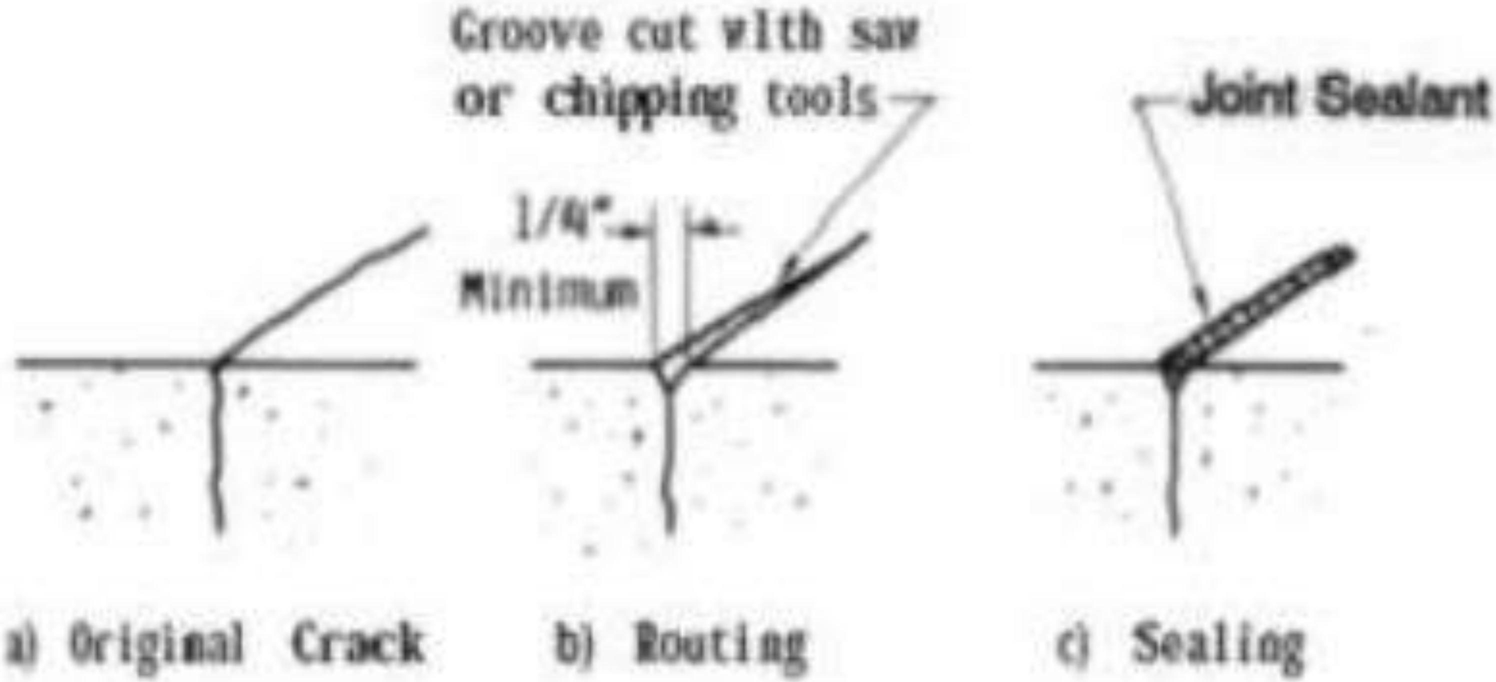
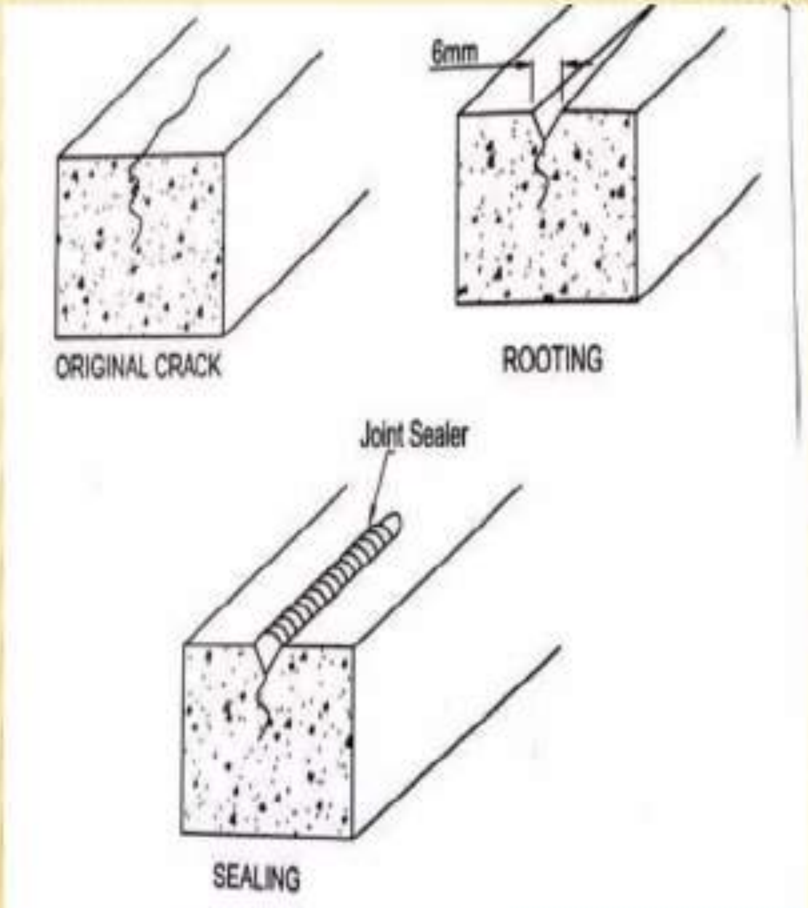


Fig. 3.1-Repair of crack by muting and sealing (Johnson 1965)

REPAIR BY ROUTING AND SEALING



Resin injection

- Epoxies are rigid and not suitable for active cracks.
- This method is used to restore structural soundness of members where cracks are dormant or can be prevented from further movements.

Methods of repairing cracks

1. **Bonding with epoxies**

- Cracks in concrete may be bonded by the injection of epoxy bonding compounds under pressure
- Usual practice is to
  - drill into the crack from the face of the concrete at several locations

- inject water or a solvent to flush out the defect

- allow the surface to dry

- surface-seal the cracks between the injection points

- inject the epoxy until it flows out of the adjacent sections of the crack or begins to bulge out the surface seals

- Usually the epoxy is injected through holes of about ¾ inch in diameter and ¾ inch deep at 6 to 12 inches centers

- Smaller spacing is used for finer cracks

- The limitation of this method is that unless the crack is dormant or the cause of cracking is removed and thereby the crack is made dormant, it will probably recur, possibly somewhere else in the structure

- Also, this technique is not applicable if the defects are actively leaking to the extent that they cannot be dried out, or where the cracks are numerous


5


Epoxy injection fig

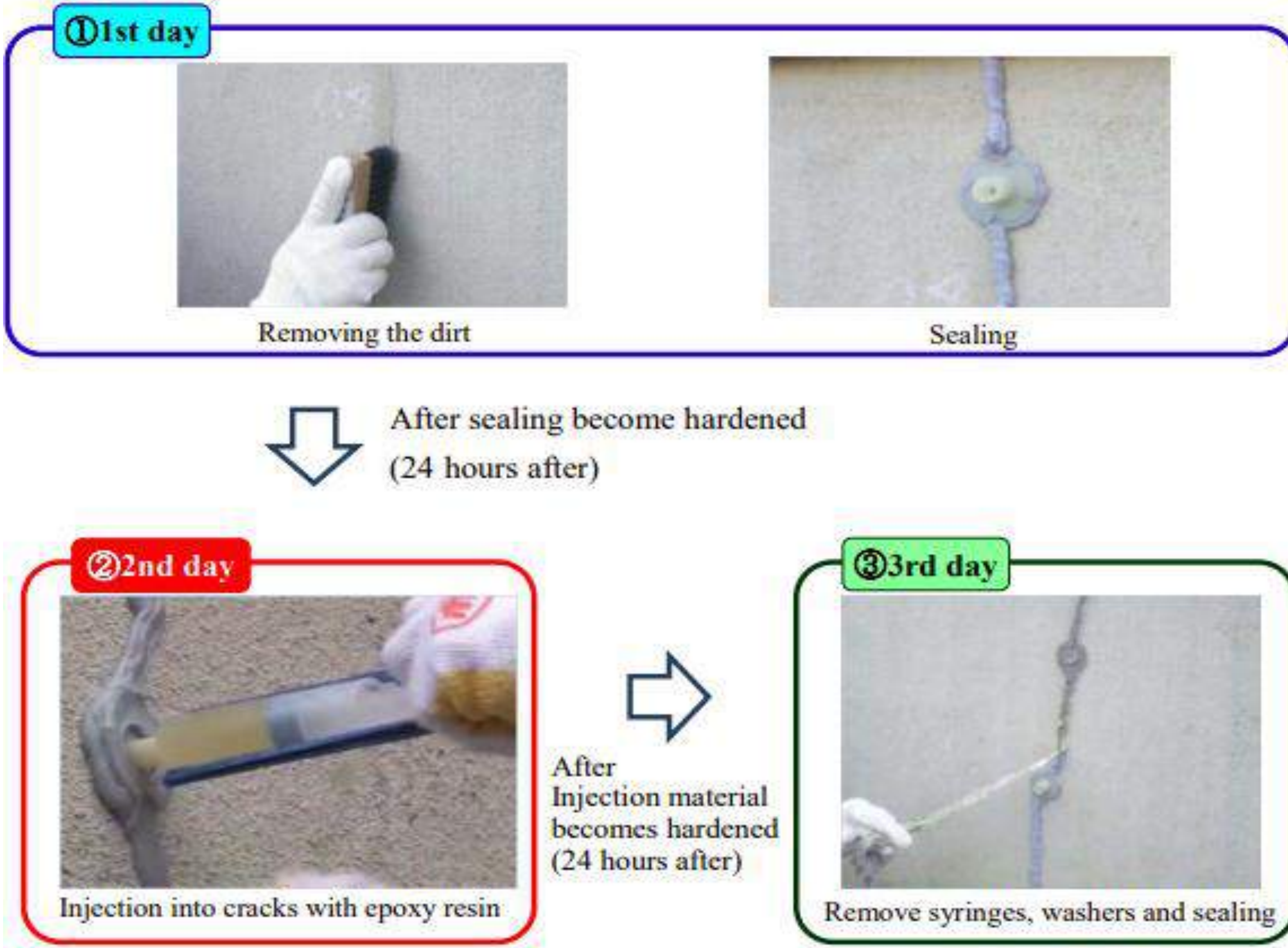


Fig. 5.2.1.2 Outline of crack repair method by Epoxy Resin

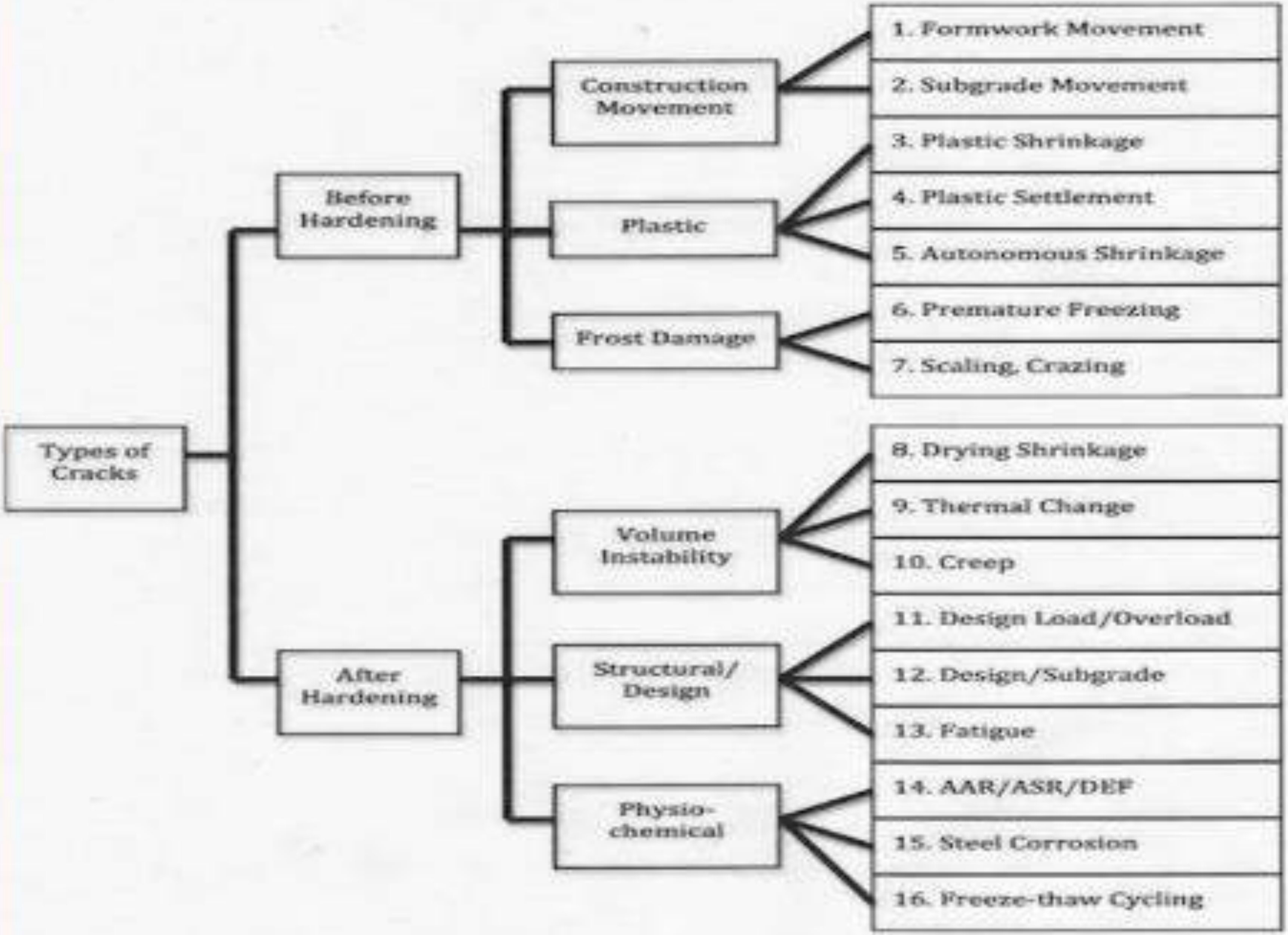


Figure Common causes of cracking in concrete structures

5. Replacement of concrete

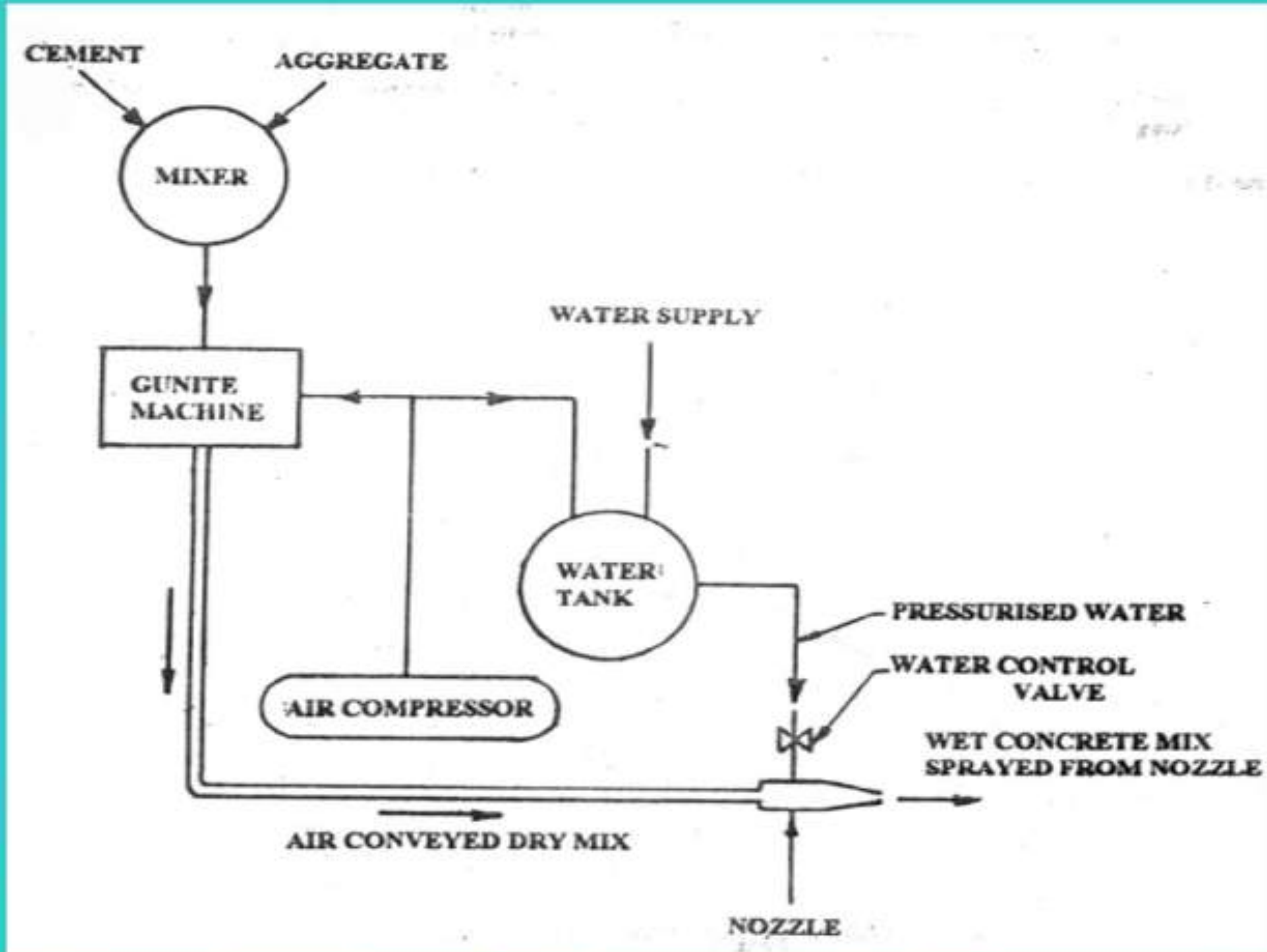
- This method consists of replacing the defective concrete with new concrete of conventional proportions, placed in a conventional manner
- This method is a satisfactory and economical solution where the repair occurs in depth (at least beyond the reinforcement), and where the area to be repaired is accessible
- This method is particularly indicated where a water-tight construction is required and where the deterioration extends completely through the original concrete section

Guniting

- Guniting is mechanically applied material consisting of cement, aggregates and water.
- The cement and sand are batched and mixed in the usual way and conveyed through a hose pipe with the help of compressed air.

