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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

- ✓ Petty 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,culvets and resurfacing the roads

1.1.1 Facts 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

1.1.2 Maintenance work is classified as

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

▪ **Maintenance work is classified as**

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.

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

1.1.3.4Yearly 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 Agencis
- ✓ Normal wear and tear
- ✓ Failure of structure

1.1.5.1 Atmospheric Agencis

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 looses 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 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

1.1.6.2Monsoon period

It is needless to mention that the emergency work carried out in monsoon period.e.g: 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 programme 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
- ✓ 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
- ✓ 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

Classification of repair:

Class of damage	Classification of repair	Repair reqirements
1.	Superficial	Cement mortar bonding by trowelling
2.	General	Non structural 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.

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.
- ✓ 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

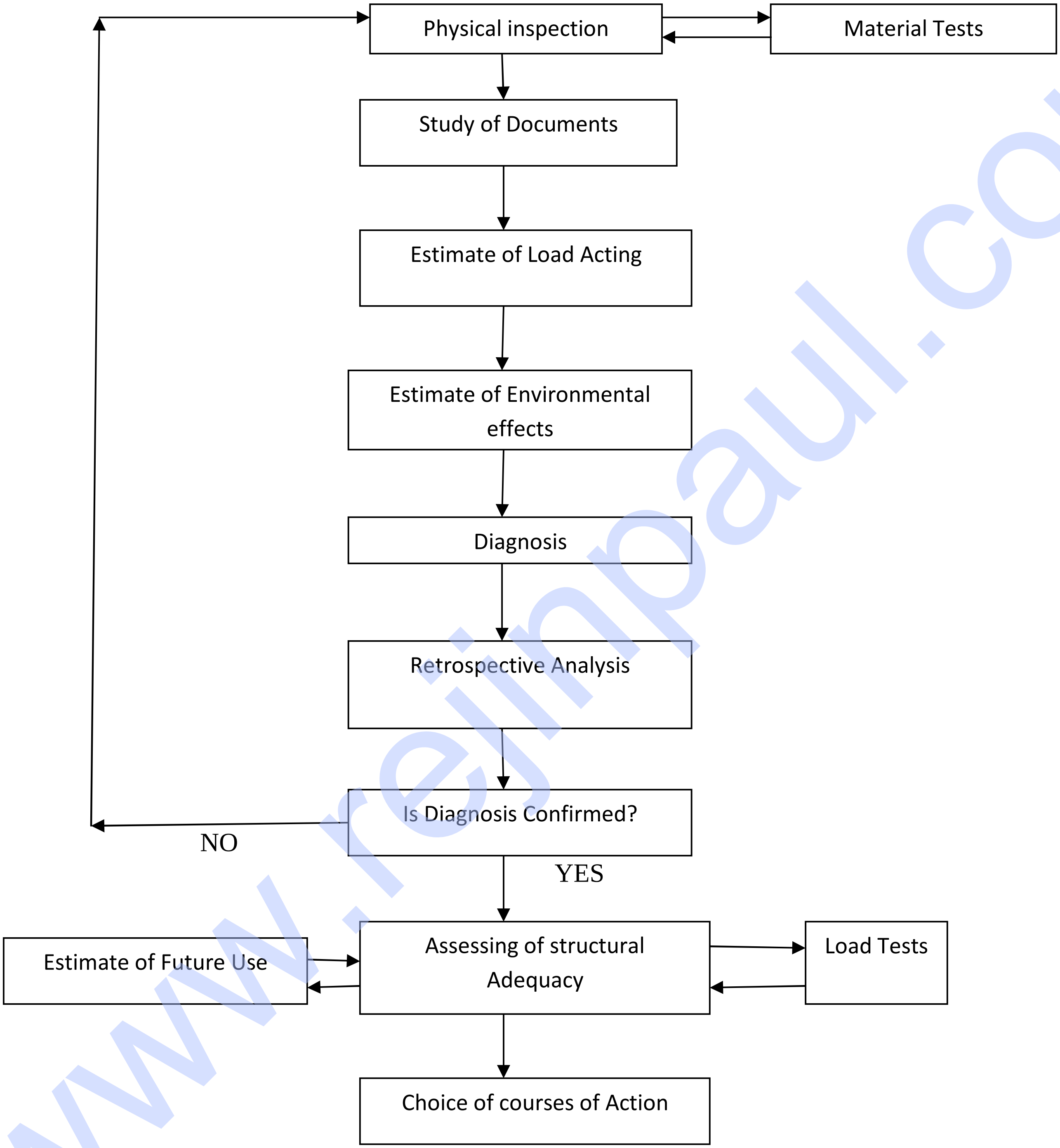
1.1.10Assessment procedure for evaluating a damaged structure

The following steps may necessary:

- ✓ Physical Inspection of damaged structure
- ✓ Prepartion 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
- ✓ 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.

1.1.10.1Flowchart for Assessment procedure for damaged structure



1.1.11Causes 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.

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

CHAPTER 2

SERVICEABILITY AND DURABILITY OF CONCRETE

Quality assurance for concrete construction concrete properties- strength, permeability, thermal properties and cracking. - Effects due to climate, temperature, chemicals, corrosion – design and construction errors - Effects of cover thickness and cracking

2.1Quality assurance for concrete construction

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

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

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

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

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

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

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

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

2.1.1Need for quality Assurance

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

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

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

2.1.1.1Causes of design faults may include:

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

2.1.1.2 Causes of faults in construction may include:

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

2.2strength of concrete

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

The compressive strength of concrete is generally determined by testing cubes or cylinders made in laboratory or field or cores drilled from hardened concrete at site.

Strength of concrete is its resistance to rupture; It may be measured in a number of ways, such as Strength in compression, in tension, in shear or in flexure. All these indicate strength with Reference to a particular method of testing. When concrete fails under a compressive load the failure is essentially a mixture of crushing and shear failure.

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

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

2.3 Permeability of concrete

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

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

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

High-pressure steam cured concretes in conjuction with crushed silica decreases the permeability. This is due to the formation of coarser C-S-H gel, lower drying shrinkage and accelerated conversion of Ca (OH)2 into cementitious products.

2.4 Thermal Properties

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

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

- ✓ Thermal conductivity
- ✓ Thermal diffusivity
- ✓ Specific heat
- ✓ Coefficient of thermal expansion

2.4.1Thermal Conductivity

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

The conductivity of concrete depends on type of aggregate moisture content, density and temperature of concrete. When the concrete is saturated, the conductivity ranges generally between about 1.4 to 3.4 J/S/^{m2}

2.4.2 Thermal Diffusivity

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

Diffusivity=Conductivity/CP

Where C is the specific heat, and P is the density of Concrete. The range of diffusivity of concrete is between 0.002 to 0.006^{m2}/h

2.4.3Specific heat

It is defined as the quantity of heat, required to raise the temperature of a unit mass of a material by one degree centigrade. The common range of values for concrete is between 840 to 1170 j/$^{kg3/C}$

2.4.4Coefficient Thermal Expansion

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

2.5 Cracking

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

2.5.1Classification of cracks

It may be classified in terms of their effects:

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

Class I-Cracks leading to Structural Failure

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

Class II Cracks causing Corrosion

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

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

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

Class III-cracks affecting Function

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

Severe or very severe exposure-0.2mm

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

Class IV-cracks affecting appearance

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

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

Causes of cracking:

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

Other types of cracks due to:

- ✓ Delayed curing
- ✓ Formwork movement
- ✓ Excess vibration
- ✓ Sub grade settlement
- ✓ Finishing
- ✓ Early frost damage
- ✓ Unsound materials
- ✓ Long-term drying shrinkage

2.6 Effects due Climate

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

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

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

Concrete can be protected from freeze-thaw damage by the entrainment of the appropriate quantities of air distributed through the cement paste, with spacing between bubbles of not more

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

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

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

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

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

2.7Effects due to temperature

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

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

2.8Effects due to Chemical

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

- ✓ High porosity, and hence high permeability
- ✓ Improper choice of cement type for the conditions of exposure
- ✓ Inadequate curing prior to exposure
- ✓

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

2.9Effects due to Corrosion

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

Corrosion Mechanism – Wet or Electro-Chemical Corrosion

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

These travel through the electrolyte and combine with the ferrous ions to form ferric hydroxide, which is converted by further oxidation to rust.

