

Course/Branch: B.E/CIVIL	Year / Semester : IV/VIII	Format No.	NAC/TLP-07a.5
Subject Code : CE6021	Subject Name: REPAIR AND REHABILITATION STRUCTURES	Rev. No.	02
Unit No :1	Unit Name : MAINTENANCE AND REPAIR STRATEGIES	Date	14-11-2017

LECTURE NOTES



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PRESENTATION

• LISTEN ... LEARN... LEAD...



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DEPARTMENT OF CIVIL ENGINEERING



IVth YEAR / VIIIth SEMESTER

SUBJECT CODE :CE6021

SUBJECT NAME :REPAIR AND REHABILITATIONS OF STRUCTURES



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Engineering & Technology

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CE6021 REPAIR AND REHABILITATION OF STRUCTURES L T P C

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OBJECTIVES:

□ To make the students to gain the knowledge on quality of concrete, durability aspects, causes of deterioration, assessment of distressed structures, repairing of structures and demolition procedures.

UNIT I MAINTENANCE AND REPAIR STRATEGIES 9

Maintenance, Repair and Rehabilitation, Facets of Maintenance, importance of Maintenance, Various aspects of Inspection, Assessment procedure for evaluating a damaged structure, causes of deterioration.

UNIT II STRENGTH AND DURABILITY OF CONCRETE 9

Quality assurance for concrete – Strength, Durability and Thermal properties, of concrete - Cracks, different types, causes – Effects due to climate, temperature, Sustained elevated temperature, Corrosion - Effects of cover thickness.

UNIT III SPECIAL CONCRETES 9

Polymer concrete, Sulphur infiltrated concrete, Fibre reinforced concrete, High strength concrete, High performance concrete, Vacuum concrete, Self compacting concrete, Geopolymer concrete, Reactive powder concrete, Concrete made with industrial wastes.

UNIT IV TECHNIQUES FOR REPAIR AND PROTECTION METHODS 9

Non-destructive Testing Techniques, Epoxy injection, Shoring, Underpinning, Corrosion protection techniques – Corrosion inhibitors, Corrosion resistant steels, Coatings to reinforcement, cathodic protection.

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UNIT V REPAIR, REHABILITATION AND RETROFITTING OF STRUCTURES 9

Strengthening of Structural elements, Repair of structures distressed due to corrosion, fire, Leakage, earthquake – DEMOLITION TECHNIQUES - Engineered demolition methods – Case studies.

TOTAL: 45 PERIODS

OUTCOMES:

□ Students must gained knowledge on quality of concrete, durability aspects, causes of deterioration, assessment of distressed structures, repairing of structures and demolition procedures.

TEXTBOOKS:

1. Denison Campbell, Allen and Harold Roper, “Concrete Structures, Materials, Maintenance and Repair”, Longman Scientific and Technical UK, 1991. 2. Allen R.T. & Edwards S.C, Repair of Concrete Structures, Blakie and Sons, UK, 1987

REFERENCES:

1. Shetty M.S., "Concrete Technology - Theory and Practice", S.Chand and Company, 2008.
2. Dov Kominetzky.M.S., "Design and Construction Failures", Galgotia Publications Pvt. Ltd., 2001
3. Ravishankar.K., Krishnamoorthy.T.S, "Structural Health Monitoring, Repair and Rehabilitation of Concrete Structures", Allied Publishers, 2004.
4. CPWD and Indian Buildings Congress, Hand book on Seismic Retrofit of Buildings, Narosa Publishers, 2008.
5. Gambhir.M.L., "Concrete Technology", McGraw Hill, 2013

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CHAPTER 1 MAINTENANCE AND REPAIRS STRATEGIES

Maintenance, repair and rehabilitation, Facets of Maintenance, importance of Maintenance
 Various aspects of Inspection, Assessment procedure for evaluating a damaged structure,
 Causes of deterioration

1.1 Maintenance

Maintenance Engineering is defined as the work done to keep the civil Engineering structures and work in conditions so as to enable them to carry out the functions for which they are constructed.

It is preventive in nature. Activities include inspection and works, necessary to fulfill the intended function, or to sustain original standard of service.

Scope of maintenance

- ✓ Minor repairs, replacements and structural repairs of buildings, white and color washing, distempering and painting at prescribed intervals
- ✓ Repair and renewal of furniture
- ✓ Operation, periodical maintenance, repairs renewals of machinery and equipment for electric etc.
- ✓ Repair of roads, culverts and resurfacing the roads

1.1.1 Facets of Maintenance

Aims of Maintenance work classified as

- ✓ The avoidance of accidents, which may harm people or plant
- ✓ The continued operation of a facility
- ✓ The protection of the capital investment in the asset

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1.1.2 Maintenance work is classified as

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

▪ **Maintenance work is classified as**

✓ **Preventive maintenance**

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

1.1.2.1 Remedial maintenance

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

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

1.1.2.2 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.