- A separate pipe line brings water under pressure and the water and cement aggregate mix are passed through and intimately mixed in a special manifold and then projected at high velocity to the surface being repaired.
- In good quality work, a density around 2100kg/m3 is achieved. For effective guniting, the nozzle should be kept at 60cm to 150cm from the work normal to the surface.

- Before guniting is applied, the old concrete surface is prepared properly, all the cracks treated and the new reinforcement fixed in position.
- Cracks wider than about 0.5 mm should be cut out and filled with hand-applied mortar or with gunite.



Diagrammatic representation of gunite process

Shortcreting

- Mortar or concrete pneumatically projected at high speed onto a surface".
- Types of shorcrete:

    i) Dry mix

    ii) Wet mix

- **Dry mix:**

Dry cement, sand and coarse aggregate are premixed with only sufficient water to reduce dusting.

- **Wet mix:**

The cement, sand and coarse aggregate are mixed with water and the resulting concrete is then pumped to the nozzle where compressed air propels the wet mixture onto the surface.

4. Drypack

- Drypacking is the hand placement of a very dry mortar and the subsequent tamping of the mortar into place, producing an intimate contact between the new and existing works

- Because of the low water-cement ratio of the material, there is little shrinkage, and the patch remains tight. The usual mortar mix is 1:2.5 to 1:3

Grouting (chemical):

- Chemical grouts consist of solution of two or more chemicals (such as urethanes, sodium silicate) that react to form a gel. This grout opposed to cement grouts that consist of suspension of solid particles in a fluid.
- Advantages of chemical grout include applicability in moist environment and their ability to be applied in very fine facture.
- Disadvantage is high degree of skill needed for satisfactory use and their lack of strength.
- Crack as narrow as 0.05 mm can been filled with chemical grout.

5. Grouting

- same manner as the injection of an epoxy
- cleaning the concrete along the crack
- installing built-up seats at intervals along the crack
- sealing the crack between the seats with a cement paint or grout
- flushing the crack to clean it and test the seal; and then grouting the whole

GROUTING

Grouting is a process of injecting mixture of cement, sand water at high pressure in the cracks, joints, voids etc.

Purpose of grouting:

- To strengthen the porous Concrete
- To prevent the seepage in dam and water retaining structures
- To fill the cracks in concrete structure

GROUTING

Procedure for grouting:

Drilling of Grouting holes

For drilling grouting holes, equipment's like jack hammer, diamond drill, shot drill etc are used. The choice of type of drilling equipment depends upon the type of stone, size of hole and depth of hole.

Arrangement of grout pipes

Grout pipes or packer of 4 to 5 cm dia and 45 to 90 cm length are inserted in the grout holes. The space surrounding the pipe is filled with cement mortar. The top end of the pipe is connected to the pump.

Cleaning of cracks

Before injecting grout mixture in the cracks, it is necessary to clean the cracks.

Inserting grout in holes

Normally grout is inserted in the holes at a pressure 0.65kg/cm2 per m depth hole.

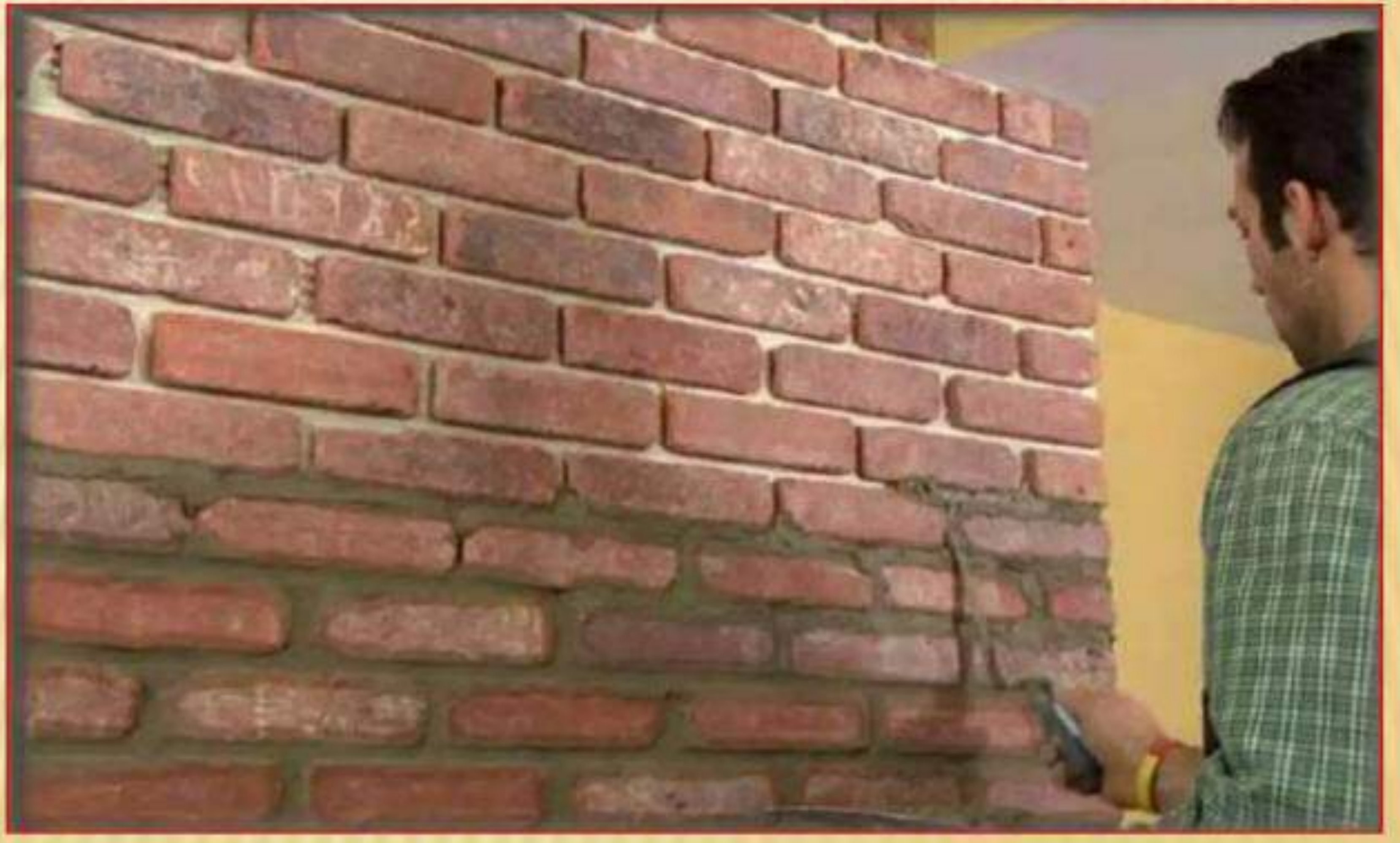
TYPES OF GROUTING

- Based on grouting material used, there are three methods:
- Portland Cement Grouting
- Chemical Grouting
- Epoxy Grouting

PORTLAND CEMENT GROUTING

- This type of grouting is particularly used in dams and thick walls.
- This method is effective in preventing water leakage.
- First of all clean the cracks by air jetting or water jetting.
- Flushing the crack to clean it.
- Installing grout at suitable interval and seal the crack .
- Then grout the whole area.
- Grout mixtures may contain cement and water or cement plus sand and water,depending upon the width of crack
- Water reducers or admixtures may be used to improve the properties of the grout.
- For large volumes , a pump is used and for small volumes ,a manual injection gun may be used for injection of grouting.
- After the crack is filled, the pressure should be maintained to ensure proper penetration of grout.

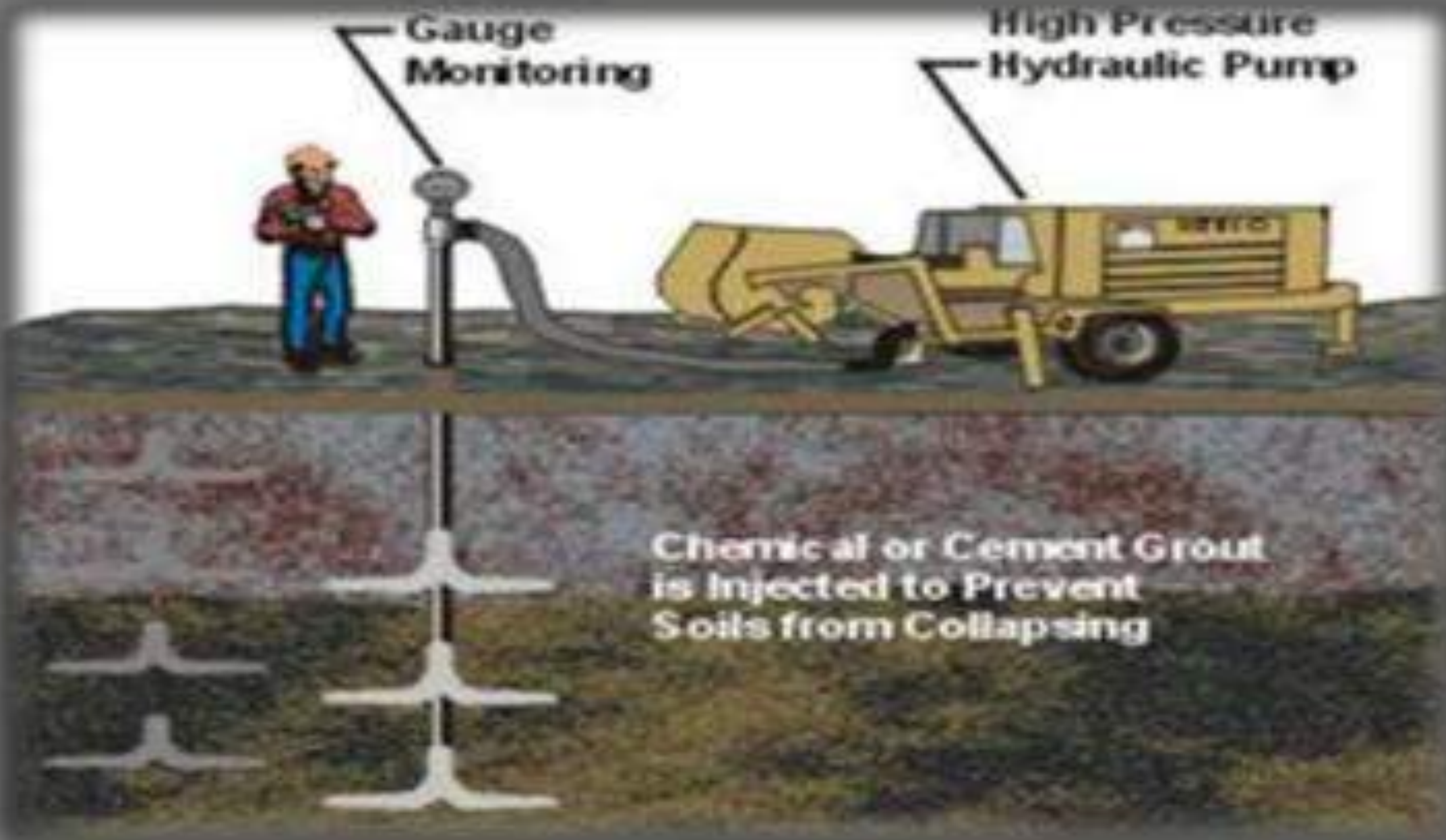
PORTLAND CEMENT GROUTING



CHEMICAL GROUTING

- Chemicals used for grouting are sodium silicates, urethanes and acrylamides. Two or more chemicals are combined to form gel, a solid precipitate or a foam as opposed to cement grouts that consists of suspension of solids particles in a fluid. The advantages of chemical grouts include applicability in moist environments and their ability to be applied in very fine cracks.

Chemical Grouting



BEFORE AFTER

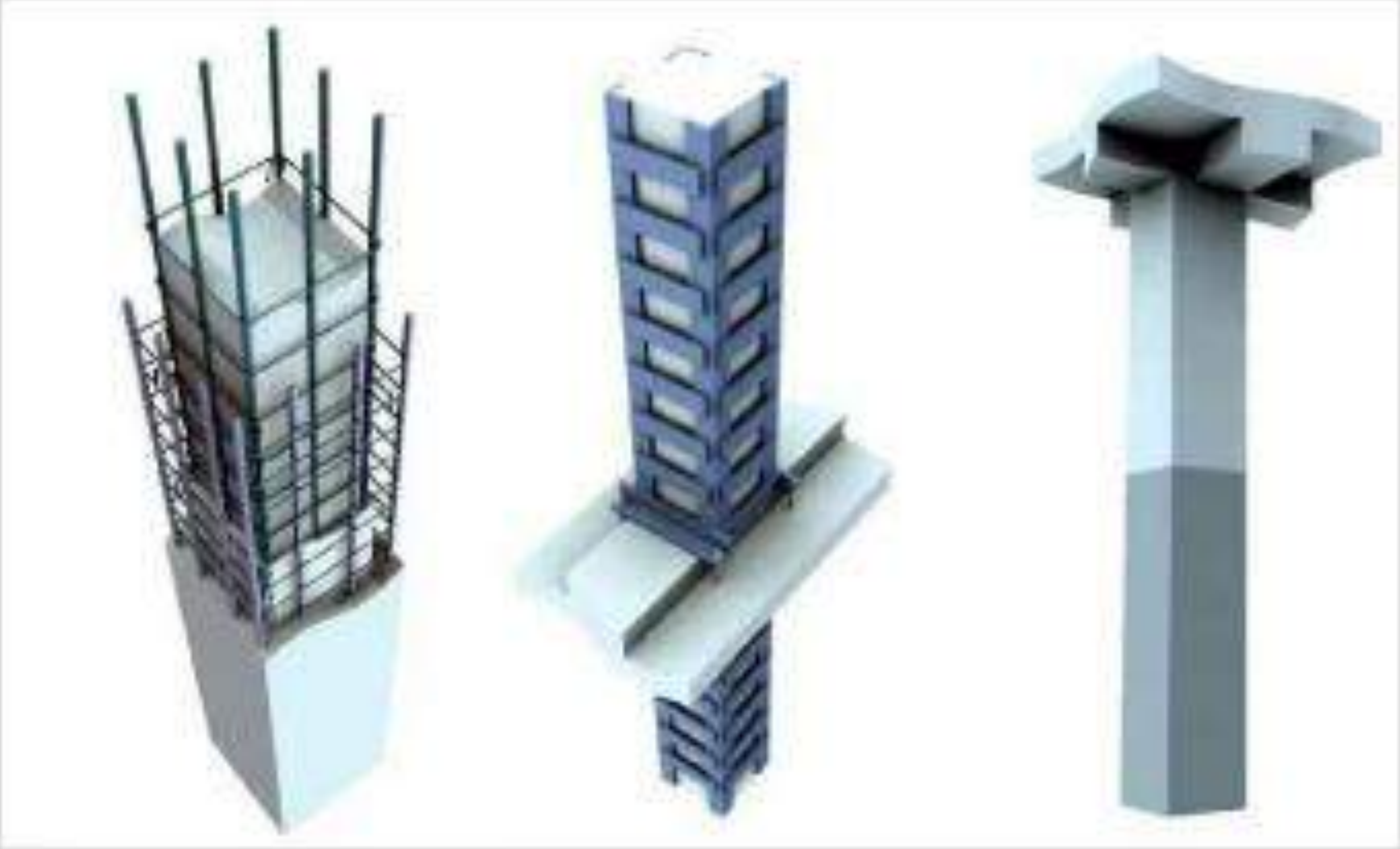
Column Jacketing

- Column Jacketing is done to improve the load carrying capacity of the column. The procedure followed is:
- Open the footing of the column by excavating soil around it.
- Remove the plaster from the surface of the column.
- Make the surface of column concrete rough by sand blasting.
- Remove the corroded bars by cutting them. Add new bars from footing to the slab as per the instruction of engineers.
- Apply bonding agent on the old concrete for proper bonding between old and new concrete.
- Erect necessary shuttering around the column.
- Pour minimum M-25 grade of concrete, vibrate and cure it.