The reactions are described below:

Anodic Reactions:

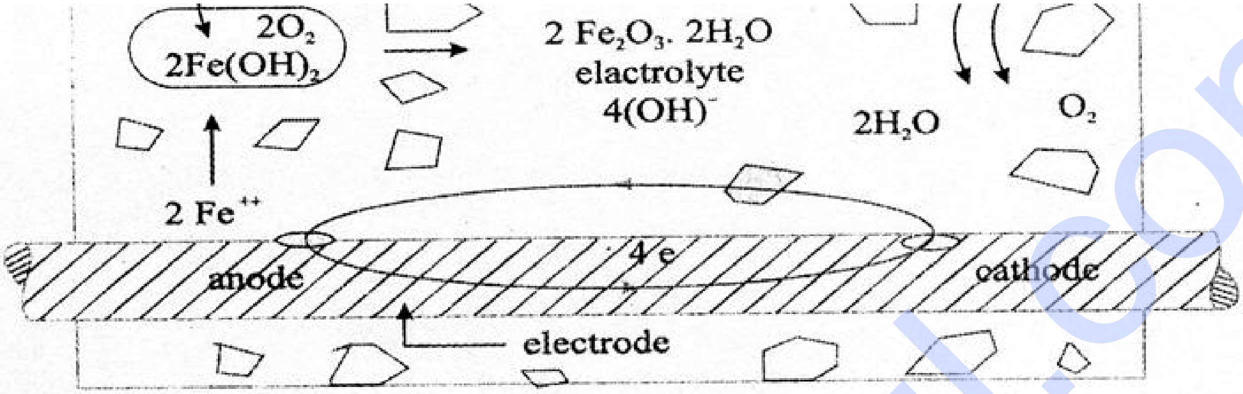
$Fe \longrightarrow Fe^{++} + 2e^{-}$

$Fe^{++} + 2(OH)_2 \longrightarrow Fe(OH)_2$

$Fe(OH)_2.2H_2O + O_2 \longrightarrow 4Fe(OH)_3$

Cathodic Reaction

$4e^{-} + O_2 + H_2O \longrightarrow 4(OH)$



Simplified model representing corrosion mechanism

It can be noted that no corrosion takes place if the concrete is dry probably below relative humidity of 60%, because enough water is not there to promote corrosion. it can also be noted that corrosion does not take place, id concrete is fully immersed in water, because diffusion of oxygen does not take place into the concrete. Probably the optimum relative humidity for corrosion is 70-80%

The products of corrosion occupy a volume as much as 6 times the original volume of steel, depending upon the oxidation state. Figure below shows the increase in volume of steel, depending upon the oxidation state.

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

Increase the oxygen content has 2 effects:

(i) It forces the cathode reaction to the right, producing more OH- ions and

(ii) It removes more electrons and therefore, accelerates the corrosion at the anode.

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

2.10 Design and construction errors

<u>Misconceptions of Structural Action</u>

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

As a result, when the tank wall rotated under water load, the faces came into contact and the corner behaved as a knee-joint, transmitting moment. The compression components of this moment produced a diagonal tensile

Resultant, which caused a substantial piece of un-reinforced concrete to spall off, as shown in figure and exposed reinforcement then corroded.

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

The primary beam shown in the figure below as to transfer the negative moments from the secondary beams, to the supporting columns.

As the columns and the primary beams are both stiff members, this transfer involves a torque in the primary beam, for which torsion reinforcement is needed. When this reinforcement was omitted from the design, helical cracks appeared.

<u>Reinforcement Detailing</u>

Inadequate detailing of reinforcement is a wideparead cause of cracking and particularly of those severe cracks, which affect the limit state of collapse

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

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

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

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

Construction Errors

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

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

A. Deficiencies in the control of concrete materials, batching & mixing
- ✓ Use of salt water as mixing water
- ✓ Excess fines in the aggregates

B. Inadequate preparation before concreting.
- ✓ Salt water contamination of reinforcement
- ✓ Lack of cover to reinforcement

C. Inadequacies of placing & subsequent treatment
- ✓ Plastic cracking & settlement cracking
- ✓ Lack of curing

D. Faults of construction planning &procedure
- ✓ Overloading of members by construction loads
- ✓ Loading of partially constructed members
- ✓ Differential shrinkage between section of construction
- ✓ Omission of designed movement joints
- ✓ Unexpected behavior and restraint during prestressing

2.10 effects of cover thickness & cracking

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

It provides the nominal cover requirements to meet:

- ✓ The durability requirements
- ✓ Specified period of fire resistance

Requirements of concrete cover

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

UNIT III

MATEIALS FOR REPAIR

Special concretes and mortar, concrete chemicals, special elements for accelerated strength Gain, Expansive cement, polymer concrete, sulphur infiltrated concrete, ferro cement, Fibre Reinforced concrete.

3.1 Special concrete and mortar

- ✓ High Aluminates Cement Concrete
- ✓ Shrinkage Compensated Concrete
- ✓ Polymer Cement concrete
- ✓ Polymer Impregnsed Concrete
- ✓ Epoxy Concrete
- ✓ Latex modified concrete

3.2 Necessity of adding concrete chemicals

- ✓ To improve the performance of concrete
- ✓ To have the early strength gain as early as possible
- ✓ To accelerated the setting time of concrete
- ✓ To make the structure waterproof

3.3 special elements for accelerated strength

In repairs of certain structures, particularly roadways and bridges, it may be desired that early strength gain should be rapid as possible. The engineer may, as a first approach, consider using admixtures, so that ordinary types of Portland cement can be used. The chief chemical admixture

Now used for this purpose is Super plasticizer of one type or another. Formerly, high doses of calcium chloride were advocated, but this producer has been rejected on the basis of corrosion, problems associated with calcium chloride were advocated, but this procedure has been rejected on the basis of corrosion, problems associated with calcium chloride use. The time of setting of Portland cement concrete and its strength gain may be shortened by the use of calcium aluminates cement, because of problems associated with the conversion under hot humid conditions, of the calcium aluminates hydrates from one from to another, and the resultant strength losses, other types of cements have been preferred.

Regulated set cement is a modified Portland cement, which contains a substantial amount of calcium fluro-aluminate. This cement contains a substantial amount of fluorite as a substitute for limestone. The burning process is not without problems, due to the release of small amount of fluoro compounds.

When prepared and ground, the initial and final set of this type of cement occurs almost simultaneously, and therefore the time between mixing and set is often referred to as the handling time.

As a rule, this varies between 2 and 45minutes. The strength level is adjusted by controlling the amount of calcium fluoro-alminate in the cement. The time of set

Is reduced, and compressive strength gain increased in regulated cement mortars and concrete by an increase in the cement content of mix, reduction of the w/c ratio, increased temperature of the mix and increase in curing temperature. The chemical reactions of this type of cement are much more energetic, than those of Portland cements. For that reason, retardation is necessary.

Conventional retarders for Portland cement are not effective in controlling the set of regulated set cement. However, citric acid is used in the mix as a retarder. Where practical, the setting action can be effectively controlled by reducing the mix temperature. Such reductions in the temperature of the mix are also advantageous, as the heat of hydration is considerably higher than that of Portland cement concrete. For this reasons, all exposed surfaces of newly placed regulated set Portland cement concrete must be protected from moisture loss. Chlorinated rubber, butadiene styrene sealing as well as polyethylene sheets or wet burlap are recommended for this purpose.

Special cements based on chemical reactions, which are completely different from those of normal Portland or similar cements, are now part of the technology. These include fast-setting magnesium phosphate and aluminum-phosphate cements, which used for concrete patching of pavements, allow traffic flow after only 45 minutes.

3.4 Expansive cement

Expansive cement, when mixed with water, forms a paste that, after setting, tends to increase in volume to a significantly greater degree than Portland cement paste. This expansion may be used to compensate for the volume decrease due to shrinkage, or to induce tensile stress in reinforcement.

Types of Expansive cements:

Type K:

An expansive cement containing anhydrous tetra calcium alumino-sulphate, which is burnt simultaneously with a Portland cement composition, or burnt separately, when it is to be interground with Portland cement clinker or blended with Portland cement, calcium sulphate and free lime.

Type M:

It is a mixture of Portland cement, calcium-aluminate cement and calcium sulphate

Type S:

It is a Portland cement, containing a large compound of tricalcium-aluminate content and modified by an excess of calcium sulphate, above the usual optimum content.

In all cases, the specific surfaces or fineness of expansive cement has a major influence on its expansion characteristics.

The increase in specific surface accelerates very early formation of ettingite in the plastic mix, and as a result, with the increase in the specific surface for a given sulphate content, the amount of expansion decreases with increasing surface area.

3.5 polymer concrete

Polymers are used in the production of 3 types of polymer concrete composites: polymer-impregnated concrete (PIC), polymer concrete (PC, polymer Portland cement concrete (PPCC).

Polymer concrete is formed by polymerizing a monomer, mixed with aggregate at ambient temperature, using curing agents or a chemical catalyst. Just as cement is used as a binder in cement concrete. Monomer or resin is added to bind preheated aggregates consisting of course fine ultrafine and other aggregates. The commonly used binders are styrene, methyl-methacrylate, polyesters and epoxies.