1.1.2.3 Special maintenance

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

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1.1.3 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

1.1.3.1 Daily Routine Maintenance

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

1.1.3.2 Weekly Routine Maintenance

- ✓ Electrical Accessories
- ✓ Flushing sewer line
- ✓ Leakage of water line

1.1.3.3 Monthly Routine Maintenance

- ✓ Cleaning Doors, windows, etc
- ✓ Checking Septic Tank/Sewer
- ✓ Observation for cracks in the elements
- ✓ Cleaning of overhead tanks

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1.1.3.4 Yearly Routine Maintenance

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

1.1.4 Stages of inspection

A. Inspection

Collect data at specified intervals in specified form

B. Analysis

- i. Add latest information to database
- ii. Examine progression of defects
- iii. Relate defects to action criteria

C. Action possibilities

- i. Note and wait for the next inspection
- ii. Alter inspection frequency
- iii. Institute repairs
- iv. Further detailed investigation
- v. Put safety procedures in place

1.1.5. Necessitation of the maintenance

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

- ✓ Atmospheric Agencies
- ✓ Normal wear and tear
- ✓ Failure of structure

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1.1.5.1 Atmospheric Agencies

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

Expansion And contraction

- ✓ The material is subjected to repetitive expansion and contraction while they become wet and dry and develops the stresses
- ✓ Dissolving and carrying away minerals as it is universal solvent

Chemical: The water available in nature contains acids and alkali and other compound in dissolved form acts over the material to give rise, which is known as chemical weathering.

- i. **Wind:** It is the agent, which transports the abrasive material and assists the physical weathering.
- ii. **Temperature:** The diurnal, seasonal and annual variation of the temperature, difference in temperature it causes expansion and contraction.

1.1.5.2 Normal wear and tear

During the use of structure it is subjected to abrasion and thereby it loses appearance and serviceability

1.1.5.3 Failure of structure

- ✓ **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 control and supervision.
- ✓ **Improper use of structure-** overloading, selecting the structure for the

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use they not designed impurities from industrial fuel burning, sea water minerals etc.

1.1.6. Inspection periods

- ✓ Pre-monsoon period
- ✓ Monsoon period
- ✓ Post-monsoon period

1.1.6.1 Pre-monsoon period

To decide the maintenance programmer to be done before monsoon such as cleaning of drains, checking of roof leakage, collection material etc

1.1.6.2 Monsoon period

It is needless to mention that the emergency work carried out in monsoon period: railway tracks, collapse of roof etc.

1.1.6.3 Post-monsoon inspection

It is made to repair the damage caused by water and draw up the programmed of repair according to the priorities.

1.1.7 Maintenance processes

- ✓ Design for maintainability
- ✓ Preventive maintenance
- ✓ Predictive maintenance
- ✓ Reliability centered maintenance
- ✓ Reactive maintenance
- ✓ Spares management
- ✓ Maintenance logistics support
- ✓ Total productive maintenance

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- ✓ Organizing for maintenance
- ✓ Computerized maintenance management program
- ✓ Statutory requirements

1.1.8 Inspection of building

- ✓ Condition of wall paint
- ✓ Condition of paint on woodwork and grill
- ✓ Condition of flooring
- ✓ Roof leakage, leakage etc
- ✓ Condition of service fittings
- ✓ Drainage from terrace
- ✓ Growth of vegetation
- ✓ Structural defects like Crack, Settlement, and Deflection

1.1.9 Repair and rehabilitation

Repair is the technical aspect of rehabilitation. It refers to the modification of a structure, partly or wholly which is damaged in appearance or serviceability.