Column Jacketing

Column Beam Junction

- The techniques of columns strengthening:



Concrete jacket Steel jacket FRP jacket

COMPOSITION OF FRP

RESINS

POLYSTER

VINYLESTER

EPOXY

FIBRES

GLASS

CARBON

ARAMID

CARBON FIBER REINFORCED POLYMER

Type of composite material in which carbon constitutes the fiber phase.

- High performance fiber polymer.
- It contains 93 to 95% of carbon.
- Each fiber is 5 to 10 microns in diameter.
- Twice as stiff as steel and five times as strong as steel.
- It is used to make aircrafts, spacecraft parts, racing car bodies, bicycle frames etc.,

USE OF CFRP IN STRUCTURAL STRENGTHENING

CFRP STRIPS

- Performance of CRPF strips depend on the strength of adhesive used to bond the strips to the concrete surface.
- Strong, ductile and durable structural system can be achieved.
- These are four times stronger than structural steel.

CFRP WRAPS

- Mainly used for corrosion control and retrofitting of rcc members.
- resistance to collapse under earthquake loading
- In a circular column an increase in axial capacity is also achieved by wrapping.
- the confinement of the CFRP wrap enhances the compressive strength of the concrete and increase in load bearing strength.
- Immediate strength gain and open to traffic.

The most common methods for columns' strengthening in Egypt are concrete or steel jackets

Structural engineers don't prefer using FRP jackets because of :

1-high cost 2-lacking of trained workers 3-weakness of fire protection.

There is still a need of design equations to refine the design of strengthening.

So this work focused on the analysis of concrete and steel jackets to :

1- Get simple equations for design.

2- Perform experimental investigation.

3- Compare theoretical analysis by experimental work to validate the refined equations.

➢ The two types of columns jackets were used at sites :

Concrete jacket

The cage

- Reinforced concrete jacket:

Advantages:

economy, compatibility with the original concrete substrate, and the ability to enhance durability and impact fire protection.

Disadvantages:

the loss of floor space due to enlargement of the column cross-section, and difficulties in casting and compacting.

- Steel jacket:

Advantages:

increase the confinement, capacities, ductility and stiffness. Steel jackets/cages have also advantageous due to their light weight and insignificant increase in cross sectional area of the column compared to concrete jackets.

Disadvantages:

Compared to concrete jacket: More expensive and weaker at fire protection.

1. Jacketing

- primarily applicable to the repair of deteriorated columns, piers and piles
- Jacketing consists of restoring or increasing the section of an existing member, principally a compression member, by encasement in new concrete
- The form for the jacket should be provided with spacers to assure clearance between it and the existing concrete surface

- The form may be temporary or permanent and may consist of timber, wrought iron, precast concrete or gauge metal, depending on the purpose and exposure

- Timber, Wrought iron Gauge metal and other temporary forms can be used under certain conditions

- Filling up the forms can be done by pumping the grout, by using prepacked concrete, by using a tremie, or, for subaqueous works, by dewatering the form and placing the concrete in the dry

- The use of a grout having a cement-sand ratio by volume, between 1:2 and 1:3 , is recommended

- The richer grout is preferred for thinner sections and the leaner mixture for heavier sections

- The forms should be filled to overflowing, the grout allowed to settle for about 20 minutes, and the forms refilled to overflowing

- The outside of the forms should be vibrated during placing of the grout

4. External stressing

- cracks can be closed by inducing a compressive force, sufficient to overcome the tension and to provide a residual compression
- The principle is very similar to stitching, except that the stitches are tensioned; rather than plain bar dogs which apply no closing force to the crack
- Some form of abutment is needed for providing an anchorage for the prestressing wires or rods

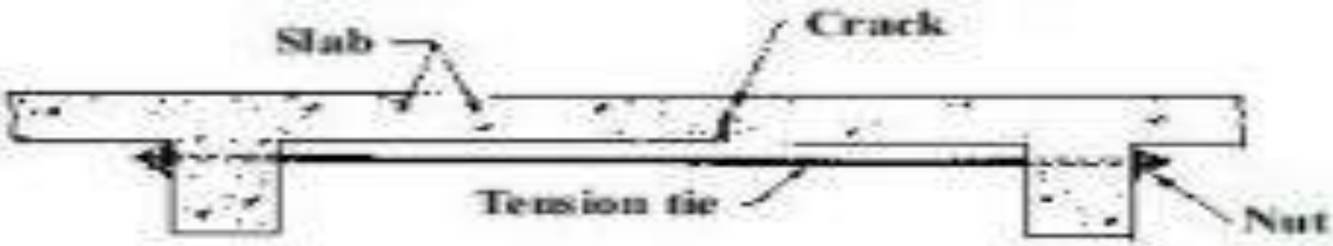
4. EXTERNAL STRESS

- The development of cracking is due to the tensile stress ,thus can be arrested by suppressing this stress
- Cracks can be closed by inducing a compression force to over come the tensile stresses
- The compressive force is applied by

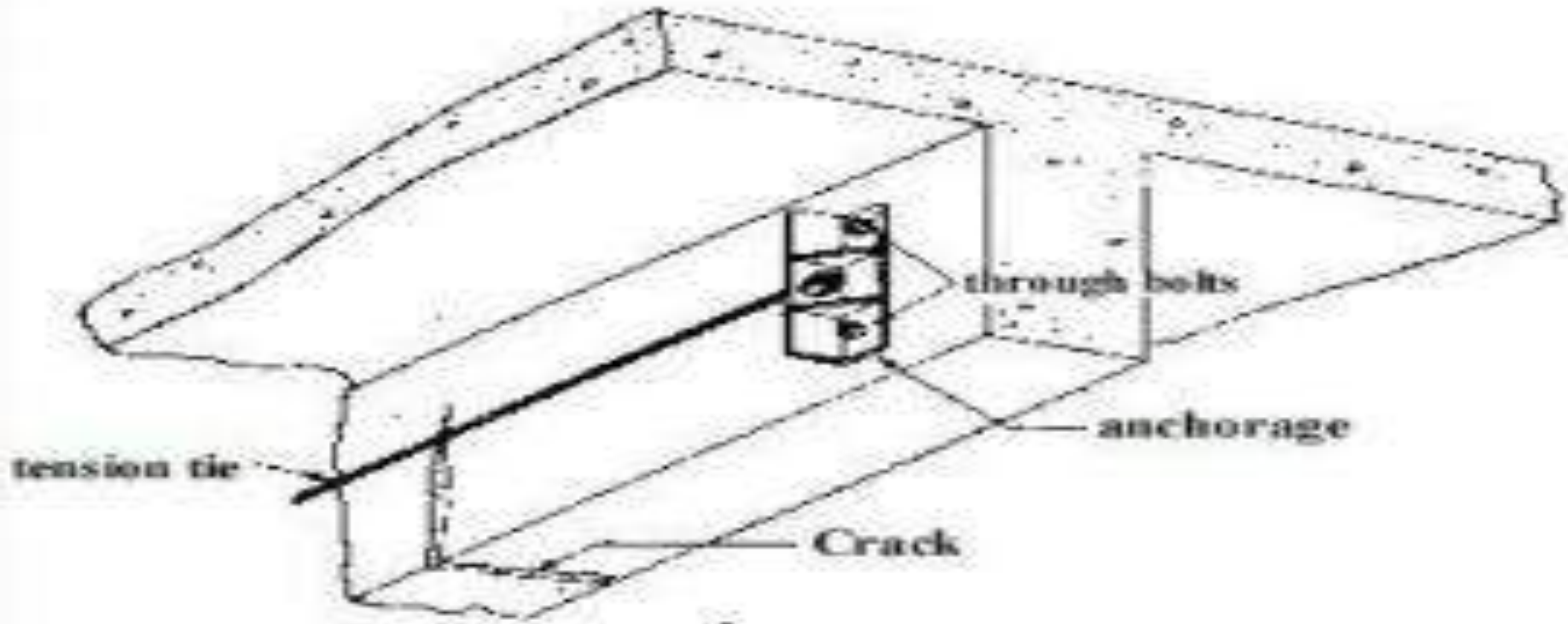
1. Pre-stressing wires or rods
2. Wedging – by opening the cracks and filling with expanding mortar,by jacking and grouting or by actual driving wedges

REPAIR BY PRESTRESSING STEEL

- When a major portion of a member is to be strengthened, or a crack is to be closed, post-tensioning is often the desirable solution. The technique uses prestressing strands or bars to apply a compressive force. Adequate anchorage must be provided for the prestressing steel. The method of correction crack in slab and beam.



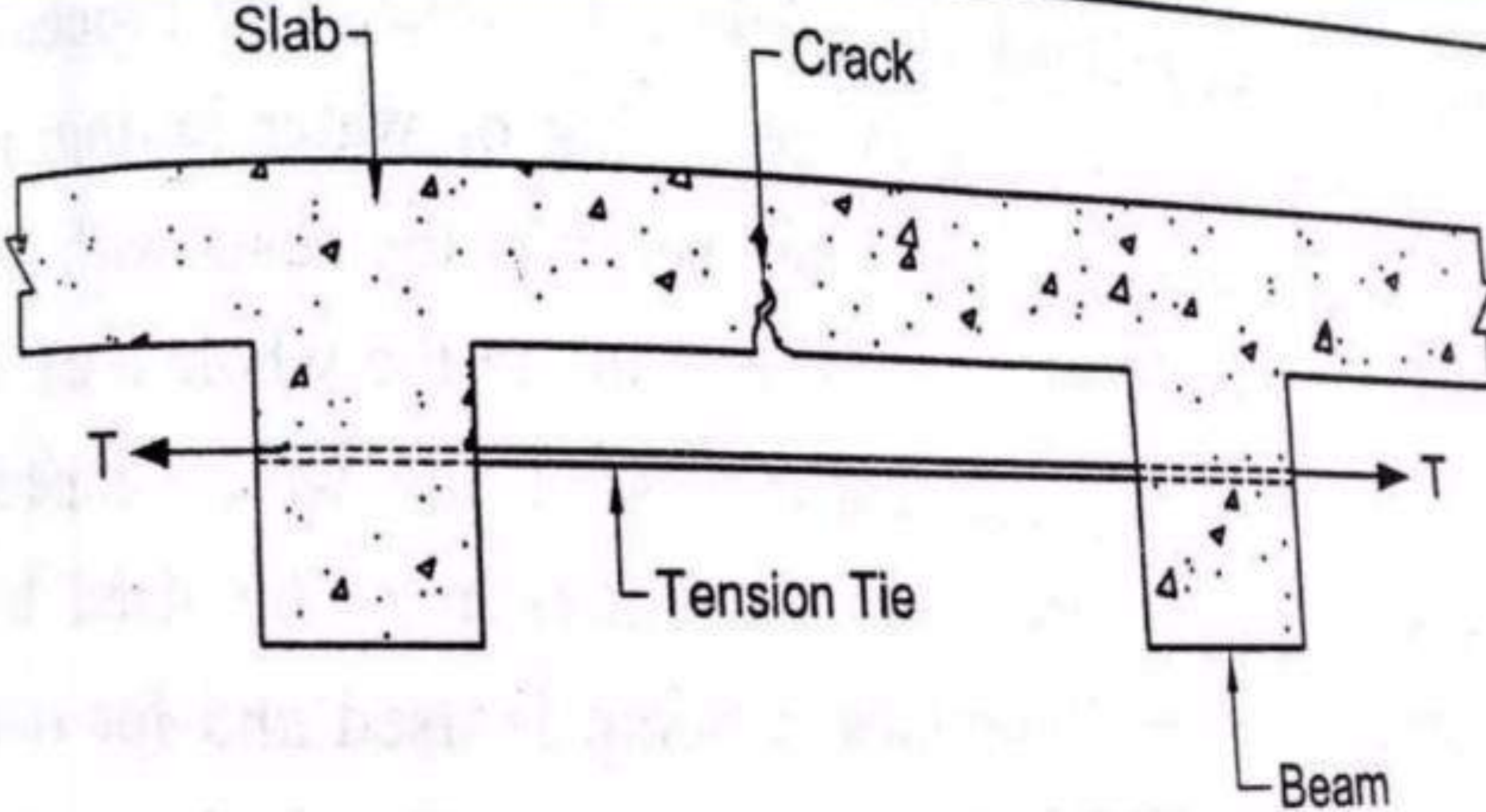
a) to correct cracking in beams



b) to correct cracking in slabs

Fig. 4 External stressing

REPAIR BY PRESTRESSING STEEL



(a)To correct cracking of slab

Cracking Repair by Prestressing Steel

- When a major portion of a member is to be strengthened, or a crack is to be closed, post-tensioning is often the desirable solution. The technique uses prestressing strands or bars to apply a compressive force. Adequate anchorage must be provided for the prestressing steel. The method of correction crack in slab and beam.

Cracking Repair by Pre-stressing Steel

Providing Additional Reinforcement

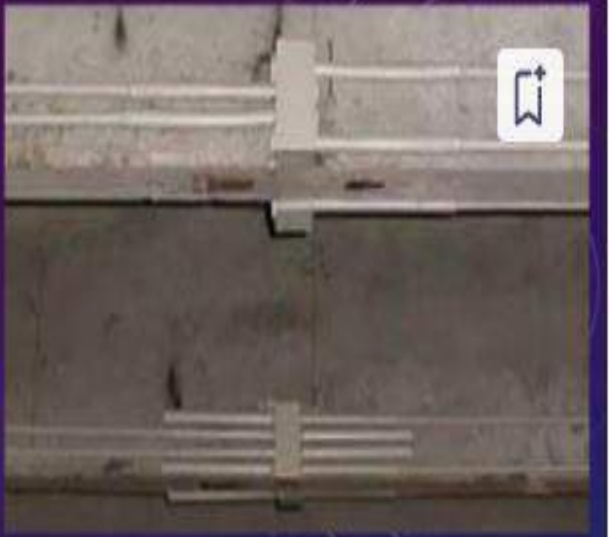
- The cracked reinforced concrete bridge gird can be successfully repaired by using epoxy injection and reinforcing bars. This techniques consists of sealings the crack, drilling holes of 20 mm diameter that intersect the crack plane at approximately 90 ^{0}, filling the hole and crack with injected epoxy and placing a reinforcing bar into drilled hole. Typically, 12 to 16 mm diameter bars extending at least 500 mm on each side of the crack are used. The epoxy bonds the bar to the sides of the hole. The epoxy used to rebond the crack should have a very low viscosity.

EXTERNAL POST TENSIONING.

- High strength steel strands or pre-stressing tendons are used.
- Tendons are pulled and connected to anchor points on member.
- Very much suitable for retrofitting of bridges.

Advantages

- Ability to restress, destress and exchange any external pre-stressing cable.
- Crack free members.
- Reduce deflection.
- High fatigue and impact resistance.



CONTD.

Disadvantages

- Usually requires a greater section depth.
- Exposed to environmental influences.
- Handling of the tensioning devices may be more difficult.
- High cost.