In the prepack method, graded dry aggregates are packed in the moulds, and polymer is poured into the voids, if necessary by vacuum process.

In the premix method, polymer and aggregates are mixed in conventional mixers and mix transferred to moulds. The mix is vibrated for compaction.

Properties

They are highly resistant to chemical attack, freeze and thaw. Permeability a

nd absorption ids almost zero.

Application

Even though the initial cost is high, the material cost efficiency is estimated to be 400% compared to ordinary cement concrete. Hence they are used to manufacture polybeton pipes for carrying chemicals in industries.

Polymer concrete has been used for surface patching and full depth patches of bridge decks, as for example, the work on the Major Degan Expressway in New York City. Manufacture of wall panels and pipes are other uses, to which this material has been put. It has been used as a corrosion-resistant pipe liner, and could be used as such in repair procedures.

3.6 Sulphur – Inflitrated Concrete

New types of composites have been produced by the recently developed techniques of impregnating porous materials like concrete with sulphur. Sulphur impregnation has shown great improvement in strength. Physical properties have been found to improve by several hundred per cent and large improvements in water impermeability and resistance to corrosion gave also been achieved.

In the past, some attempts have been made to use sulphur as a binding material instead of cement. Sulphur is heated to bring it not molten condition to which condition to which coarse and fine aggregates are poured and mixed together

. On cooling, this mixture gave fairly good strength, exhibited acid resistance and also other chemical resistance, but it proved to be costlier than ordinary cement concrete.

Recently, use of sulphur was made to impregnate lean porous concrete to improve its strength and other useful properties considerably. In this method, the quantity of sulphur used is also comparatively less and thereby the processes is made economical. It is reported that compressive strength of about 100 MPa could be achieved in about 2 days time. The following procedures have been reported in making sulphur-infiltrated concrete.

A coarse aggregate of size 10 mm and below, natural, well graded, fine aggregate and commercial sulphur of purity 99.9 per cent are used. A large number of trail mixes are made to determine the best mix proportions. A water/cement ratio of 0.7 or over has been adopted in all the trials. A number of 5 cm cubes, 7.5 cm x 15 cm cylinders and also 10 mm x 20 cylinders are cast from each batch of concrete. These samples are stored under wet cover for 24 hours, after which they are removed from moulds and the densities determined. Control specimens are moist cured at 24^0C for 26 hours.

Two procedures are adopted. In procedure “A” after 24 hours of moist curing, the specimen is dried in heating cabinet for 24 hours at 121^0C. Then the specimen are placed in a contained of molten sulphur at 121^0C for 3 hours. Specimens are removed from the container, wiped clean of sulphur and cooled to room temperature for one hour and weighed to determine the weight of sulphur infiltrated concrete.

In procedure “B” the dried concrete specimen is placed in an airtight container and subjected to vacuum pressure of 2mm mercury for two hours. After removing the vacuum, the specimens are soaked in the molten sulphur at atmospheric pressure for another half an hour. The specimen is taken out, wiped clean and cooled to room temperature in about one hour. The specimen is wighed and the weight of sulphur-impregnated concrete is determined.

The specimens made adopting procedure A and B tested by compression and splitting tension tests. It is seen that the compression strength of sulphur-infiltrated cubes and cylinders are enormously greater than the strength of plain moist cured specimen. It is found that when water/cement ratio of 0.7 is adopted an achievement of about 7 fold increase in the strength of the test cube when procedure B is adopted and five-fold increase in strength when procedure A is adopted was obtained. When water/cement ratio 0.8 is adopted, procedure B gave about a tenfold increase in strength.

Similarly, the sulphur-infiltrated concrete showed more than four times increase in splitting tensile strength when procedure B was adopted.

It was also found that the elastic properties of sulphur-infiltrated concrete have been generally improved 100 per cent and also sulphur-infiltrated specimen showed a very high resistance to freezing and thawing. When the moist cured concrete was disintegrated after about 40 cycles, the sulphur impregnated concrete was found to be in fairly good condition, even after 1230 cycles, when procedure b was adopted and the sample deteriorated after 480 cycles when the

sample was made by procedure A. table 12.8 and table 12.9 show the typical values of strength test conducted.

The improvement in strength test attributed to the fact that porous bodies having randomly distributed pores have regions of stress concentration when loaded externally. The impregnation of a porous body by some material would modify these stress concentrations. The extent of modification will depend on how well the impregnant has penetrated the smaller pores.

Application of Sulphur – Infiltrated concrete

The sulphur-infiltration can be employed in the precast industry. This method of achieving high strength can be used in the manufacture of pre-cast roofing elements, fencing posts. Sewer pipes, and railway sleepers, sulphur-infiltrated concrete should find considerable use in industrial situations. Where high corrosion resistant concrete is required. This method cannot be conveniently applied to cats-in place concrete.

Preliminary studies have indicated that sulphur-infiltrated precast concrete units are cheaper than commercial concrete. The added cost of sulphur and process should be offset by considerable savings in concrete.

The techniques are simple, effective and inexpensive. The tremendous strength gained in pressure application, where in immersion accompanied by evacuation may also offset the extra cost. The attainment of strength in about two days time makes this process all the more attractive.

3.7 Ferro cement

Ferro cement technique, though of recent origin, have been extensively used in many countries, notably in U.K. There is a growing awareness about the advantages of this technique, all over the world. It is well known that conventional reinforced concrete members are too heavy, brittle, cannot be satisfactorily repaired if damaged, develop cracks and reinforcements are liable to be corroded. The above disadvantages of normal concrete make it efficient for certain types of work.

Ferro cement is a relatively new material, consisting of wire meshes and cement mortar. This material was developed by P.L.Nervi, an Italian architect and engineer, in 1940. It consists of closely spaced wire meshes, which are impregnated with rich cement mortar mix. The wire mesh is usually of 0.5 to 1.0mm dia wire at 5mm to 10mm spacing, and cement mortar is of cement sand ratio of 1:2 with water/cement ratio of 0.4 to 0.45. The ferrocement elements are usually of the order of 2 to 3cm in thichness with 2 to 3mm external cover, to the reinforcement.

The steel content varies between 300Kg to 500kg per cubic meter of mortar. The basic idea behind this material is that, concrete can undergo large strains in the neignbourhood of the reinforcement, and the madnitude of strains depends on the distribution and subdivision of reinforcement, throughout of the mass of concrete.

Ferrocement is widely accepted in UK as about building material. It has also found various other interesting civil engineering applications. The main advantages are simplicity of its construction, lesser weight of the elements due to their small thickness, its high tensile strength, less crack widths compared to conventional concrete, easy repairability, non-corrosive nature and easier mould ability to any required shape.

There is also saving in basic materials namely, cement and steel. This material is more suitable to special structures like shells, which have strength through forms and structures like roofs, silos, water tank and pipe lines.

The material is under active research in various countries, and attempts are being made to give a sound theoretical backing to establish the material behavior. This is a highly suitable material for precast products, because of its easy adaptability to prefabrication and lesser dad weight of the units cast. The development of ferro-cement depends on suitable casting techniques for the required shape. Development of proper prefabrication techniques for ferro-cement is still not a widely explored area, and gap needs to be filled.

3.8 Fiber Reinforced Concrete

Plain concrete possess a very low tensile strength, limited ductility and little resistance to cracking, Internal micro – cracks are inherently present in the concrete and its poor tensile strength is due to the propagation of such micro –cracks eventually leading to brittle fracture of the concrete.

In the past, attempts have been made to impart improvement in tensile properties to concrete in embers, by way if using conventional reinforced steel bars and also applying restraining techniques, although both these methods provide tensile strength to the concrete members, they however, do increase the inherent Leslie strength concrete itself.

In plain concrete and similar brittle materials, structural cracks develop even before loading, particularly due to drying shrinkage or other causes of volume changes. The width of these initial cracks seldom exceeds a few microns, but their other two dimensions may be higher magnitude

When loaded, the micro cracks propagate open up, and owing to the effect of stress concentration additional cracks form in places of motion defects. The structural cracks proceed slowly or by liny jumps, because they are retarded by various obstacles, changes of direction in bypassing the more resistant grains in matrix. The development of such micro –cracks is the main cause of ineleastic deformation in concrete.

It has been recognized that the addition of small, closely spaced and uniformly dispersed fibres to concert would act as crack arrester, and would subliminally improve its statie and dynamic properties. This type of concrete is known as Fibre Reinforced concrete. \ FRC can be defined as a composite material, consisting of mixtures of cement, mortar or concrete and discontinuous, discrete, uniformly dispersed suitable fibres. Continuous meshes woven fabrics and long wires or rods are not considered to be discrete fibres.