The following factors to be considered repair of concrete structures:

- ✓ The cause of damage
- ✓ Type, shape and function of the structure
- ✓ The capabilities and facilities available with builders
- ✓ The availability of repair materials

1.1.9.1 Stages of concrete repair

Repair of concrete structures is carried out in the following stages:

- ✓ Removal of damaged concrete

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- ✓ Pre treatment of surfaces and reinforcement
- ✓ Application of repair material
- ✓ Restoring the integrity of individual sections and strengthening of structure as a whole

1.1.9.2 Repair procedure

A repair procedure may be selected to accomplish on or more of the following objectives:

- ✓ To increase strength or restore load carrying capacity
- ✓ To restore or increase stiffens
- ✓ To improve functional performance
- ✓ To provide water tightness
- ✓ To improve durability
- ✓ To prevent access of corrosive material to reinforcement

1.1.9.3 Types and classification of repair

Types of repair:

- ✓ Cosmetic treatments on surfaces
- ✓ Partial replacement of surface and subsurface material
- ✓ Additional of reinforcements and bonding materials to strengthen the element
- ✓ Total replacement of the structural element

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Class of damage	Classification of repair	Repair requirements
1	Superficial	Cement mortar bonding by troweling
2	General	Nonstructural or minor structural; restoring cover to rebars
3	Principal	Significant loss of concrete strength; shotcreting for slabs and beams, jacketing for columns etc.
4	Major	Demolition and recasting required.

1.1.9.4 Methods of Repairs

The following considerations are to be taken care of and observed:

- ✓ Determination of extent, location and width of cracks
- ✓ Classification of cracks as structural and non-structural

Dormant cracks:

Dormant cracks are caused by some event in the part, which is not expected to recur. They remain constant in width, and may be repaired by filling then with a rigid material.

Active cracks:

Do not remain constant in width, but open and close as the structure in loaded, or due to thermal and hydras changes in the concrete.

Growth cracks:

Increase in width becomes the original reason for their occurrence persists.

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1.1.9.5 Applications:

The repair of cracks can be achieved with the following techniques:

- ✓ Resin injection
- ✓ Routing and Sealing
- ✓ Stitching
- ✓ External stressing
- ✓ Bonding
- ✓ Blanketing
- ✓ Overlays
- ✓ Dry pack
- ✓ Vacuum impregnation
- ✓ Polymer impregnation

1.1.9.6 Rehabilitations

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

It is the processes of restoring the structure to service level, once it had and now lost, strengthening consists in endowing the structure with a service level, higher than that initially planned by modifying the structure not necessarily damaged area.

The following steps are generally used in the rehabilitation of distressed concrete structure:

- ✓ Support the structural members properly as required.

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- ✓ Remove all cracked, spalled and loose concrete.
- ✓ Clean the exposed concrete surfaces and steel reinforcement
- ✓ Provide additional reinforcing bars, if the loss in reinforcement is more than 10%
- ✓ Apply protective coatings over the exposed/repaired surface.

1.1.9.6.1 Applications:

- ✓ Shotcrete/Gunite
 - ✓ Resin injection
 - ✓ Dry pack and Epoxy-bonded dry pack
 - ✓ Slab jacking Technique
 - ✓ Sprayed concrete

1.1.10 Assessment procedure for evaluating a damaged structure

The following steps may necessary:

- ✓ Physical Inspection of damaged structure
- ✓ Preparation and documenting the damages
- ✓ Collection of samples and carrying out tests both in-situ and in lab
- ✓ Studying the documents including structural aspects
- ✓ Estimation of loads acting on the structure
- ✓ Estimate of environmental effects including soil structure interaction
- ✓ Diagnosis
- ✓ Taking preventive steps not to cause further damage
- ✓ Retrospective analysis to get the diagnosis confirmed
- ✓ Assessment of structural adequacy
- ✓ Estimation on future use

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- ✓ Remedial measures necessary to strengthen and repairing the structure
- ✓ Post repair evaluation through tests
- ✓ Load test to study the behavior
- ✓ Choice of course of action for the restoration of structure.

1.1.11 Causes of Deterioration

a) Design and construction Flows

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 this similar condition. The beam-column joints are particularly probe to defective concrete, if detailing and placing of reinforcement is not done properly.

b) Environmental effects

Micro-cracks present in the concrete are the source of access of moisture and atmospheric carbon- di-oxide into the concrete, which attack reinforcement and react with various ingredients of concrete. In aggressive environment, concrete structures will deteriorate faster and strength/life of concrete structures will be severely reduced.

c) Usage of poor Quality Material

Quality of materials to be used in construction, should be ensured by means of various tests, as specified in the IS codes. Alkali-aggregate and Sulphate attack results in early deterioration. Clayed materials in the fine aggregates may weaken the mortar-aggregate bond, and reduce the strength.

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d) Quality of Supervision

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

e) Deterioration due to Corrosion

- ✓ Spalling of concrete cover
- ✓ Cracks parallel to the reinforcement
- ✓ Spalling at edges
- ✓ Swelling of concrete
- ✓ Dislocation