Need of Structural Strengthening for Structures

Concrete structures need to be strengthened for any of the following reasons

1. Load increases due to higher live loads, increased wheel loads, installations of heavy machinery, or vibrations.
2. Damage to structural parts due to aging of construction materials or fire damage, corrosion of steel reinforcement, and/or impact of vehicles.
3. Improvements in suitability for use due to limitation of deflections, reduction of stress in steel reinforcement and/or reduction of crack widths.
4. Modification of structural system due to elimination of walls/columns and/or openings cut through slabs.
5. Errors in planning or construction due to insufficient design dimensions and/or insufficient reinforcing steel.

Factors Affecting Selection of Strengthening Method

There are many factors which govern during selecting material and methods for strengthening, some of them are following-

1. **Environmental conditions-** When we are using adhesives for strengthening, then it might be unsuitable for applications in high temperature environments.

When we are using external steel for strengthening, it may not be suitable in corrosive environments.

2. **Size of project-** methods involving special materials and methods may be less cost-effective on small projects
3. **In-place concrete strength and substrate integrity-** the effectiveness of methods relying on bond to the existing concrete can be significantly limited by low concrete strength.
4. **Dimensional/clearance constraints-** Section enlargement might be limited by the degree to which the enlargement can encroach on surrounding clear space.
5. **Operational constraints-** Methods requiring longer construction time might be less desirable for applications in which building operations must be shut down during construction. Construction cost, maintenance costs, and life-cycle costs also affect.
6. Availability of materials, equipment, and qualified contractors.

Methods of Shear Strengthening Technique

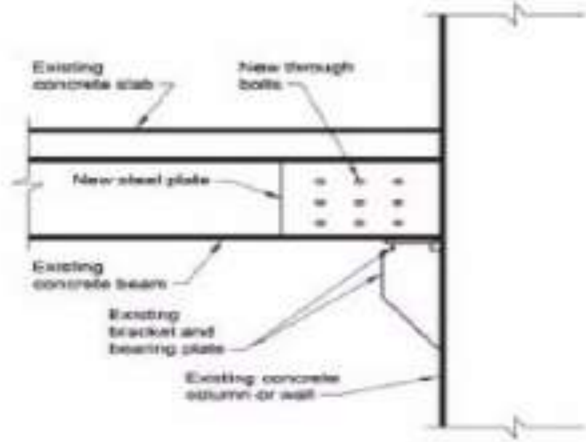
Shear strengthening is required for structural members when the shear stress applied is higher than the corresponding design shear resistance.

$$V_{sd} \leq V_{rd}$$

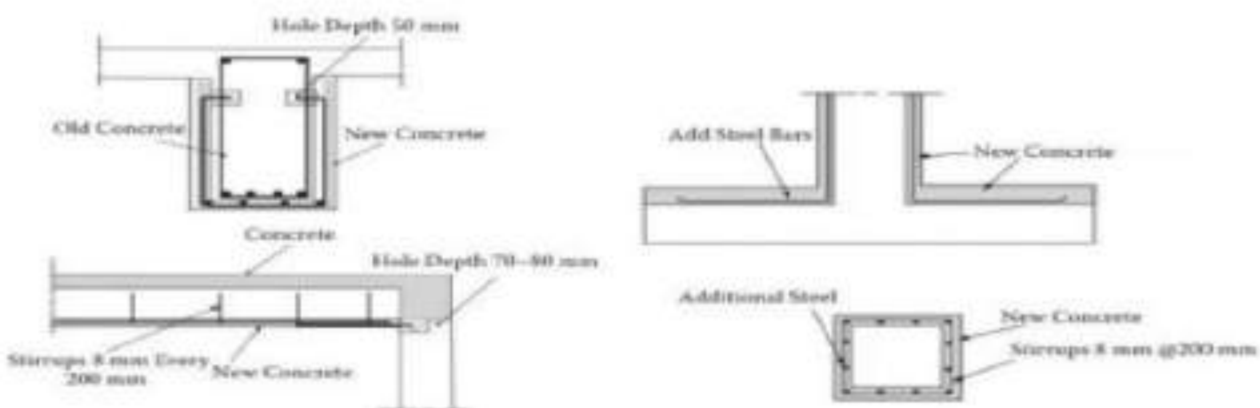
For strengthening there is a lot of method are available which can be applied based on requirement. For example-

1. External steel reinforcement
2. Section enlargement
3. Internal steel and FRP reinforcement
4. External and internal post Tensioning
5. Supplemental members
6. FRP plates or strips
7. Near-surface-mounted reinforcement

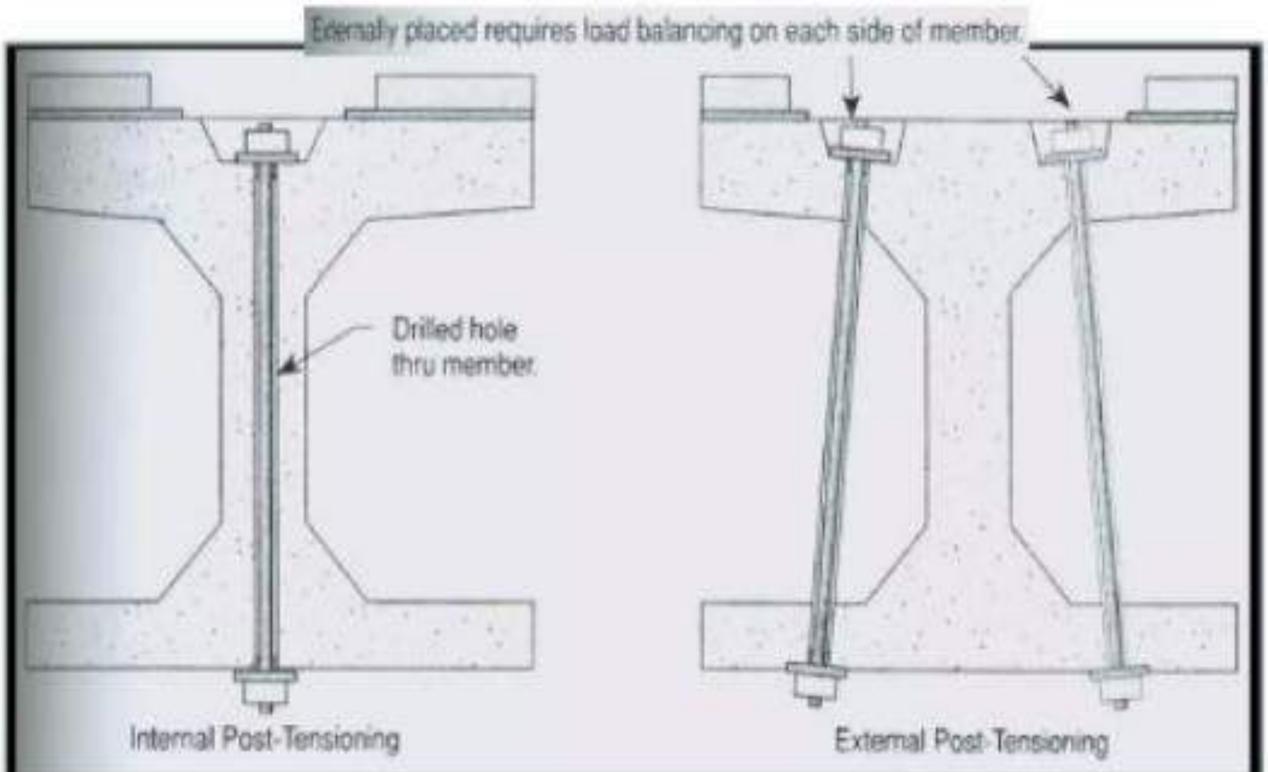
External steel reinforcement- The shear capacity of concrete members, such as columns, beams, slabs, and shear walls, can be increased by attaching steel plates to the concrete surface with epoxy bonding, mechanical anchorage, or both.



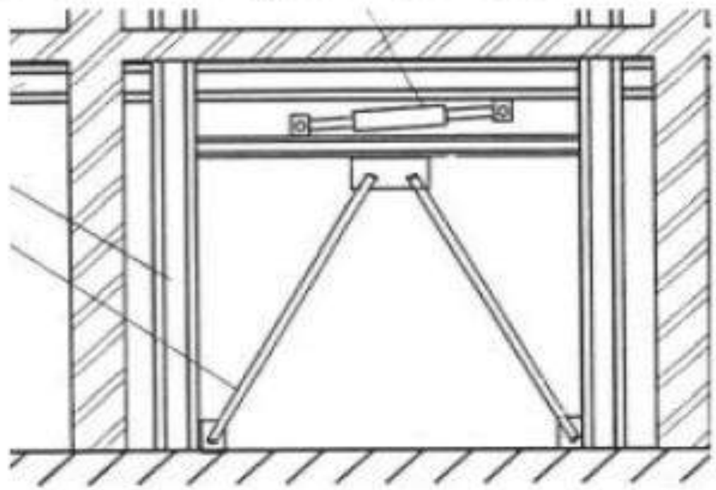
Section enlargement- This method of strengthening involves placing additional "bonded" reinforced concrete to an existing structural member in the form of an overlay or a jacket. With section enlargement, columns, beams, slabs, and walls can be enlarged to increase their load-carrying capacity or stiffness. For example, columns can be strengthened by using jackets, beams by increasing the section, shear walls by increasing the wall thickness.



External and internal post Tensioning - The post-tensioning technique has been used effectively to increase the flexural and shear capacity of both reinforced and prestressed concrete members. The post-tensioning forces are delivered by standard pre-stressing tendons or high-strength steel rods. Usually located outside the original section.



Supplemental members- Supplemental structural members, such as posts or beams, can be added to reduce shear stress. When architectural constraints allow, this can often be a cost-effective and practical solution.



FRP plates or strips - FRP materials may be used as either externally bonded plates or strips. The advantage of using strips is that they do not entrap moisture in the structure and more closely resemble conventional shear reinforcement. The advantage of FRP material is light in weight- easy to install, High strength- 5 times of steel, Corrosion resistant- durable structure and highly versatile- it suit for any project.

Polymer material which can be used with structural fiber - fiberglass(GFRP), Carbon fiber(CFRP), Aramid fiber. The FRP is typically bonded to concrete with a structural grade epoxy. FRP can be wrapped around the member by many mechanism, for example complete wrapping, U-wrap, side bonding.

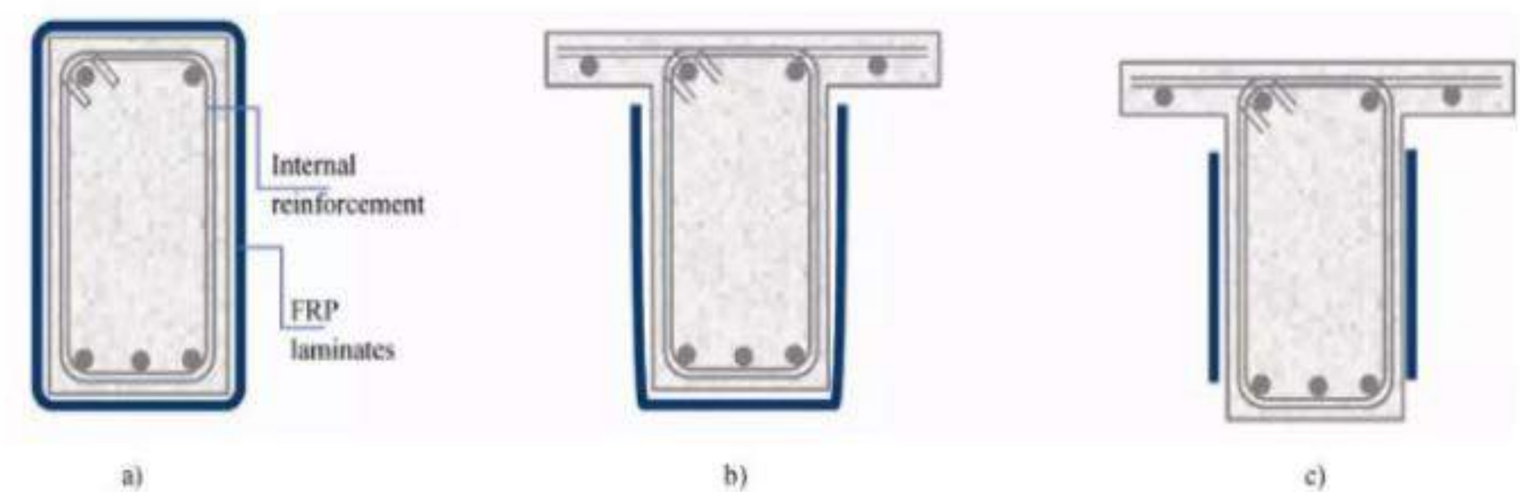


Fig. 1. Wrapping schemes for externally bonded FRP laminates; (a) complete wrapping, (b) U-Wrap and (c) side bonding

What is SEALANT?

- The Layman's definition of 'SEALANT' is "any material placed in a joint opening generally for the purpose of weather proofing a building, so designed to prevent the passage of moisture, air, dust, and heat through all joints and seams in the structure."

OR

- The ASTM Committee C-24 definition for 'SEALANT' is "in building construction, a material that has the necessary adhesive and cohesive properties to form a seal."

Functions

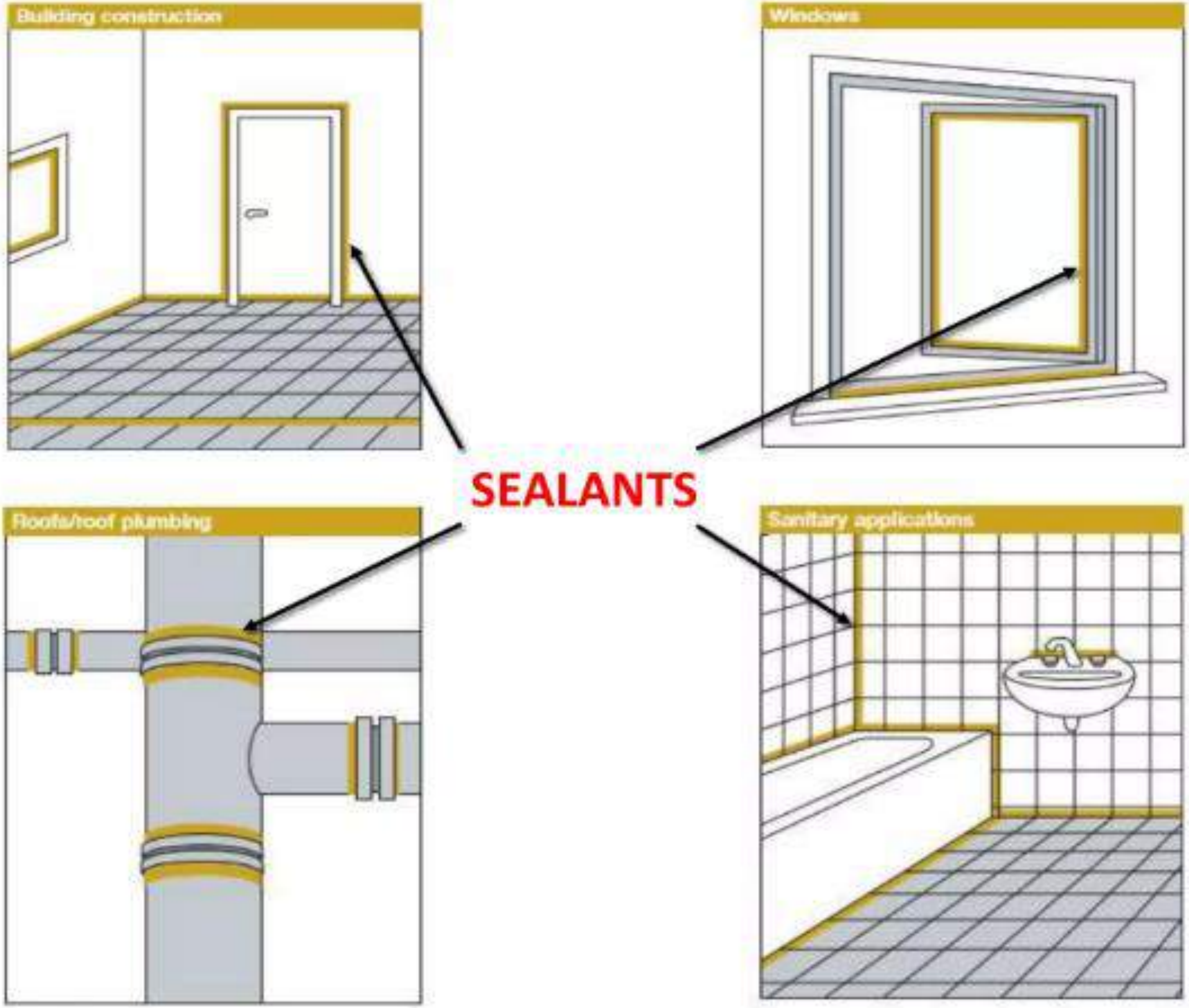
- Sealants, despite not having great strength, convey a number of properties. They seal top structures to the substrate, and are particularly effective in waterproofing processes by keeping moisture out (or in) the components in which they are used.
- They can provide thermal and acoustical insulation, and may serve as fire barriers.
- They may have electrical properties, as well. Sealants can also be used for simple smoothing or filling.
- They are often called upon to perform several of these functions at once.
- A corking sealant has three basic functions: It fills a gap between two or more substrates; it forms a barrier through the physical properties of the sealant itself and by adhesion to the substrate; and, it maintains sealing properties for the expected lifetime, service conditions, and environments.
- The sealant performs these functions by way of correct formulation to achieve specific application and performance properties.