Fibre is a small piece of reinforcing material, possessing certain characteristic properties, they can be circular or flat. The fibre is often described by a convenient parameter called ‘aspect ratio’. The aspect ratio of the fibre is the true ratio of its diameter. Typical aspect ratio runges from 30 to 150.

Steel fibre is one of the most commonly used generally, round fibres are used. The diameter may very from 0.25 to 0.75mm.

The steel fibre is likely to get rusted and lost some of its strengths. But investigations have shown that the rusting of fibres tacks place only at the surface. Use of steel fibres makes significant improvements in flexural, impact and fatigue strength of concrete. It has been extensively used in various types of structures, particularly for overlays of roads, airfield pavements and bridge decks. Thin shells and plates have also been contracted using steel fibres.

Polypropylene and Nylon fibres are found to be suitable to increase the impact strength. They possess very high tensile strength, but their low modules of electricity and higher elongation do not contribute to the flexural strength.

Glass fibre is a recent introduction in making fibre concrete. It has very tensile strength 1020 t 4080 N/mm. Glass fibre, which is originally used in conjunction with cement was found to be affected by alkaline condition of cement. Therefore, alkali-resistant glass by tradename 'CEM-FIL' has been developed and used. The alkali resistant fibre reinforced concrete shows considerable improvement in durability when compared to the conventional E –Glass fibre.

Carbon fibres, perhaps possess very high tensile strength -2110 to 2815 N/mm and Young's Modulus. It has been reported that cement composite made with carbon fibre, as reinforcement, will have very high modulus of Elaticity and flexural strength. The limited studies have shown good durability. The use of carbon fibres for structure like cladding, panels and shells will have promising future.

UNIT IV

TECHNIQUES FOR REPAIR AND DEMOLITION

Rust eliminators and polymers coating for rebars during repair, foamed concrete, mortar and dry pack, vacuum concrete, Gunite and Shotcrete, Epoxy injection, Mortar repair for cracks, shoring and underpinning. Methods of corrosion protection, corrosion inhibitors, corrosion resistant steels, coatings and cathodic protection. Engineered demolition techniques for dilapidated structures - case studies.

4.1Foamed concrete

Aerated concrete is made by introducing air or gas into a slurry composed of Portland cement or lime and finely crushed siliceous filler so that when the mix set and hardens, a uniformly cellular structure is formed. Though it is called aerated concrete it is really not a concrete in the correct sense of the word. As described above, it is a mixture of water, cement and finely crushed sand. Aerated concrete is also referred to as gas concrete, foam concrete, cellular concrete. In India we have at present a few factories manufacturing aerated concrete. A common product of aerated concrete in India is Siporex.

There are several ways in which aerated concrete can be manufactured,

(a) By the formation of gas by chemical reaction within the mass during liquid or plastic state.

(b) By mixing performed stable foam with the slurry

(c) By using finely powdered metal (usually aluminum powder) with the slurry and made to react with the calcium hydroxide liberated during the hydration process, to give out large quantity of hydrogen gas. This hydrogen gas when contained in the slurry mix, gives the cellular structure.

Powered zinc may also be added in place of aluminum powder. Hydrogen peroxide and bleaching powder have also been used instead of metal powder. But this practice is not widely followed at present.

In the second method performed, stable foam is mixed with cement and crushed sand slurry causing the cellular structure when this gets sets and hardened. As a minor modification some foam-giving agents are also mixed and thoroughly churned or beaten (in the same manner as that of preparing foam with the white of egg) to obtain foam effect in the concrete. in a similar way, air entrained agent in large quantity can also be used and mixed thoroughly to introduce cellular aerated structure in the concrete. however, this method cannot be employed for decreasing the density of the concrete beyond a certain point and as such, the use of air entrainment is nor often practiced for making aerated concrete.

Gasification method is of the most widely adopted methods using aluminum powder or such other similar material.

This method is adopted in the large scale manufacture of aerated concrete in the factory wherein the whole process is mechanized and the product is subjected to high pressure steam curing i.e., in

other words, the products are autoclaved. Such products will suffer neither retrogression of strength nor dimensional instability.

The practice of using performed foam with slurry is limited to small scale production and in situ work where small change in the dimensional stability can be tolerated. But the advantage is that any density desired at site can be made in this method.

Properties

Use of foam concrete has gained popularity not only because of the low density but also because of other properties mainly the thermal insulation property. Aerated concrete is made in the density range from 300 kg/m^3 to about 800 $kg.m^3$, lower density grades are used for insulation purposes, while medium density grades are used for the manufacture of building blocks or load bearing walls and comparatively higher density grades are used in the manufacture of prefabricated structural members in conjunction with steel reinforcement.

4.2 Mortar and dry pack

Dry pack is a combination of Portland cement and sand passing a No. 16 sieve mixed with just enough water to hydrate the cement. Dry pack should be used for filling holes having a depth equal to, or great then, the least surface dimension of the repair area, for cone bolt, she holt, core holes, and grout-insert holes; for holes left by the removal of form ties; and for narrow slots cut for repair cracks. Dry pack should not be used for relatively shallow depressions where lateral restraint cannot be obtained, for filling behind reinforcement, or for filling holes that extend completely, through a concrete section.

For the dry-pack, method of concrete repair, holes should be sharp and square at the surface edges, but corners within the holes should be rounded, especially when water tightness is required. The interior surfaces of holes left by cone bolts and she bolts should be roughened to develop an effective bond; this can be done with a rough stub of 7/8-inch steel-wire rope, a notched tapered reamer, or a star drill. Other holes should be undercut slightly in several places around the perimeter. Holes for dry pack should have a minimum depth of 1 inch.

4.2.1 Preparation and application

Application of dry-pack mortar should be preceded by a careful inspection of the hole, which should be thoroughly cleaned and free from mechanically held loose pieces of aggregate. One of three methods should be used to ensure good bond of the dry-pack repair. The first method id the application of a stiff mortar ar grout bond coat immediately before applying the dry-pack mortar. The mix for the bonding grout is 1: 1 cement and fine sand mixed with water to a fluid paste consistency.

All surfaces of the hole are thoroughly brushed with the grout, and dry packing is done quickly before the bonding grout can dry. Under no circumstances should be bonding coat be so wet or applied so heavily that the dry-pack material becomes more has slightly rubbery.

When a grout bond coat is used, the hole to be repaired can be dry. Presoaking the hole overnight with wet rags or burlap prior to dry packing may sometimes give better results by reducing the loss of hydration water, but there must be no free surface water in the hole when the bonding grout is applied.

The second method of ensuring good bond starts with presoaking the hole overnight with wet rags or burlap. The hole is left slightly wet with a small amount of free water on the inside surfaces. The surfaces have been covered and the free water absorbed. Any dry cement in the hole should be removed using a jet of air before packing begins.

The hole should not be painted with neat cement grout because it could make the dry-pack material too wet and because high shrinkage would prevent development of the bond that is essential to a good repair. A third method of ensuring good bond is use of an epoxy bonding resin. Epoxies bond best to dry concrete. It may be necessary to dry the hole immediately prior to dry packing using hot air, a propane torch, or other appropriate method.

The concrete temperature however should not be high enough to cause instant setting of the epoxy or to burn the epoxy when it is applied. After being mixed, the epoxy is thoroughly brushed to cover all surfaces, but any excess epoxy is removed. Dry-pack mortar is then applied immediately, before the epoxy starts to harden.

The epoxy must be either fluid or tacky when dry packing takes place. If it appears that the epoxy may become hard before dry packing is complete, fresh fluid epoxy can be brushed over epoxy that has become tacky.

If the epoxy becomes hard, it must be comes hand, it must be removed before a new coat is applied. The epoxy ensures a good bond between the dry-pack repair and the old concrete. It also reduces can loss of hydration water from the repair to the surrounding concrete, thus assisting in good curing; however, the epoxy-bonded dry pack still requires curing as discussed below. Where appearance is not important, epoxy has sometimes been used on the surface in place of a curing compound. This procedure is not recommended.

4.3 Vacuum Concrete

It has been amply brought out in the earlier discussion that high water/cement ratio as harmful to the overall quality of concrete. Whereas low water/cement ratio does not give enough workability for concrete to be compacted hundred per cent. Generally, higher workability and higher strength or very low workability and higher strength do not go hand in hand. Vacuum process of concreting enables to meet this conflicting demand. This process helps a high workable concrete to get high strength.