BEFORE

AFTER

Applications

- Horizontal and vertical metal-to-metal and masonry-to-masonry expansion and control joints
- Dissimilar material joints, such as metal-to-masonry or concrete-to-wood
- Joints between precast concrete façade panels
- Spandrels
- Perimeter of doors and fixed window frames
- Exposed exterior masonry control joints
- Expansion or control joints in curtain wall
- Joints in exterior walls
- Concealed masonry-to-floor structure joints
- Repair of larger cracks


Building construction
Windows
SEALANTS
Roofs/roof plumbing
Sanitary applications

Types of Construction Sealants

- Silicone Sealants
- Epoxy
- Hybrid Polyurethanes Sealants
- Polyurethanes Sealants
- Elastic Sealants
- Varnish
- Acrylic Latex Sealants
- Bituminous Sealants
- Synthetic Rubber Sealants
- Thermoplastics Sealants
- Butyl Sealants
- Hot Wax
- Proof Sealants
- Polysulfide Sealants

Butyl Sealants

Epoxy Sealants

Advantages

- Improves Product Durability and Reliability.
- Increases Product Performance.
- Increases Design Flexibility.
- Increases Product Quality.
- Enhances Product Aesthetics.
- Improves Process Productivity and Reduced Manufacturing Costs.
- Increases weathering characteristics.

Common Problems OR Disadvantages

- Deterioration of sealants causes due to prolonged exposure to water, ultraviolet light, and freeze-thaw cycles.
- Loss of Adhesion caused by the presence of coatings or contaminants that prevent proper adhesion.
- Cohesive failure due to deterioration of the internal integrity of the sealant; cracking parallel to the interface of the joint is an indication of this type of failure.
- Inappropriate Choice of Sealant and Improper Joint Design may fail the joint and losses the adhesion.
- Uncured Sealant that is uncured is often due to incomplete or improper mixing of the sealant components, or from using materials that have outlived their shelf life losses the adhesion and fails the joints.
- Bubbling and Blistering of the Surface losses the adhesion and fails the joints.

What is Cathodic protection?

- Cathodic protection (CP) is a method of corrosion control that can be applied to buried and submerged metallic structures.
- It is normally used in conjunction with coatings and can be considered as a secondary corrosion control technique.
- Cathodic protection can, in some cases, prevent stress corrosion cracking.

Principle involved

- The principle of cathodic protection is to prevent anodic sites occurring on the structure under protection by allowing the anodic reactions to occur on specially designed and installed anodes

Discription:

- The simplest method to apply CP is by connecting the metal to be protected with another more easily corroded "sacrificial metal" to act as the anode of the electrochemical cell.
- The sacrificial metal then corrodes instead of the protected metal. For structures where passive galvanic CP is not adequate, for example in long pipelines, an external DC electrical power source is sometimes used to provide current.
- Cathodic protection systems are used to protect a wide range of metallic structures in various environments. Common applications are; steel water or fuel pipelines and storage tanks such as home water heaters, steel pier piles; ship and boat hulls; offshore oil platforms and onshore oil well casings and metal reinforcement bars in concrete buildings and structures. Another common application is in galvanized steel, in which a sacrificial coating of zinc on steel parts protects them from rust.
- Another method of protection impresses a small direct current on a structure.

UNIT-III

REPAIRS TO TIMBER AND STEEL STRUCTURES

Testing of Timber Structures for rots, Creosote retention, Planning for repairs in Timber Structures- Repairs to Timber Structures, Dynamic Loading and Fatigue, welding technology, weldability, Cleaning and surface Preparation of Corroded Structural Steel, replacement and addition of new members, different Types of Steel and Composite Joints.

Introduction

- Wood: One of the best engineering materials
- Used in almost all fields of engineering
- Used by man since pre-historic times
- Common applications: Building construction, railways, agricultural, mining and navigation industries.







Advantages of Timber

- Stronger than other construction materials in proportion of weight
- Workable: Can be easily worked to any size and shape
- Lightweight
- Economical: wastage is minimum
- Durable
- Non-conductor of heat and electricity.

Some Technical Terms

I. **Standing timber**: the timber in the form of a living tree

II. **Green timber**: the freshly felled tree which has not lost much of its moisture

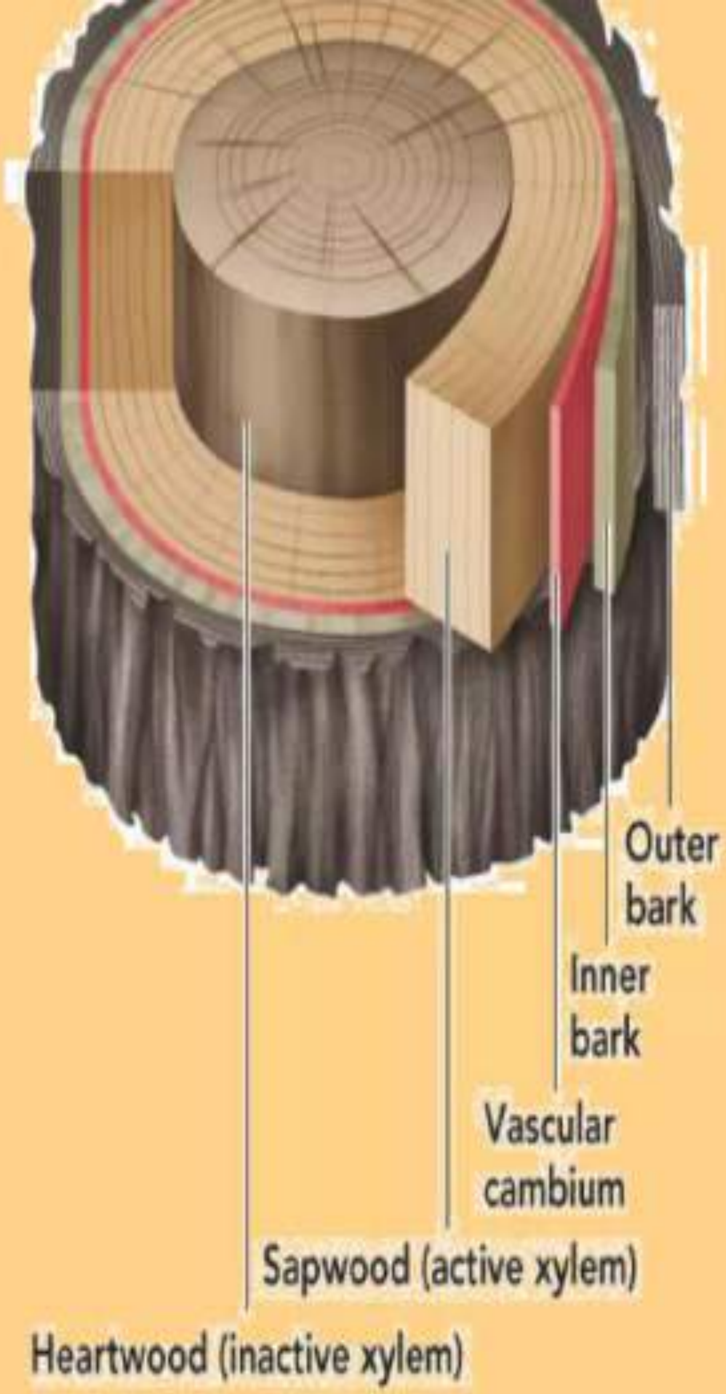
III. **Rough timber**: the timber in the form of a felled tree

IV. **Converted timber**: the timber when sawn into various market sizes like beams, battens, planks etc.

V. **Dressed timber**: Timber which has been sawn, placed and worked to the exact required condition.

VI. **Structural timber**: Timber used in framing and load bearing structures

VII. **Clear timber**: Timber clear from defects and



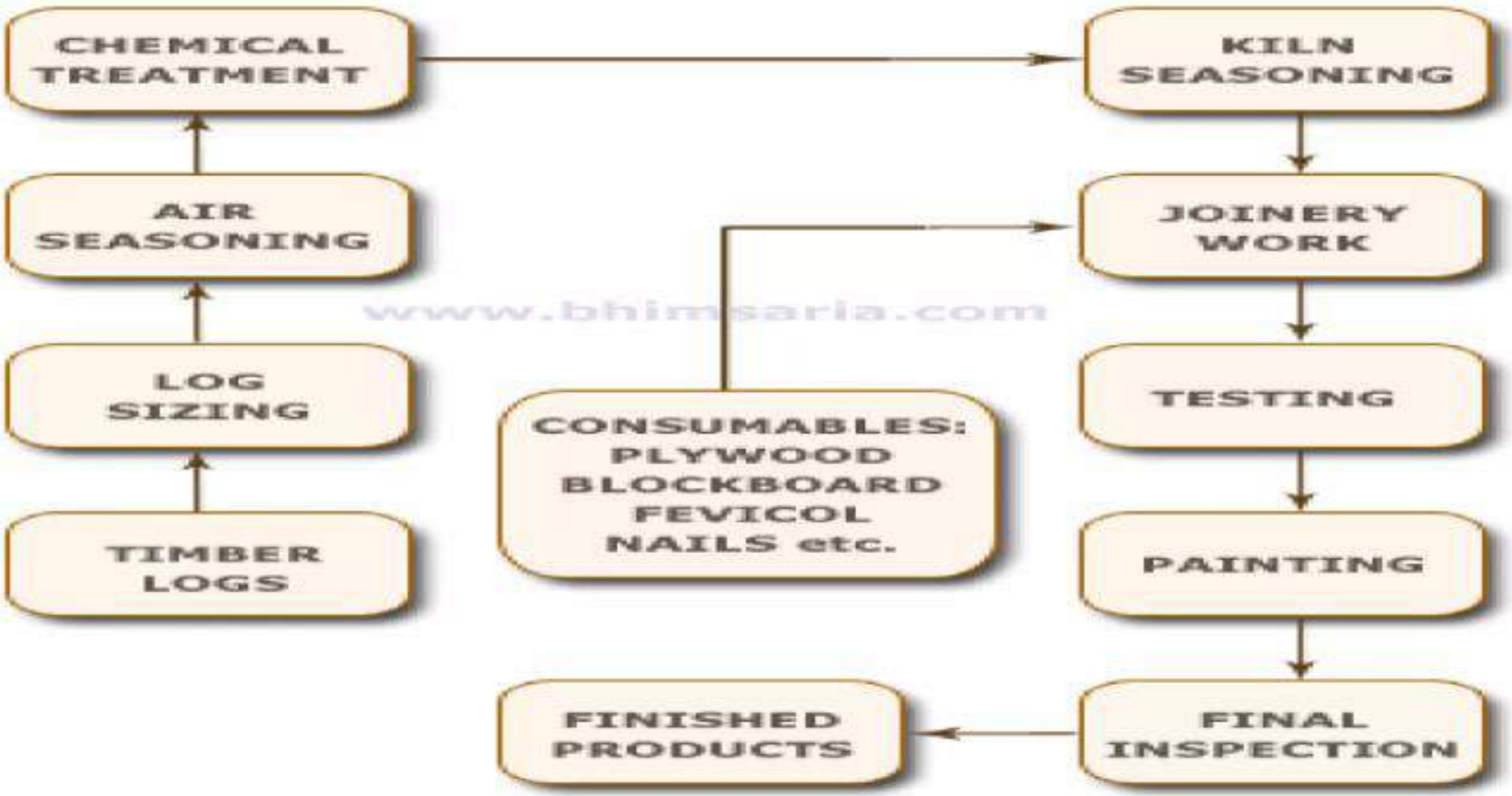
Characteristics of Timber

Sapwood / Heartwood

- **Sapwood** contains cells still used to transport nutrients
- Cells and vessels are open.
- Contains starches used as “food” for the tree – also used as food for insects and fungi – lower durability
- Cell walls increasing in thickness as tree grows

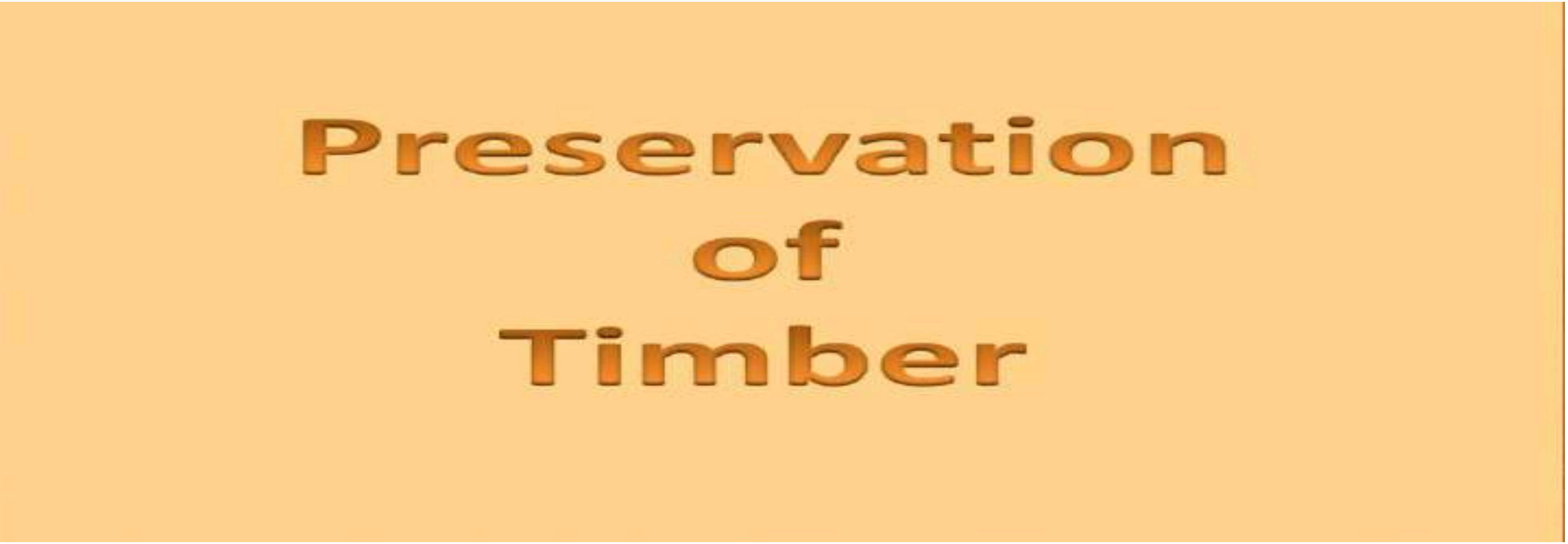
- **Heartwood** contains blocked cells and is used for waste disposal and strength
- Cells and vessels closed
- Contains waste products from tree growth – extractives – many are harmful to insects and fungi – gives natural durability
- Cell wall thickness stable

PROCESS FLOW CHART



CREOSOTE RETENTION

Creosote is derived from the distillation of tar from wood or coal and is used as a wood preservative. Pesticide products containing creosote as the active ingredient are used to protect wood used outdoors (such as railroad ties and utility poles) against termites, fungi, mites and other pests.



Requirements of a good preservative:-

- Cheap and easily available.
- Should allow coats of paints etc without discoloring.
- Highly penetrative.
- Should be of permanent nature.
- Should be extremely poisonous, even in small doses, fungi and other insects.
- Shouldn't reduce the strength of the timber and should be non corrosive to metals in contact.
- Should not catch fire easily.
- Shouldn't give bad smell
- Should not be injurious to workmen.

Types of Preservatives

1) Water-borne preservatives :-

Water is the most common solvent carrier in preservative formulations due to its availability and low cost.

I. **Chromated copper arsenate (CCA)** :- It consists of copper sulphate ($CuSO_4.5H_2O$),arsenic pentoxide ($As_2O_5.2H_2O$) and sodium dichromate ($Na_2Cr_2O_7.2H_2O$) in the proportion 3:1:4.

II. **Chromated zinc chloride** :- It consists of zinc chloride ($ZnCl_2$) and sodium dichromate in the ratio 1:1.

III. **Copper chrome boric composition** :- It consisits of boric acid (H_3BO_3), copper sulphate and sodium dichromate in the ratio 1.5:3:4.

IV. **Zinc meta arsenite** :- It consisits of arsenious trioxide (As_2O_3) and zinc oxide (ZnO) in the ratio 3:2.

V. **Acid cupric chromate composition** :- It consists of 1.68 parts of chromic acid (CrO_3), 50 parts of copper sulphate and 47.5 parts sodium dichromate.

VI. **Zinc chrome boric composition** :- It consists of 1 part of boric acid, 3 parts of zinc chloride and 4 parts of sodium dichromate in 100 parts of water.

2)Oil borne preservatives :-

These include pentachlorophenol and creosote. They are toxic, have an unpleasant odour and are generally not used in consumer products.

3) Organic solvent type preservatives:

These preservatives are available in the following forms-

1. Copper Napthenate and Zinc Napthenate.
2. Pentachlorephenal (Chlorinated derivative of phenol).
3. Benzene Hexa Chloride (Chloro compound of benzene).
4. Dichloro-diphenyl-trichloroethane (DDT).

4) Natural preservatives :-

I. Mud treatment :-

Wood and bamboo can be buried in mud to help protect it from insects and decay.
Used widely in Vietnam to build farm houses consisting of a wooden structural frame, a bamboo roof frame and bamboo with mud mixed with rice hay for the walls.

II. Heat treatment :-

There is ongoing research as to whether heat treatments can be used to make timber more durable.
By heating timber to a certain temperature, it may be possible to make the wood-fibre less appetizing to insects.
Heat treatment can also improve the properties of the wood with respect to water: lower equilibrium moisture, less moisture deformation, and weather resistance.

III. Tung oil :-

Known for hundreds of years in China, where it was used as a preservative for wood ships.

Oil penetrates wood and hardens to form an impermeable hydrophobic layer up to 5 mm into the wood.

Types of preservative treatment :-

I. Surface application or brush and spray method:-

This is done either by brush, spray or dipping the member in the preservative solution for a short period of time.

II. Soaking treatment:-

This treatment is carried out by submerging the timber in the preservative solution for a sufficiently long until the required penetration of the preservative is obtained. It is also known as steeping.

III. Boucherie process:-This type of treatment is done by attaching the butt end of a pole to rubber which is connected to a reservoir containing the preservative solution, placed at high level. Due to hydrostatic pressure, the preservative displaces the sap which is then forced out at the narrow end and required penetration is obtained.

IV. Pressure process:-

In this method, the cylinder is loaded with the timber and door is closed. Vacuum is created and maintained for half an hour so as to exclude as much air as possible from the wood cells. Then preservative is filled into the cylinder under pressure and i9s held until the desired absorption is obtained.

V. Hot and cold process:-

In this process, the timber is submerged in the preservative oil or solution which is heated to a suitable temperature and maintained at that temperature for a suitable period, depending on the change.

Some other methods of preservation :-

a. **Tarring :-**
It consists of coating the timber with coal tar while hot.

b. **Charring :-**
It is carried out at the lower ends of posts that are to be embedded in the ground to prevent dry rot and the attack of insects. It is done by charing to depth of 1.5 cm over a wood fire and then quenching the post with water.

c. **Painting or soligum treatment :-**
It protects the timber from the attack of white ants certain insecticides.

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Well Processed Wood

Sapwood	No sapwood at all on the surface, but very small portion is acceptable for the back side
Knot	No knots at all on the surface; but small young knot not bigger than 10mm in size and not more than two per 300mm on the back side, is acceptable
Crack	No crack at all for all surfaces
Color	Color variation may not be restricted among pieces, but color variation on single product must not be apparent
Grain	No restriction
Black resin	Thin and straight , but not dispersing into many different di'rection acceptable
Machine defect	Not allowed at all

Characteristics for Suitability of Timber

1. Strength
2. Toughness
3. Elasticity
4. Resistance to shear
5. Hardness
6. Fire resistance
7. Retention of shape
8. Durability
9. Workability

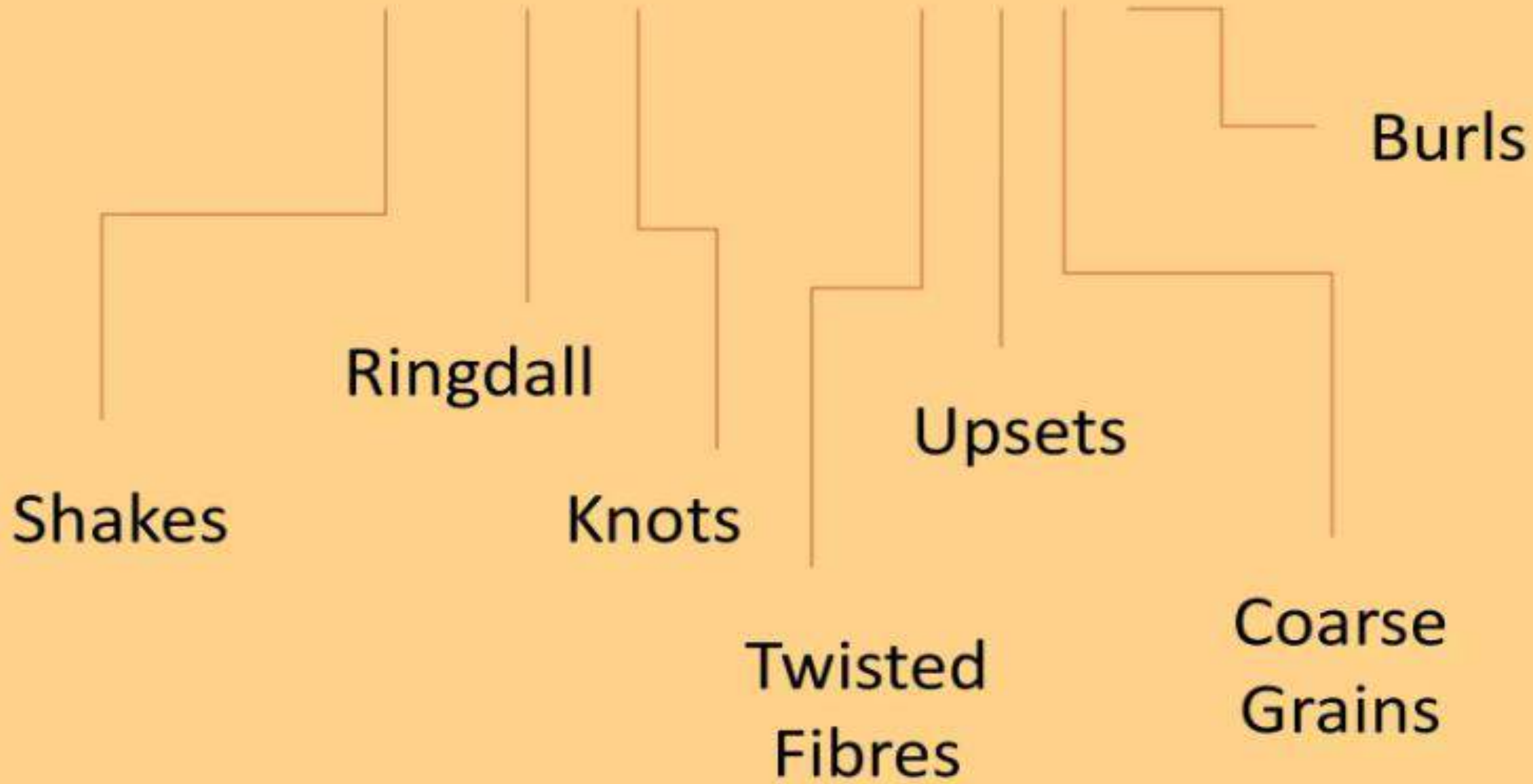
Requirements of Good Timber

I. It should have uniform colour and regular annual rings.
II. It should be from the heart of a sound tree and have straight fibres.
III. It should have bright appearance with a silky luster when planned.
IV. It should be sweet to smell when freshly cut.
V. It should be sonorous.
VI. It should be well seasoned and when cut with a saw, the surface should not clog the teeth of the saw.
VII. It should be free from natural defects.
VIII. It should not be affected by wood rotting, fungi and other insects.
IX. It should have firm adhesion of fibres and compact medullary rays.
X. It should be hard.
XI. It should be durable.
XII. It should be tough i.e., resistant to shocks.
XIII. It should be elastic.

Defects in Timber

- Natural defects developed during the growth of tree.
- Defects occurring after a tree is felled.

Natural Defects



a) **Shakes** :- The partial or complete separation between adjoining layers of tissues.

- Lower the resistance to shear
- Commonly formed in logs which are allowed to stand even after attaining maturity
- Indicate old age
- Caused due to the shrinkage of wood

Types of Shakes:

I. Heart shakes and star shakes

Radial ruptures in annual rings or splits radiating from the heart and extending towards the sapwood are called heart shakes

The shake occurring at near the pith and giving the appearance of a star at the end is called star shake

These shakes are caused by the quick drying of the central part of the tree.

II. Radial Shakes

The radial splits which extend from the bark towards the centre.

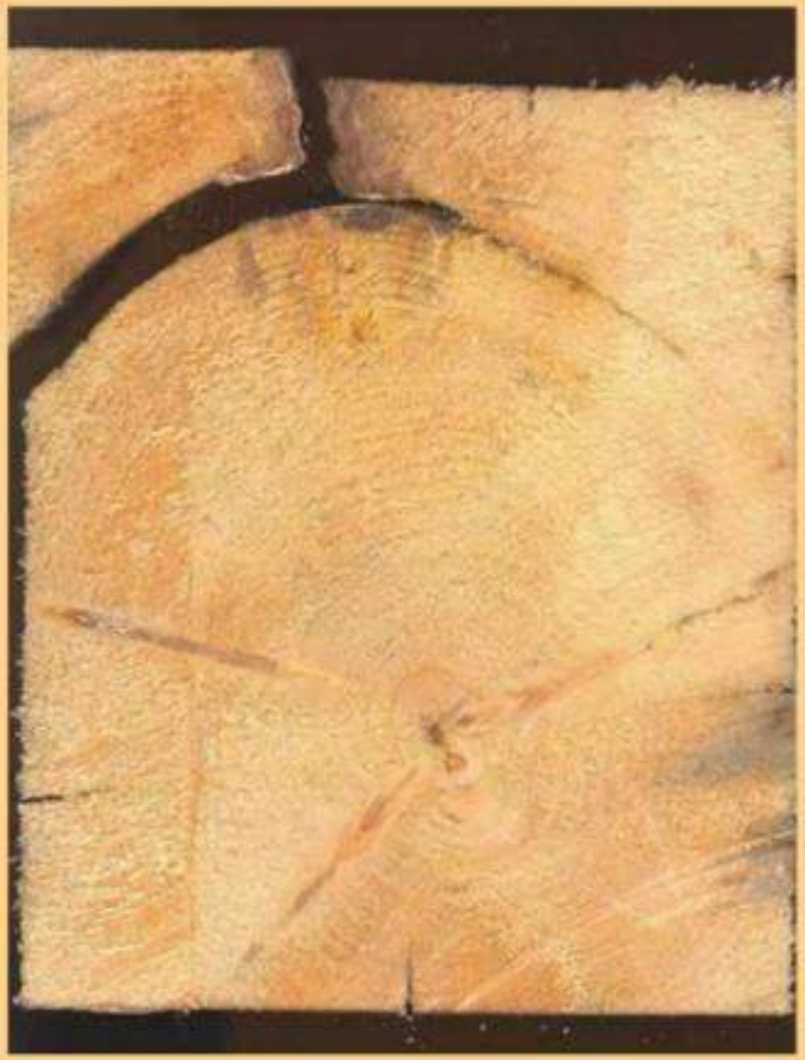
These are caused when the outer tissues dry faster than the inner ones.

III. Cup shakes or ring shakes

The openings along the growth rings are called cup shakes or ring shakes.

Caused due to sudden increase of moisture supplied

S H A K E



Splits and Checks

Splits

Extend through full width of timber

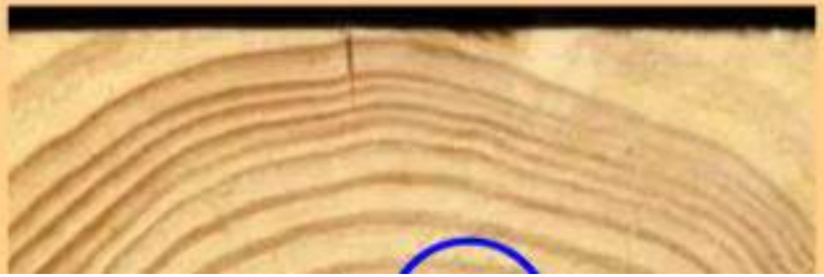
Can be caused by

- Aggressive drying
- Overstressing

Can be unsightly

Can cause reduction in strength

- Checks
- Shallow – do not extend through timber
- Can be caused by
  - Normal drying
  - Weathering
- Can normally be filled
- Have little effect on strength



Checking

A "Check" is a long crack that appears as the sap wood of a timber shrinks around the heart wood over time.

b) Rindgall: Curved swelling resulted from the growth of sap wood layers on wound, left by falling or cut off branch in an irregular manner

- caused because the new growth does not unite properly with the old wood and leaves a cavity where decaying action may set in

c) **Knots**: The dark hard pieces indicating places from where branches have been cut off

- When the knot is free from decay and is firmly intact its called live knot or sound knot.

- Knot which is not firm is called dead knot or loose knot.


centre


margin


edge


arris

d) Twisted fibres :-

The defect due to the fibres of tree which get twisted when young, by the force of wind is called twisted fibres.

e) Upsets :- The defect caused by crushing or by injury in wood fibres .

f) Burl/ burr/ excrescence:

The growth of a large excrescence bulge which is formed on the trunk or the branch of a tree due to certain injury inflicted when the tree is young is called burl, burr or excrescence.

g) Coarse grains:

The widening of annual rings due to rapid growth of certain trees is called coarse grains.

Want and Wane

Mechanical damage knocking off corner

Unsightly if on exposed corner

Discontinuity of grain can affect strength

Can have wane on timber cut from anywhere in tree – needn't be a sign of sapwood

- Piece is cut from outer part of tree so that part of corne is missing
- Can have rustic appearance
- Rarely affects bending strength, make affect bearing
- Shows that piece contains sapwood

Inclusions

- Bark
- Gum veins

Included bark

Defects occurring after the tree is felled

- Case Hardening
- Honey Combing
- Collapse
- Foxiness
- Twistiness & Bowling

Case hardening :- During kiln seasoning, the outer side of timber gets hard while the inner core remains still wet due to rapid surface drying .

Honey combing :- This defect is due to the separation of the tissues in the interior of timber of timber due to drying stresses, caused by incorrect kiln seasoning as the interior wood dries earlier than the external surface.

Collapse :- This defect is due to corrugated appearance of timber, caused due to excessive and uneven shrinkage during drying.

Foxiness :- This defect is due to the yellowish or reddish stains, caused by over maturity and lack of ventilation during storage.

Diseases in Timber

- Dry Rot
- Wet Rot
- Insects

Dry Rot

The turning of timber tissues to almost dry powder by fungi is called dry rot.
Eg. Of fungi :mushroom, spongy plant
The fungus feed upon the wood and eats the wood tissue, thus penetrating the wood fibres from all direction.

Prevention:

1.well seasoned timber should be used.
2.timber should be used where there is free circulation and access of air.

Remedy:

1.the timber should be painted with a solution of copper sulphate.
2.the high temperature of seasoning of kiln helps in killing the fungi.

Wet Rot

The disintegration of tissue of timber due to alternate wetting and drying is called wet rot.
The attacks take place through the wounds in bark by the access of water.

Prevention:

All timber for exterior or underground work should be first properly seasoned and then coated with tar to keep out the dampness.

Remedy:

The best remedy for treating wet rot is by using a suitable preservative.

Insects

Certain insects such as termites, larva etc causes decay of timber. They build up mud tunnels to keep their movements covered and continue their activity of eating into the wood under the surface.

Prevention:

1.damp proof condition

2.cement mortar in joints

3. well seasoned wood

Remedy:

1.suitable preservatives

2.Providing copper bottom to wood which comes in contact with water.