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

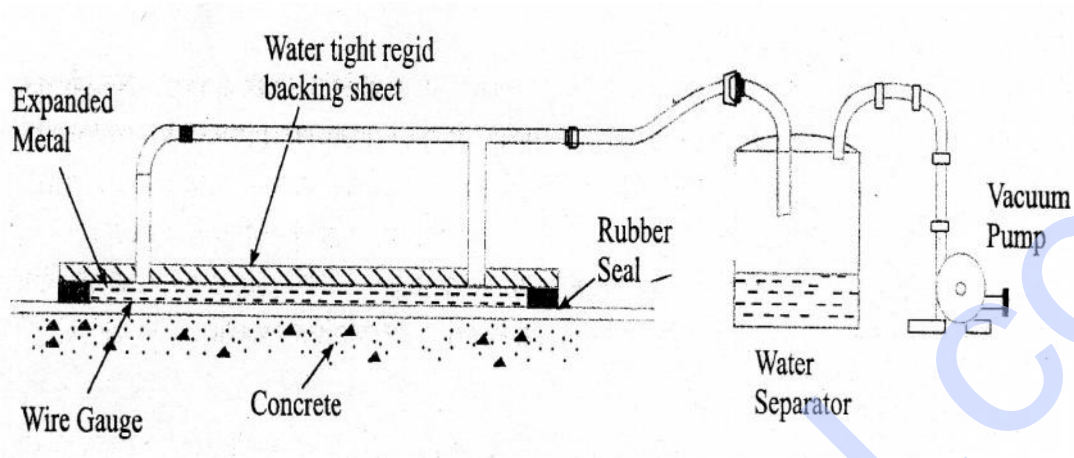


Fig 4.3.1 **Vacuum Concrete pumps arrangement**

The equipment is shown in Figure 4.3.1. It essentially consists of a vacuum pump, water separator and filtering mat. The filtering consists of a backing piece with a rubber seal all round the periphery. A sheet of expanded metal and then a sheet of wire gauge also forms part of the filtering mat. The top of the suction mat is connected to the vacuum pump. When the vacuum pump operates, suction is created within the boundary of the suction mat and the excess of water is sucked from the concrete through the fine wire gauge or muslin cloth. At least one face of the concrete caused by loss of water must be vibrated.

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

Rate of Extraction of Water

The rate of extraction of water is dependent upon the workability of mix , maximum size of aggregate, proportion of fines and aggregate cement ratio. In general, the following general tendencies are observed:

(a) The amount of water which may be withdrawn is governed by the initial workability or the amount of free water. A great reduction in the water/cement ratio can, therefore, be obtained with higher initial water/cement ratio.

(b) If the initial water / cement ratio is kept the same the amount of water which can be extracted is increased by increasing the maximum aggregate size or reducing the amount of fines in the mix.

(c) Although the depression of the water/cement ratio is less, the lower the initial water/cement ratio, the final water / cement ratio is also less, the lower the initial value.

(d) The reduction in the water / cement ratio is very slightly less with mixes leaner than 6 to 1, but little advantage is gained with mixes richer than this

(e) The greater the depth of concrete processed the smaller is the depression of the average water/cement ratio.

(f) The ability of the concrete to stand up immediately after processing is improved if a fair amount of fine material is present, if the aggregate size is restricted to 19 mm and if a continuous grading is employed.

(g) Little advantage is gained by prolonging the period of treatment beyond 15 to 20 minutes and a period of 30 minutes is the maximum that should be used.

It is found that there is a general tendency for the mix to be richer in cement near the processing face. This may be due to the fact that along with water, some cement gets sucked and deposited near the surface. It is also found that the water/cement ratio near the surface will be lower in value, anything from 0.16 to 0.13, than the original water /cement ratio. Because of the above reasons the vacuum processed concrete will not be of uniform strength.

The simultaneous vibrations or the subsequent vibrations will reduce this shortcoming to some extent and also increase the strength of the concrete. If vibration is not done, the continuous capillary channels may not get disturbed and the strength would not be improved in relation to decreased water/cement ratio. Table 12.15 shows the comparisons of strength of processed and unprocessed cubes.

Table. 4.3.1 Comparison of Strength of Processed and unprocessed cubes having the same water/cement ratio

Initial water/cement ratio of processed cubes	0.74	0.71	0.65	0.60
Average final water/cement ratio of processed cubes	0.68	0.59	0.57	0.55
Strength of unprocessed cubes of the same water/cement ratio as the initial water/cement ratio of the processed cubes MPa	18.0	15.3	19.1	30.1
Strength of fully vibrated processed cubes and increase of strength due to processing (per cent) : MPa	23.3 30	22.6 48	27.5 43	33.4 11
Strength of unprocessed cubes of the same water/cement ratio as the average final water/cement ratio of the processed cubes and increase of strength due to the reduction in water/cement ratio MPa (per cent	24.9 38	33.7 74	36.5 91	39.4 30
Increase in strength due to the reduction of water/cement ratio according to Road Note No. 4 (Per Cent)	20	44	27	16

4.4Gunite or Shotcrete

Gunite can be defined as mortar conveyed through a hose and pneumatically projected at a high velocity on to a surface. Recently the method has been further developed by the introduction of small sized coarse aggregate into the mix deposited to obtain considerably greater thickness in one operation and also to make the process economical by reducing the cement content.

Normally fresh material with zero slump can support itself without sagging or peeling off. The force of the jet impacting on the surface compact the material. Sometimes use of set accelerators to assist overhead placing is practiced. The newly developed 'Redi-set cement" can also be used for shotcreting process.

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

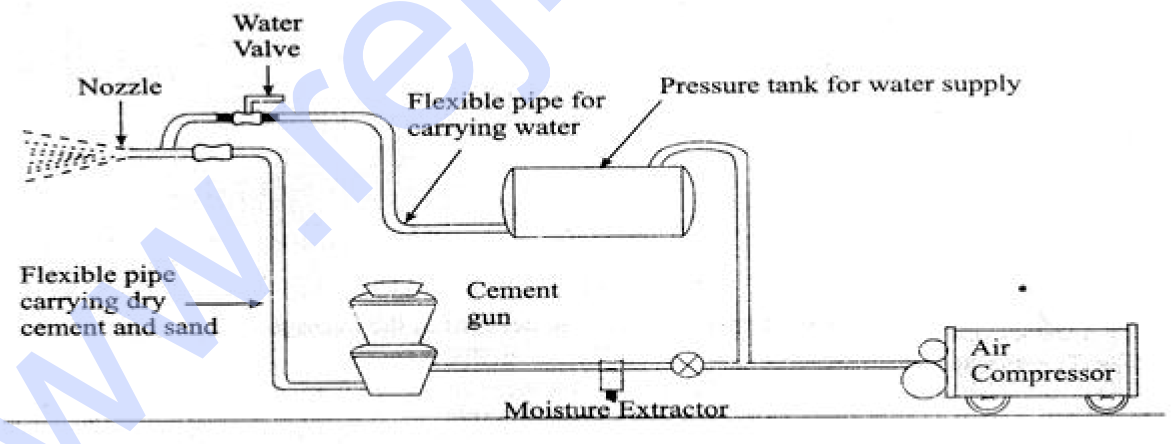
There are two different processes in use, namely the 'Wet-mix" process and the 'dry-mix" process. They dry mix process is more successful and generally used.

Dry-mix process

The dry mix process consists of a number of stages and calls for some specialized plant. A typical plant set-up is shown in Fig

The stages involved in the dry mix process is given below :

(a) Cement and sand are thoroughly mixed.



General arrangement of apparatus in gunite system.

(b) The cement/sand mixture is fed into a special air-pressurized mechanical feeder termed as "gun".

(c) The mixture is metered into the delivery hose by a feed wheel or distributor within the gun.

(d) This material is carried by compressed air through the delivery hose to a special nozzle. The nozzle is fitted inside with a perforated manifold through which water is sprayed under pressure and intimately mixed with the sand/cement jet.

(e) The wet mortar is jetted from the nozzle at high velocity onto the surface to be gunited.

The Wet-mix Process

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

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

The dry-mix methods make use of high velocity or low velocity system. The high velocity gunite is produced by using a small nozzle and a high air pressure to produce a high nozzle velocity of about 90 to 120 metres per second.

This results in exceptional good compaction. The lower velocity gunite is produced using large diameter hose for large for large output. The compunction will not be very high.

Advantages of Wet and Dry process

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

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

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

Pockets of lean mix and of rebound can occur with the dry process. It is necessary for the nozzelman to have an area where he can dump unsatisfactory shotcrete obtained when he is adjusting the water supply or when he is having trouble with the equipment.

These troubles and the dust hazard are less with the wet process, but wet process does not normally give such a dense concrete as the dry process. Work can be continued in more windly weather with the wet process than with the dry process. Owing to the high capacities obtainable with concrete pumps, a higher rate of laying of concrete can probably be achieved in the wet process than with the dry process.