Common Market Forms of Timber

I. Log
II. Baulk
III. Bole
IV. Bolt
V. Billet
VI. Batten
VII. Plank
VIII. Board
IX. Cant
X. Deal
XI. Deal wood
XII. Hewn Timber
XIII. Pole
XIV. Post
XV. Scantling
XVI. Slat
XVII. Sleeper
XVIII. Strip

products

Veneer

Veneer refers to thin slices of wood, usually thinner than 3 mm (1/8 inch), that are typically glued onto core panels (typically, wood, particle board or medium density fiberboard) to produce flat panels such as doors tops and panels for cabinets, parquet floors and parts of furniture

Plywood

Plywood is a type of engineered wood made from thin sheets of wood, called plies or wood veneers. The layers are glued together so that adjacent plies have their grain at right angles to each other for greater strength

Plywood is specified by both faces, two letters; the first being the face veneer quality and the second the back veneer quality

STANDARD TESTS ON TIMBER SPECIMENS

STRENGTH

The strength of wood is its ability to resist external forces tending to alter its shape. These forces depending on the direction of application, may be compressive, tensile or shearing, hence there is the necessity of qualifying the strength- in compression, tension or shear. A timber specimen strong in one respect may not be equally strong in another, other things being equal, strength varies with density, conditions of seasoning, soundness and absence or presence of defects.

The results of laboratory tests have shown the strength properties of some of the timbers as under:

Exceptionally strong: *Mesua ferrea, Schleichera trijuga, Shorea robusta, Xylia dolabriformis.*

Extremely strong: *Anogeissus acuminata, Acacia nilotica, Grewia tiliaefolia, Terminalia alata.*

Very strong: *Tectona gradis, Anogeissus latifolia, Termnalia belerica.*

Strong: *Dalbergia latifolia and D.sissoo, Syzygium cuminii, Albizia lebbeck and A.procera.*

Moderately strong: *Adina cordifolia, Cedrus deodara, Cederla serrata, Chukrasia tabularis, Mangifera indica.*

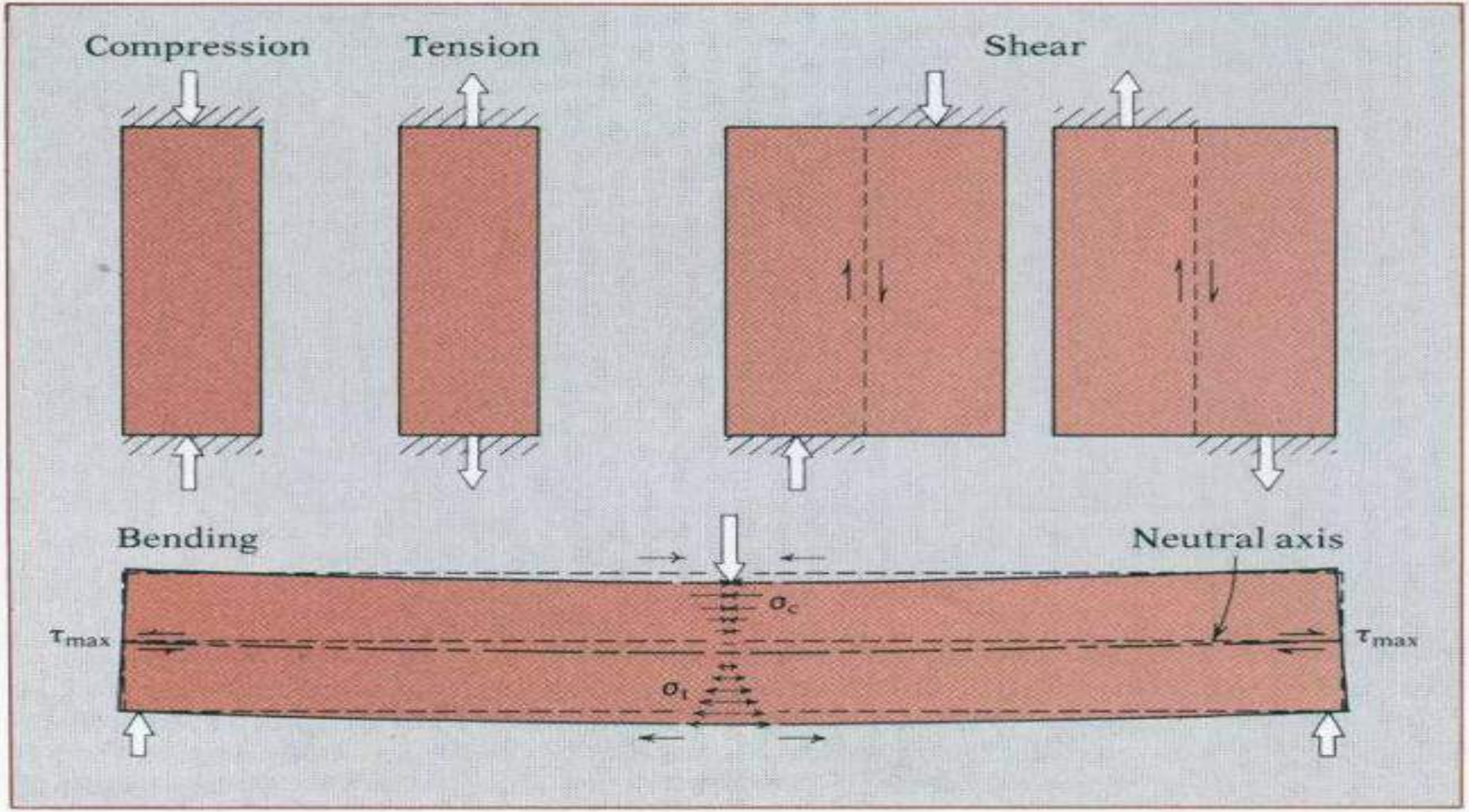
Somewhat weak: *Abies pindrow, Bischofia javanica, Pinus roxburgii, Holoptelia integrifolia.*

Weak*: Picea smithiana, Cedrela toona, Pinus wallichiana, Lannea cormandelica, Boswellia serrata.*

Very weak: *Hymenodictyon excelsum, Bombax ceiba, Cryptomeria japonica.*

IMPORTANT TESTS TO DETERMINE THE STRENGTH OF WOOD

- Tension
- STATIC BENDING
- COMPRESSION
- INDENTATION TEST
- Shear
- Brittleness test
- Nail and screw pulling test


Compression
Tension
Shear
Bending
Neutral axis
τ_{max}
σ_c
σ_t
τ_{max}

Tensile modulus of elasticity (kN/mm^2)

$$\text{Modulus of elasticity} = \frac{PL}{\Delta A}$$

Where,

P	=	Load at limit of proportionality in Newton (N)
L	=	Gauge length of the specimen in mm
Δ	=	Displacement at limit of proportionality in mm
A	=	Cross- sectional area in mm^2

What Are The Common Methods of Steel Preparation?
Solvent Cleaning – Before any further cleaning or preparation, steel sections are first wiped down with acetone, a thinner, or another type of solvent. This helps remove mill scale, oxides, and some corrosion.

Abrasive Grit Blasting – Grit blasting is the most effective method for removal of particularly difficult dirt, mill scale, rust and old coatings and other impurities. This is achieved using a shot-blasting machine, which the raw steel is passed through.

Prior to blasting, steelwork needs to be cleaned of any oils or grease. It is then blasted with shot or another abrasive material, which bombardes the steel surface, removing any impurities. The machine then brushes off any debris. There are all different types of classifications for blast cleaning a steel section, which will depend on what it is being used for, and what is being done afterwards (such as painting, coating or welding).

Hand & Power Tool Cleaning – Scrapers, wire brushes and other hand held tools are relatively ineffective in removing mill scale or corrosion. However, power tools like rotary brushes, rotary grinders, and needle guns may be useful for cleaning hard-to-reach places where grit blasting is not possible.

Acid Pickling – This involves immersing the steel in a bath of suitable inhibited acids that dissolve or remove the mill scale and rust. This technique is normally only used for structural steel intended for hot-dip galvanising.

Flame Cleaning – This involves passing an oxy/gas flame over the steel surface. The heat causes rust scales to flake off, which can then be removed by scraping and wire brushing followed by dust removal. It is not he most efficient process and is rarely used.

Wet Abrasive Blast Cleaning – As the name implies, this is similar to the girt blasting technique, however, water is employed rather than shot. This contributes to the reduction of a dust hazard, particularly when removing lead-based paints and water-soluble contaminants. Ultra-high pressure water jetting is also used, which is favoured by some because it removes high percentages of soluble salts from the surface.

Repairs to Special Structures

The world around us is full of complex structures that we rely on for transportation, water supply, and other essential services. From bridges spanning rivers to towering dams holding back water, these structures are vital to our lives. However, over time, these structures can suffer from damage due to environmental factors, wear and tear, or even accidents. When repairs are needed, they often involve specialized techniques and skilled professionals to ensure the continued safety and functionality of these critical assets.

Repairs to Concrete Structures Under Water

Challenges

Repairing concrete structures underwater presents a unique set of challenges. Divers need to work in challenging conditions, often with limited visibility and strong currents. Additionally, the pressure of the water can make it difficult to apply materials and ensure proper adhesion.

Techniques

Specialized techniques are used for underwater concrete repair, including the use of underwater welding, epoxy injections, and protective coatings. Divers may use specialized tools and equipment, such as underwater grinders, pumps, and cameras, to assess damage and perform repairs.

Safety

Safety is paramount in underwater repair operations. Divers undergo rigorous training and follow strict safety protocols to minimize risks. They often work in teams and use communication systems to ensure coordination and safety.

Case Study: Underwater Concrete Repair Project

1

Assessment

A team of experienced divers conducted a thorough underwater inspection of a bridge pier, identifying areas of significant concrete damage. They used underwater cameras and sonar equipment to create detailed images and data.

2

Preparation

Before starting the repair work, the divers cleaned and prepared the damaged areas by removing loose debris and rust. This ensured that the new materials would adhere properly to the existing concrete.

3

Repair

The divers used a specialized epoxy injection system to repair the cracks and voids in the concrete. The epoxy was pumped into the damaged areas, filling them completely and restoring the structural integrity of the pier.

4

Inspection

After the repair work was completed, the divers conducted another thorough inspection to ensure that the epoxy had properly filled the damaged areas and that the structure was safe for continued use.

Repairs to Bridges

1 Deck Replacement

Bridge decks are often subject to wear and tear, especially from heavy traffic and weather conditions. They may require replacement or repairs, including resurfacing, crack sealing, and joint repairs.

2 Girder Repairs

The girders that support the bridge deck can also experience damage over time. Repairs may involve replacing sections of the girders, strengthening them with reinforcing steel, or applying protective coatings.

3 Expansion Joints

Expansion joints are essential for accommodating the expansion and contraction of the bridge deck due to temperature changes. Repairs may involve replacing or repairing damaged joints, ensuring proper drainage, and maintaining their functionality.

4 Substructure Repairs

The substructure of a bridge, which includes the piers, abutments, and foundations, can also require repairs. These repairs may involve addressing erosion, repairing cracks, strengthening foundations, or replacing damaged elements.

Case Study: Bridge Rehabilitation Project

1

Assessment

A comprehensive assessment of the bridge structure revealed significant deterioration in the deck, girders, and expansion joints. This included cracking, spalling, and corrosion.

2

Preparation

The bridge was closed to traffic, and a construction zone was set up. This involved installing scaffolding, setting up traffic control measures, and preparing the work area.

3

Deck Replacement

The old bridge deck was removed, and a new deck was constructed using reinforced concrete and high-performance materials. The deck was designed to meet current traffic load requirements and withstand environmental conditions.

4

Girder Repairs

The existing girders were inspected for damage and repaired as needed. This involved replacing sections of the girders, strengthening them with additional reinforcing steel, and applying corrosion-resistant coatings.

5

Expansion Joint Replacement

The old expansion joints were removed, and new expansion joints were installed. These joints were designed to accommodate the movement of the bridge deck and prevent leaks and water damage.

6

Final Inspection

After the repair work was completed, the bridge was inspected to ensure that the repairs were properly completed and that the bridge was structurally sound. The bridge was then reopened to traffic.

Repairs to Water Tanks

Corrosion

Corrosion is a common problem in water tanks, especially those made of steel. It can weaken the tank walls and lead to leaks. Repairs may involve removing corroded sections, applying protective coatings, or replacing damaged sections.

Cracks

Cracks can develop in the tank walls due to stress, temperature changes, or settling. Repairs may involve injecting epoxy into the cracks, applying a sealant, or using specialized repair patches.

Leaks

Leaks can occur at the seams, joints, or any areas where the tank has been damaged. Repairs may involve using sealant, welding, or applying a patch to seal the leak.

Linings

Tank linings are used to protect the tank walls from corrosion and contamination. Repairs may involve replacing damaged sections of the lining, applying a new lining, or cleaning and maintaining the existing lining.

Case Study: Water Tank Repair Techniques

Repair Technique	Description	Application
Epoxy Injection	Filling cracks and voids with a strong epoxy resin to restore structural integrity.	Repairing cracks in the tank walls, seams, and joints.
Sealant Application	Applying a flexible sealant to seal leaks and prevent water seepage.	Sealing cracks, joints, and areas where the tank has been damaged.
Patching	Using pre-fabricated or custom-made patches to cover damaged areas and seal leaks.	Repairing large holes or damaged sections of the tank walls.
Lining Replacement	Replacing the existing tank lining with a new one to protect the tank walls from corrosion and contamination.	Restoring the lining of old tanks or when the existing lining is damaged beyond repair.

Repairs to Tunnels

Lining Repairs

Tunnel linings, typically made of concrete or steel, protect the tunnel from water ingress and provide structural support. Repairs may involve patching cracks, replacing damaged sections, or applying waterproofing coatings.

Drainage System Repairs

Effective drainage is crucial to prevent water accumulation within the tunnel. Repairs may involve clearing blockages, repairing leaks, or installing new drainage systems to ensure proper water removal.

Case Study: Tunnel Restoration Project

Inspection & Assessment

A thorough inspection of the tunnel revealed significant damage to the lining, including cracks, spalling, and leaks. The drainage system was also found to be clogged and ineffective.

Cleaning & Preparation

The tunnel was closed to traffic, and the damaged areas were cleaned and prepared for repair. This involved removing loose debris, cleaning the concrete surface, and applying a bonding agent to ensure proper adhesion of new materials.

Lining Repairs

The damaged sections of the tunnel lining were repaired using a combination of techniques, including epoxy injection, patching, and applying a waterproofing sealant.

Drainage System Upgrade

The existing drainage system was replaced with a new, more efficient system to ensure proper water removal and prevent future damage. This involved installing new drainage pipes, grates, and sumps.

Repairs to Dams

1 Concrete Repairs

Dams are typically constructed with large amounts of concrete. Over time, this concrete can be damaged by erosion, weathering, and other factors. Repairs may involve patching cracks, replacing damaged sections, and applying protective coatings.

2 Grouting

Grouting is used to seal cracks and voids in the dam's foundation and walls. It involves injecting a grout mixture into the cracks, filling them and restoring the dam's structural integrity.

3 Spillway Repairs

The spillway is a critical part of the dam, allowing excess water to flow safely over the dam. Repairs may involve addressing erosion, replacing damaged sections, or adjusting the spillway's capacity to ensure proper water management.

4 Monitoring & Inspection

Regular monitoring and inspection are essential for identifying potential problems early on. This involves using instruments to measure dam movement, monitor water levels, and inspect for signs of damage.

Seismic Retrofitting of Structures

Seismic retrofitting is the process of strengthening existing structures to resist earthquake damage. It involves modifying and upgrading a building's structural system to improve its resistance to seismic forces. This is crucial for enhancing the safety and resilience of structures in earthquake-prone regions.

by shiva shiva

Retrofit of Reinforced Concrete Buildings

1

Assessment

A comprehensive assessment is conducted to evaluate the building's current seismic performance. This involves examining structural elements, materials, and potential weaknesses.