4.5 Epoxy injection

Resin injection is based to repair concrete that is cracked or delaminated and to seal cracks in concrete to water leakage. Two basic types of resin and injection techniques are used to repair concrete; epoxy resins and polyurethane resins. Epoxy resins cure to form solids with high strength and relatively high module of elasticity.

These materials bond readily to concrete and are capable, when properly applied, of resorting the original structural strength to cracked concrete. The high modules of elasticity causes epoxy resin systems to be unsuitable for rebonding cracked concrete that will undergo subsequent movement.

The epoxies, however, do not cure very quickly, particularly at low temperatures, and using them to stop large flows of water may not be practical. Cracks to be injected with epoxy resins should be between 0.005 inch and 0.25 inch in width.

It is difficult or impossible to inject resin into cracks less than 0.005 inch in width, while it is very difficult to retain injected epoxy resin in cracks greater than 0.25 inch in width, although high viscosity epoxies have been used with some success Epoxy resins cure to form relatively brittle materials with bond strengths exceeding the shear or tensile strength of the concrete.

If these materials are used to rebound cracked concrete that is subsequently exposed to loads exceeding the tensile or shear strength of the concrete, if should be excepted that the cracks will recur adjacent to the epoxy bond line. In other words, epoxy resin should not be used to rebond “working” cracks.

Epoxy resins will bond with varying degrees of success to wet concrete, and there are a number of special techniques that have been developed and used to rebond and seal water leaking cracks with epoxy resins. These special techniques and procedures are highly technical and, in most cases, are proprietary in nature.

Polyurethane resins are used to seal and eliminate or reduce water leakage from concrete cracks and joints. They can also be injected into cracks that experience some small degree of movement. Such systems, with the exception of the two-part solid polyurethanes, have relatively low strengths and should not be used to structurally rebond cracked concrete.

Cracks to be injected with polyurethane resin should not be less than 0.005 inch in width. No upper limit on crack width has been established for the polyurethane resins at the time this is being written.

Polyurethane resins are available with substantial variation in their physical properties. Some of the polyurethanes cure into flexible foams.

Other polyurethane systems cure to semi-flexible, high-density solids that can be used to rebond concrete cracks subject to movement.

Most of the foaming polyurethane resins require some form of water to initiate the curing reaction and are, thus, a natural selection for use in repairing concrete exposed to water or in wet environments.

At the time this is written, there are no standard specifications for polyurethane resins equivalent to the standard specification for Epoxy-Resin-Base Bonding Systems for Concrete. ASTM Designation C-881.

4.6 Mortar repair for cracks

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

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

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

4.6.1 Preparation and materials

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

4.6.2Curing

Failure to cure properly is the most common cause of failure of replacement mortar.

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

4.6.3 Applications

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

4.7 Shoring and underpinning

The arrangement employed to prevent a damaged structure, due to either foundation settlement or other reasons from collapse, is called shoring. It is also used for providing temporary support to a structure which is being remodeled.

The shores are of types :

- ✓ **Racking Shores :** In this type, notches are cut in the walls of the building and inclined posts are property, while demolishing the building, are called horizontal or flying shores.
- ✓ **Horizontal of Flying Shores :** The shores, which are employed to support the walls of adjoining property while demolishing the building are called horizontal or flying shores.
- ✓ **Vertical Dead Shores :** The vertical shores used to support walls temporally are called vertical or Dead shores.

Underpinning

The operation of providing new permanent foundation is known as underpinning

The under pining may be done by the following methods.

Pit Underpinning

In this method, a pit is dug to expose the foundation to b remodeled & the old foundation is either removed completely or strengthened suitably.

Pier Underpinning

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

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

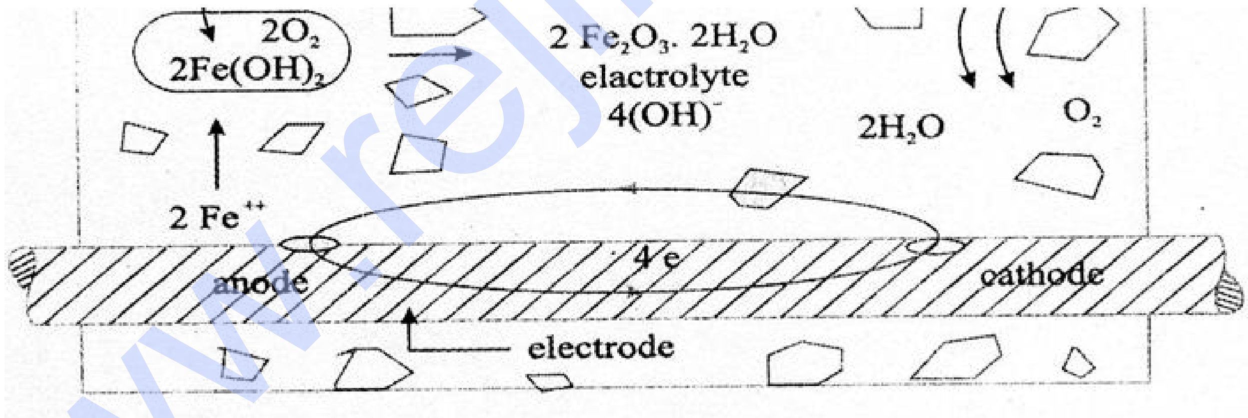
In this method piles are jacked into the ground with case for underpinning building, where underlying ground has water bearing strata.

4.8 Methods of corrosion protection, corrosion inhibitors, corrosion resistant Steels, coatings and cathodes protection

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

4.8.1Corrosion Mechanism – Wet or Electro-Chemical Corrosion

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



Simplified model representing corrosion mechanism

The reactions are described below:

Anodic Reactions:

$Fe \longrightarrow Fe^{++} + 2e^{-}$

$Fe^{++} + 2(OH)_2 \longrightarrow Fe(OH)_2$

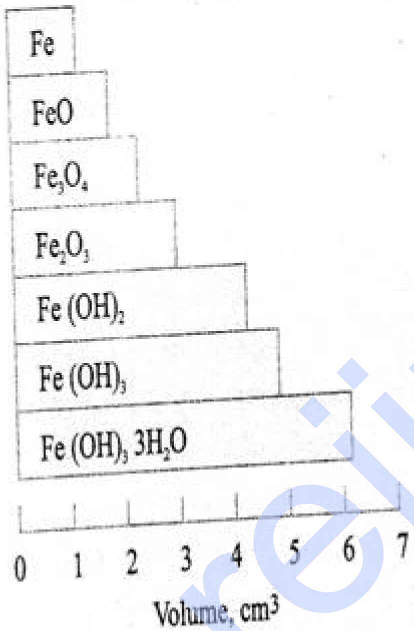
$Fe(OH)_2.2H_2O + O_2 \longrightarrow 4Fe(OH)_3$

Cathodic Reaction

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

It can be noted that no corrosion takes place if the concrete is dry probably below relative humidity of 60%, because enough water is not there to promote corrosion. it can also be noted that corrosion does not take place, id concrete is fully immersed in water, because diffusion of oxygen does not take place into the concrete. probably the optimum relative humidity for corrosion is 70-80%

The products of corrosion occupy a volume as much as 6 times the original volume of steel, depending upon the oxidation state. Figure below shows the increase in volume of steel, depending upon the oxidation state.



Shows that, depending on the oxidation state, metallic iron can increase more than six times in volume

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

Increase the oxygen content has 2 effects :

(i) it forces the cathodic reaction to the right, producing more OH- ions and
(ii) it removes more electrons and therefore, accelerates the corrosion at the anode.

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

4.8.2 Corrosion Inhibitors

A corrosion inhibitor is an admixture that is used in concrete to prevent the metal, embedded in concrete form cording. There exists various types of inhibitors like Cathode, Anode, mixed and Dangerous, Safe.

Of the available corrosion inhibiting materials, the most wide used admixture is based on calcium nitric. It is added to the concrete during mixing of concrete. The typical dosage id of the order of 10-30 litres per m^3 of concrete, depending on the chloride levels in concrete.

In the high pH of concrete the steel is protected by a passivating layer of ferric oxide, on the surface of steel. (passivation may be defined as ‘phenon enon in which a metal or an alloy exhibits a much higher corrosion resistance, than expected from its positon in the electrochemical series.

Passivity is the result of the formation of a highly protective, but very thin, (about 0.0004mm thick) and quite invisible film on the surface of metal or an alloy, which makes it more fine). However, the passivating layer also contains some ferrous oxide, which can initiate corrosion, when the chloride ions reach the steel. The nitrite ions present in the corrosion inhibiting admixture will oxidize the ferrous oxide

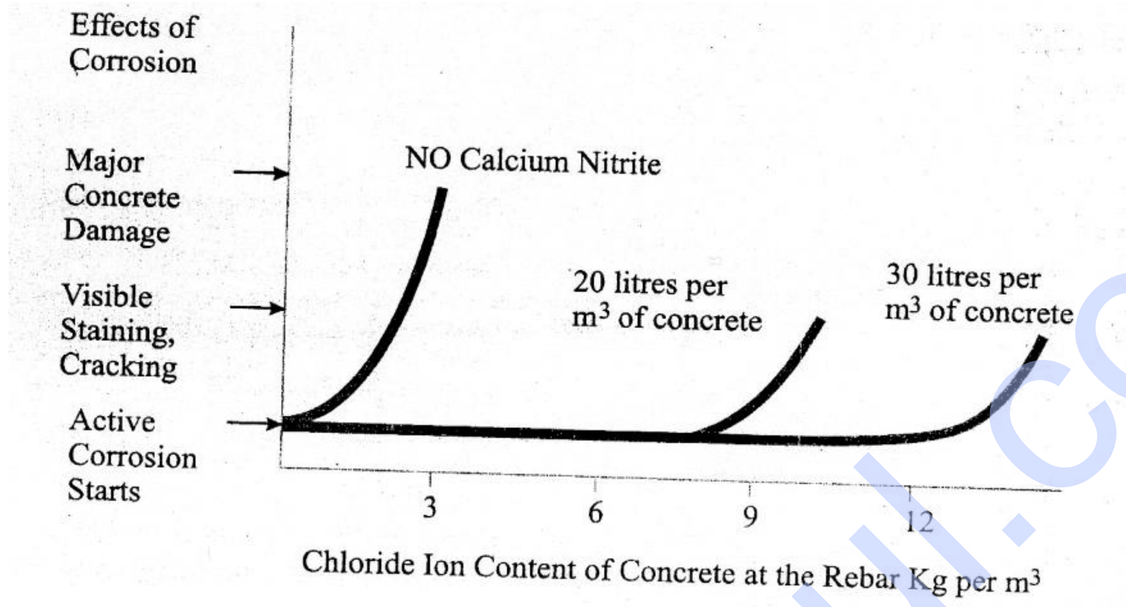
Passivating layer even in the presence of chlorides. The concentration of nitrite must be sufficient, to cope up with the continuing ingress (entrance) of chloride ion.

Calcium nitrite corrosion inhibitor comes in a liquid form, containing about 30% calcium nitrite solids by weight. The more corrosion inhibitor is added, the longer the onset of corrosion will be delayed.

Since most structures in a chloride environment reach a leyel of about 7 Kg of chloride iron per m^3 during their service life, use of less than 18 litres/m^3 of calcium nitrite solution is not recommended.

Figure shows that without an inhibitor, the reinforcing steel starts to corrode, when the chloride content at the rebar reaches a threshold level of 0.7Kg/m^3. Although the corrosion process starts when the thereshold level is reacted, it may take several years for staining, cracking & spalling to become apparent, (clear) and several more years before deterioration occurs.

Adding calcium nitrite increases this corrosion thereshold. When you ass 20 litres/m^3, corrosion will not begin until over 7.7 Kg/m^3 of chloride is present in the concrete at the rebar.



4.8.3 Cathode Protection

Cathode protection is one of the effective, well known, and extensively used methods for prevention of corrosion in concrete structures in more advanced countries. Due to high cost and long term monitoring required for this method, it is not very much used in India.

The cathode protection comprises of application of impressed current, to an electrode laid on the concrete, above steel reinforcement. This electrode serves as anode and the steel reinforcement, which is connected to the negative terminal of a DC source acts as a cathode.

In this process, the external anode is subjected to corrode and the cathode reinforcement is protected against corrosion and hence the name 'Cathode Protection".

In this process, the –ve chloride ions, which are responsible for the damage of the passivating film, are drawn away from the vicinity of steel towards the anode, where they are oxidized to form chlorine gas.

The other recent development in corrosion control methods are Re-alkalization and De-salnation. The re-alkalisation process allows to make the concrete alskline again and passivate the reinforcement steel, by electro-chemical method. This brings back the lost alkalinity of concrete of sufficiently high level to reform and maintain the passive layer on the steel.

In the desalination process, the chloride ions are removed form the concrete, particularly from the vicinity of the steel reinforcement by certain electrical method to re-establish the passive layer of the steel.

It appears that the application of cathodic systems for protection of concrete structures, offers some real hope to the concrete technologist, but the field remains open for the introduction of innovative methods to overcome problems of both technique and cost.

4.8.4 Corrosion Resistant Steel

It is found that susceptibility of mild steel to corrosion is not significantly affected by composition, grade or level of stress. Hence substitute steel for corrosion resistance must have a significantly different composition. Based on some success in atmospheric corrosion, weathering steels of the corten type were tested in concrete.

They did not perform will in moist concrete, containing chlorides. It is observed that weathering corrode in similar concrete environments, to those causing corrosion of high-yield steel. They noted that although the total amount of corrosion was less, than would occur on high-yield steel under similar conditions, deep localized pitting developed, which could be more structurally weakening.

Stainless steel reinforcement has been used in special applications, especially as fitments in precast members, but is generally too expensive to use as a substitute for mild steel. Very high corrosion resistance was shown by austenitic stainless steel in all the environments, in which they were tested, but the observations of some very minor printing in the presence of chlorides lead to the warning that crevice corrosion susceptibility was not evaluated in the test program.

High titanium alloy bar is being used in some countries. This bar is grouted into holes, drilled into the marble stabs, and the grouts are based either on Portland cement or Epoxy.

4.8.4Coatings for Steel

The object of coating to steel bar is to provide a durable barrier to aggressive materials, such as chlorides. The coatings should be robust to withstand fabrication of ribcage, and pouring of concrete and compaction by vibrating needle.

Simple cement slurry coating is a cheap method for temporary protection, against rusting of reinforcement in storage.

Central electro chemical Research institute (CECRI), Karaikudi, have suggested a method for prevention of corrosion in steel reinforcement in concrete. The steps involved in this process are :

- ✓ **Derusting**

The reinforcement are cleaned with a derusting solution. This is followed without delay by leaning the rods, with wet waste cloth and cleaning powder. The rods are then rinsed in running water and air dried.

- ✓ **Phosphating**
  - o Phosphate jelly is applied to the bars, with fine brush.

- The jelly is left for 45-60 minutes, and then removed by wet cloth an inhibitor solution is then brushed over the phosphated surface.

✓ **Cement Coating**

Slurry is made by mixing the inhibitor solution, with Portland cement and applied on the bar. A sealing solution is brushed after the rods are air cured. The sealing solution has an insite curing effect. The second coat of slurry is then applied and the bars are air dried.

✓ **Sealing**

Two coats of sealing solution are applied to the bars, in order to seal the micro-pors of the cement coated an to make it impermeable to corrosive sails.

The is patent method evolved by CECRI, and licence is given to certain agencies. Somehow or other, this method has not become very popular. Some experienced consultants and engineers doubt the effectiveness of this method.

It is one of the effective methods of coating rebars. The fusion bonded epoxy coating is a specialized job, carried out in a factory, and not at site of work. Plants are designed to coat the straight bars in a continuous process. Initially, the bar is shot blested to remove all mill scale and to give the kind of surface finish required.

This ensures an adequate bond between epoxy and steel. The bar is then heated to a carefully controlled temperature, before passing thorugh a spray booth. Eletrostatesically charged epoxy powder particulars are deposited evenly on the surface of the bar. It looks greenish in color, the coating thickness vary from 130 to 00 microns.

Although epoxy coated bars have an excellent protection to corrosion in aggressive environment, there are a few limitations.

After the treatment, cutting and bending may injure the steel, which needs certain sit treatment. The site treatment is likely to be inefficient. The presence of any defect in the treated body can induce severe localized corrosion, which defeated very purpose. The bars cannot be welded. The epoxy is not resistant to rays of sun.

The bars should not be exposed to sun for long duration before use. The coating may get damage during vibration of concrete. The treatment is very costly, as that of steel. This method of protection to the steel is being given to all the flyovers, and other structures at Mumbai.

Galvanized Reinforcement

Galvanizing of reinforcement consists of dipping the steel bars in molten zinc. This results in a coating of zinc, bonded to the surface of steel. The zinc surface with calcium hydroxide in the concrete, to form a passive layer and prevents corrosion.

4.9 Engineered demolition techniques for dilapidated structures
4.9.1 Modern Demolition Techniques

- Hydralic Rock Breakers
- Diamond sawing and Drilling
- Diamond wire sawing system
- Silent expansive chemicals
- Controlled Demolition
- Hydralic Brusting / Spliting
- Thermal lancing
- Hydro demolition
- Robolic demolition
- Cor Drilling – uses diamond tipped bits with hydraulic/electric/pneumatic geode drill motors – maximum dia – 2000mm.