2

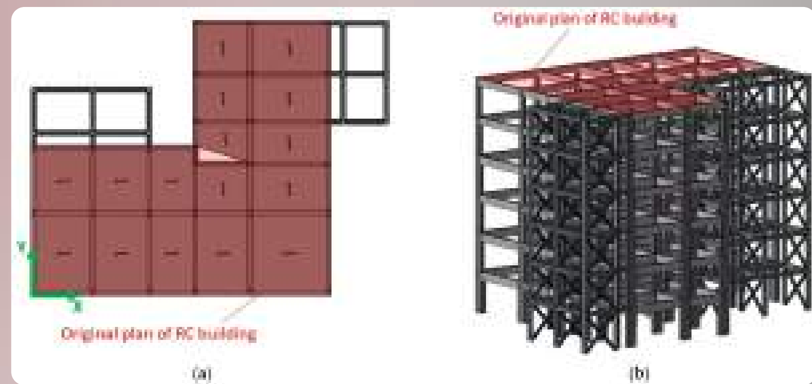
Strengthening

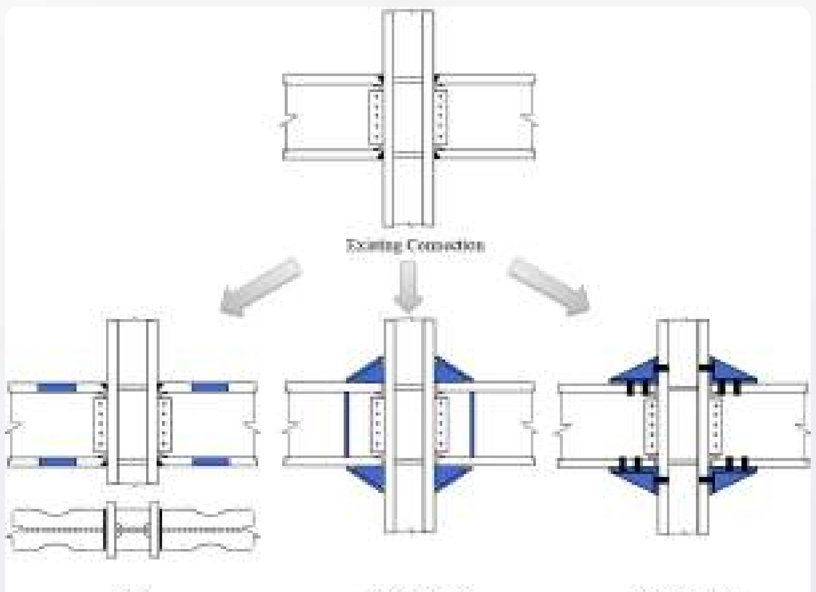
Strengthening measures are implemented to enhance the building's resistance to seismic forces. This may involve adding steel reinforcement, installing shear walls, or reinforcing existing columns and beams.

3

Upgrade Systems

Building systems like mechanical and electrical are upgraded to ensure their functionality after an earthquake. This includes securing equipment, installing flexible piping, and ensuring accessibility for repairs.





Retrofit of Steel Buildings

1. **Bracing**

   Adding bracing systems to steel frames helps resist lateral forces during an earthquake. This can be done by installing diagonal bracing, shear walls, or moment-resisting frames.

2. **Connections**

   Strengthening the connections between steel beams, columns, and walls ensures the structural integrity of the building during seismic events. This may involve upgrading existing connections or using high-strength bolts and welding.

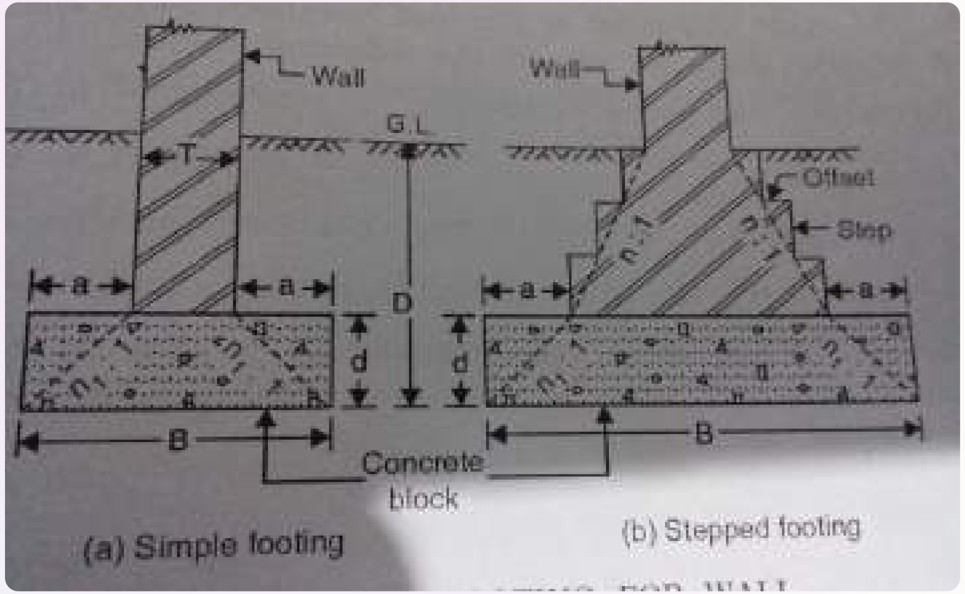
3. **Damping Devices**

   Energy dissipation devices are incorporated to absorb and reduce the impact of seismic forces. These can include viscous dampers, friction dampers, or fluid viscous dampers.

4. **Foundation Reinforcement**

   Reinforcing the foundation is crucial for distributing seismic forces evenly and preventing structural failure. This may involve adding concrete piles, reinforcing the base slab, or installing ground improvement systems.

Retrofit of Foundations



Deep Foundations

Installing deep foundations, such as piles or caissons, can improve the stability of the building by transferring loads to stronger soil layers.

Shallow Foundations

Ground improvement techniques, such as soil compaction or grouting, can increase the load-bearing capacity of shallow foundations, enhancing seismic resistance.

Base Isolation and Energy Dissipation

Base Isolation

Base isolation systems decouple the building from the ground, reducing the transmission of seismic forces to the structure. This involves placing flexible bearings or sliders between the foundation and the building.

Energy Dissipation

Energy dissipation devices are installed to absorb and dissipate seismic energy, reducing the stress on the building's structural elements. Common devices include dampers, friction devices, and viscous dampers.

Retrofit Case Studies: Residential Buildings

1

Wood-Frame Building

Strengthening the connection between walls and the foundation, installing shear walls, and upgrading roof bracing can significantly improve the seismic resistance of wood-frame homes.

2

Masonry Building

Reinforcing the masonry walls with steel straps, adding concrete columns or piers, and upgrading the roof structure can enhance the seismic resilience of masonry homes.

3

Concrete Slab on Grade

Improving the soil conditions beneath the slab, adding shear walls or concrete beams, and reinforcing the slab itself can improve the earthquake resistance of homes with concrete slabs.

Retrofit Case Studies: Commercial Buildings

Building Type	Retrofit Strategies
Office Building	Adding shear walls, strengthening columns and beams, and upgrading the roof structure.
Retail Store	Installing bracing systems, reinforcing the foundation, and upgrading the facade to resist seismic forces.
Hotel	Base isolation, energy dissipation devices, and strengthening the structural connections to improve resistance.

Retrofit Case Studies: Historic Structures

Preservation

Prioritizing the preservation of historical features and architectural details while implementing necessary seismic upgrades.

Structural Integrity

Addressing the structural vulnerabilities of the building by reinforcing walls, upgrading the foundation, and improving the roof system.

Code Compliance

Ensuring the retrofitting work meets current building codes and seismic safety standards while preserving the historical integrity of the structure.

Challenges and Considerations in Seismic Retrofitting

Cost

Retrofitting can be a significant financial investment, especially for large or complex structures. Owners need to weigh the cost of retrofitting against the potential risks and consequences of not doing so.

Time

Retrofitting projects can take a considerable amount of time, requiring careful planning and coordination. Disruptions to building occupants and businesses need to be minimized during construction.

Complexity

Retrofitting often involves intricate engineering and construction tasks, requiring skilled professionals and specialized equipment. The existing structure's condition and design can add complexity.

Regulations

Retrofitting projects must comply with local building codes and seismic safety regulations. Obtaining necessary permits and approvals can be a lengthy process.

Conclusion and Future Trends

Seismic retrofitting plays a crucial role in mitigating earthquake risks and protecting lives and property. Future trends in retrofitting include the use of advanced materials, innovative technologies, and more efficient methods. As research and development continue, we can expect even more effective and sustainable solutions for retrofitting structures in earthquake-prone areas.

Unit I: Maintenance and Repair Strategies

1. Maintenance

- **Definition:**
  - Maintenance is a set of actions aimed at keeping equipment, machinery, and infrastructure in a state where it can perform its intended function reliably and safely.
- **Types:**
  - **Preventive Maintenance:** Regularly scheduled activities aimed at preventing breakdowns and extending asset life.
  - **Predictive Maintenance:** Uses real-time data and diagnostics to predict and address potential issues before they lead to failure.
  - **Corrective Maintenance:** Reactive repairs made after a fault is detected.
  - **Condition-Based Maintenance:** Maintenance triggered by the actual condition of the equipment, usually through continuous monitoring.
- **Importance:**
  - **Safety:** Regular maintenance helps in identifying potential hazards before they lead to accidents.
  - **Cost Efficiency:** Reduces the frequency and severity of breakdowns, leading to cost savings over time.
  - **Operational Efficiency:** Ensures that operations run smoothly without unexpected interruptions.
  - **Longevity:** Extends the lifespan of equipment and infrastructure, reducing the need for early replacements.

2. Facets of Maintenance

- **Routine Maintenance:** Includes daily or periodic tasks such as lubrication, cleaning, and minor adjustments.
- **Emergency Maintenance:** Unplanned repairs required due to unexpected equipment failures.
- **Predictive Maintenance:** Uses diagnostic tools and data analytics to forecast when maintenance is needed.

3. Aspects of Inspection

- **Visual Inspection:** Observing equipment or structures to identify obvious signs of damage, wear, or deterioration.
- **Instrumental Inspection:** Using measurement tools to assess parameters like temperature, vibration, and pressure.
- **Functional Testing:** Checking the performance of equipment or systems under normal operating conditions to ensure they meet performance standards.

4. Condition Assessment of a Structure

- **Objective:** To evaluate the health and performance of a structure and determine any necessary interventions.
- **Methods:**
    - **Visual Assessment:** Inspecting the structure for visible defects such as cracks, stains, or deformation.
    - **Instrumental Testing:** Utilizing tools to measure structural properties such as stress, strain, and displacement.
    - **Load Testing:** Applying loads to a structure to assess its behavior and performance under stress.

5. Various Methods of Condition Assessment

- **Non-Destructive Testing (NDT):**
    - **Ultrasonic Testing (UT):** Uses high-frequency sound waves to detect internal defects.
    - **Radiographic Testing (RT):** Employs X-rays or gamma rays to view internal structures.
    - **Magnetic Particle Testing (MPT):** Detects surface and near-surface defects in ferromagnetic materials using magnetic fields.
    - **Dye Penetrant Testing (DPT):** Reveals surface cracks through the use of liquid dye.
- **Non-Destructive Evaluation (NDE):** Encompasses a variety of techniques, including NDT, to assess material conditions without causing damage.

6. Repair Strategies

- **Repairs:** Direct interventions to restore components to their original condition, including patching, replacement, and adjustment.
- **Rehabilitation:** Improving the overall functionality or aesthetics of a structure beyond its original state.
- **Retrofitting:** Adding new components or modifying existing ones to enhance performance or comply with updated codes.
- **Strengthening:** Enhancing the structural capacity to support additional loads or resist more severe conditions.
- **Upgradation:** Modernizing systems or structures to incorporate new technologies or improved materials.

7. Selection of Materials and Techniques for Repair

- **Materials:** Choose based on compatibility, durability, and performance characteristics (e.g., epoxy resins, high-strength concrete).
- **Techniques:** Methods such as surface treatments, coating applications, and advanced repair technologies should be selected based on the type of damage and the desired outcome.

Unit II: Repairs to Masonry and Concrete Structures

1. Methods of Crack Repair

- **Routing and Sealing:** Involves cutting out a groove around the crack and filling it with a suitable sealant to prevent water ingress and further damage.
- **Epoxy Injection:** Filling cracks with epoxy resin to restore structural integrity and prevent leakage.

2. Removal and Surface Preparation

- **Cleaning:** Removing contaminants like dust, oil, and old coatings to ensure proper bonding of repair materials.
- **Surface Roughening:** Creating a rough surface to enhance the adhesion of new materials.

3. Reinforcement Repair

- **Anchorage:** Installing devices or systems to secure and stabilize reinforcement bars.
- **Placement Methods:** Correct placement techniques to ensure effective reinforcement, including proper spacing and alignment.

4. Shotcreting and Guniting

- **Shotcreting:** Spraying a mixture of concrete onto a surface to create a dense and strong coating, often used for repairing and strengthening.
- **Guniting:** A variant of shotcreting where the concrete mix is applied using a slightly different technique.

5. Grouting

- **Portland Cement Grouting:** Using cement-based grouts to fill voids and improve structural integrity.
- **Chemical Grouting:** Employing chemical grouts to stabilize soil or fill cracks.
- **Dry Packing:** Filling voids with a dry mixture that is then compacted to strengthen the area.
- **Polymer Impregnation:** Using polymers to enhance the properties of concrete, such as increasing strength and durability.

6. Strengthening Techniques

- **Flexural Strengthening:** Enhancing the ability of a structure to resist bending, often using fiber-reinforced polymers (FRP).
- **Shear Strengthening:** Improving resistance to shear forces through methods such as adding shear walls or FRP.

- **Column Jacketing:** Adding layers of concrete or other materials around columns to increase their load-bearing capacity.
- **External Pre-Stressing:** Applying external tension to concrete structures to increase their load-carrying capacity.
- **Fiber Wrapping:** Wrapping structures with fiber-reinforced materials to enhance their strength and ductility.

7. Corrosion Protection

- **Surface Treatment:** Applying coatings or treatments to protect concrete and steel from corrosion.
- **Joint Sealants:** Using sealants to prevent water ingress through joints, which can cause deterioration.
- **Cathodic Protection:** Employing electrical techniques to protect steel reinforcement from corrosion by making it the cathode in an electrochemical cell.

Unit III: Repairs to Timber and Steel Structures

1. Testing of Timber Structures

- **Rot Detection:** Identifying wood decay caused by fungi or insects using visual inspections and specialized tools.
- **Creosote Retention:** Measuring the amount of creosote in timber to assess its preservation effectiveness.

2. Planning for Repairs in Timber Structures

- **Inspection:** Detailed examination to assess damage and deterioration.
- **Repair Techniques:** Includes replacing damaged timber, treating wood to prevent further decay, and strengthening joints and connections.

3. Dynamic Loading and Fatigue

- **Dynamic Loading:** Evaluating the impact of variable loads on structural performance.
- **Fatigue:** Assessing how repeated loading affects the strength and durability of materials.

4. Welding Technology

- **Weldability:** Assessing how easily different types of steel or other materials can be welded.
- **Cleaning and Surface Preparation:** Removing rust, paint, and contaminants to ensure a clean welding surface.

5. Cleaning and Surface Preparation of Corroded Structural Steel

- **Techniques:** Using abrasive blasting, wire brushing, or chemical treatments to remove corrosion products and prepare surfaces for painting or repair.

6. Replacement and Addition of New Members

- **Replacement:** Replacing damaged or deteriorated steel members with new ones.
- **Addition:** Installing additional steel members to enhance structural capacity or stability.

7. Types of Steel and Composite Joints

- **Steel Joints:** Includes welded, bolted, and riveted connections.
- **Composite Joints:** Combine different materials such as steel and concrete to take advantage of their combined properties.

Unit IV: Repairs to Special Structures and Special Repairing Techniques

1. Repairs to Concrete Structures Under Water

- **Techniques:**
    - **Underwater Concrete Placement:** Using special mixes and techniques for applying concrete underwater.
    - **Marine Coatings:** Applying protective coatings to resist saltwater corrosion.

2. Repairs to Bridges

- **Inspection and Assessment:** Evaluating structural health and identifying required repairs.
- **Common Repairs:** Includes resurfacing, strengthening of joints, and replacement of bearings.

3. Repairs to Water Tanks

- **Inspection:** Identifying leaks, cracks, and other damage.
- **Repair Methods:** Includes sealing leaks, resurfacing, and structural strengthening.

4. Repairs to Tunnels

- **Inspection:** Assessing structural integrity and identifying issues such as cracks or water ingress.
- **Repair Techniques:** Includes lining repairs, crack injections, and structural reinforcement.

5. Repairs to Dams

- **Inspection and Assessment:** Evaluating dam structure and identifying issues.
- **Repair Techniques:** Includes sealing leaks, reinforcing the structure, and improving spillways.
- **Case Studies:** Provide detailed examples of each type of structure repair to illustrate specific challenges and solutions.

Unit V: Seismic Retrofitting of Structures

1. Retrofit of Reinforced Concrete Buildings

- **Methods:** Includes adding shear walls, using FRP wraps, and improving foundation connections.

2. Retrofit of Steel Buildings

- **Techniques:** Strengthening connections, adding braces, and enhancing stability through various methods.

3. Retrofit of Foundations

- **Techniques:** Includes underpinning, base isolation, and strengthening foundations to improve seismic performance.

4. Base Isolation and Energy Dissipation

- **Base Isolation:** Techniques to decouple the building from ground motion, such as installing isolators.
- **Energy Dissipation:** Devices or systems to absorb and dissipate seismic energy to reduce forces on the structure.

5. Retrofit Case Studies

- **Detailed Examples:** Case studies showcasing real-life examples of successful seismic retrofitting projects, detailing the methods used and the outcomes achieved.