✓ **Wire Sawing : Ultimate Demolition Tool**

In wire sawing a diamond beaded wire is reared around the RCC members, to be cut. The wire is rotated at a high speed (100Km/hr) by a special machine while constantly applying a pulling force. The diamond wire penetrates and cuts through the steel and concrete.

Water is used as a lubricating coolant. Wire sawing has limitations on the size of RCC member, to be cut. This technique is ideal for fast primary demolition.

✓ **Hand Sawing**

Han sawing uses a light weight hand held machine, with diamond blade to cut RCC in any direction. By this technique, even over hand cutting is possible. Max. Depth of cut is 150mm.

Diamond Advantage

✓ **Time :** Diamond tools cut concrete fast, reducing down time which Leeds to early project completion.

✓ **Limensional Tolerance**: Diamond cutting is precise and controlled, little or no patching s required.

✓ **Structural Integrity :** Diamond cutting allows removal of large amounts of concrete without damaging, remaining or surrounding structures.

✓ **Noise , Dust and Debris:** Diamond cutting is relatively quiet and virtually dust free concrete pieces can be cut to specified size for easy removal.

✓ **Limited Access:** Diamond cutting techniques can e used in confined areas and arrows existing equipment

Hydraulic Splitters/Busters:

Creates enormous sresses within concrete, producing tensile cracking of concrete.

Dismantling Tools

Hand Operated Machines

Crane Mounted machines

- ✓ Special Machine
- ✓ Robotic machine

Tools to be used for job on Haul

The following factors should determine the technique

- ✓ Volume of concrete to be dismantled
- ✓ Space available for walling
- ✓ Risks involved
- ✓ Acceptable noise and Vibration levels

Hand Held Machines

- ✓ Electrically Operated
- ✓ Battery operated
- ✓ Pneumatic
- ✓ Hydraulic
- ✓ Engine

Key Factors

General

- ✓ Weight
- ✓ Multifunction – Drill, Chip, Hammer Drill
- ✓ Ergonomics

Technical

- ✓ Energy Per Stroke
- ✓ Material Removal Per minute
- ✓ Tool Mount Type
- ✓ Tool Life
- ✓ Maintenance Cost
- ✓ Safety Features
- ✓ Durability

Advantages & Disadvantages of Hand Held Machines

Advantages	**Disadvantages**
Easy to Handle	Requires great inuscular power
Unskilled labour can be used	Limited removal due to low hammer weight
Ideal for dismantling small volumes	Little impact from small diameter chisel

Ideal for short term jobs	High labour cost
Ideal for vibration less chipping.	Harmful box due to vibrations.
	Harmful to finger blood vessels
	Danger from dust & falling debris

4.10 Case studies

Demolition Practice in USA

From as early as 1940, demolition works in USA were taken up with extensive applications of mechanical contrivances (something artificial) and convenient improvisations. (Provide or construct from materials etc, which is not intended for the purpose). The impact of blows from a large-sized iron ball swung from mobile crane boom brought drawn multi-storeyed apartment buildings and old structures. With the area well cordoned, off, the rubble and debris together with the rising dust were tackled in such a way, that at no stage was there any depature form the main aim of containing the effects of the demolition within the boundary.

In course of time, more improvements came by, and a significant alternative developed around 1950 was the use of dynamite in a sophisticated arrangement, whereby the operation could be carried out instantaneously and with no risk to the adjacent buildings or disturbance to the neighbourhood. The term implosion referred to this new process, was synonymous with the phenomenon of an explosion that caused no scattening of material knocked off, but absorbed them well within the extremists of the compound.

Implosion Contract

A world wide leader in the implosion business, Controlled Demolition Inc., USA is a pioneer in this technique applied to demolition. In the works of its president Loizure, ‘it is delieate art of denoting explosives, in just the right places to make a building collapse about neatly into its footprint.” The company takes justifiable pride that it has leveled about 7000 structures till date.

It is therefore, not a wonder that its services have been hired recently in Scuttle. The project here attracted the attention, of not only professional, but every citizen around, including the die-hard, who could not tolerate the removal of any historic landmark.

Following the changing needs of the metropolis, and the American predilection for newness, something befitting the city’s huge arena, called “Kingdome”, looked incongruous.

This large indoor stadium was a multipurpose facility built in 1936 and served as the venue for all kinds of sports events, athletic meets, public functions and even music concerts. But the authorities decided on its demolition, to pave way for a modern open air starlium.

The Implosion Technique

The unique ‘Kingdome” structure was a circular building with a strong, light roof only 5’ thick and spanning 670.

It was so strong that it could endure a earthquake, and take on two feet of snow on its top, it can be seen that breaking such a dome needed all the ingenuity and the expensive of the contracting company, which had to wind. 1 miles of detonation cord through the structure, that was expected to light up like a lightening, flash followed by the sound of explosions.

. The day chosen for the demolition was a Sunday and nearly a week earlier. It is needless to add how much pre-panning and preparation had gone into this colossal scheme before actually putting into action the actual detonation. The entire series of operations formed five distinct stages from the preliminary phase, until the final explosion.

- ✓ **Stripping the Dome :** Removing of roof surfacing pieces and insulation and exposing only the concrete. Stripping of AC systems fully. Other ramp demotion and removing lower level seating outfit, leaving concrete supports like beams and cnume.
- ✓ **Rotecting Neighbourhood :** Wrapping nearby buildings with cushioning material, creating protective walls and berms around the site, and finally cottoning off (circle of police) the demolition area
- ✓ **Arranging Detonation Points:** Drilling about 6000 holes of 1.5 feet diameter and 5 to 6 feet deep in the ribs of the roof and supporting columns. Packing the holes with a pre-calculated measure of explosives and fixing a time delay circuit. Wrapping 10000 ft of detonation cord to connect all the explosive points.
- ✓ **Topping Up:** As a last phase, providing a thin top layer of the explosive material, and a hand denotation cord together with a fuse. This completed al the arrangements.
- ✓ **Explosion:** As the cord was ignited, the fuse got set off, starting explosions in a controlled, progressive way at different intervals. The rubble from the lowest section got spread out in berms across the floor. This helped to absorb to some extent the impact from falling debris of the upper levels.
- ✓ **A great Feat:** The destruction of “Kingdome”, an architectural beauty was a great engineering love loads, increased wheel loads, installations of heavy machined in demolition technology.

UNIT V
REPAIRS, REHABILITATION AND RETROFITTING OF STRUCTURES

Repairs to overcome low member strength, Deflection, Cracking, Chemical disruption, Weathering corrosion, wear, fire, leakage and marine exposure.

5.1Repairs to overcome low member strength

Need for Strengthening:

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

5.2 .1Deflection due to strengthened in Flexural members

Many situations in which flexural members, and especially bridge girders, have been found to have less than their special attention was paid to the paid to the bond between the old concrete and the new anchor blocks. The existing concrete was cut back to the depth of the cover and roughened.

After the new block had been cast in-situ the contact surface was injected with low viscosity epoxy resin under pressure, the injection being monitored ultrasonically. Some of the new tendons were deflected at existing diaphragms, reinforced required.

In view of the importance of the new anchor blocks to the success of the repair, we might have expected that dowel bars would be provided to connect the block to the existing concrete but no mention is made of this possibility and apparently what was done has been found to be successful.

The basis of this success is the roughness imparted to the old concrete. Epoxy jointing between smooth concrete surfaces would be expected to deform over a period over a period of time and relax the stressed tendons.

Strengthening of Beams

The strengthening of a beam, the load acting on it should be reduced by removing the tiles, bed mortar etc. From the slab. In addition props may be erected at mid span of each slab and tightened in such a manner that slabs are not damaged. After chipping off of the existing plaster on the beam, additional reinforcement at the bottom of beam together with new stirrups are provided.

The bars are passed through or inserted in the supporting columns through holes of appropriate diameter drilled in the columns. The spaces between bars and surrounding holes are filled with epoxy grout to ensure a good bond.

Expanded wire mesh is fixed and anchored on three sides of the beam as shown in fig. To ensure a good bond between old concrete and polymer modified mortar, an epoxy bond coat is applied to the concrete surface.

While the bond coat is still fresh, a layer of polymer modified mortar is applied. The required thickness on all the three sides is achieved by application of 2 to 3 layers of mortar. While applying mortar at the bottom of beam, the thickness of mortar layers should be so adjusted that sagging is completely covered and beam looks deflected.

The mortar is cured for appropriate period in water and thereafter it is allowed to cure in air. Epoxy resin should also be injected in the cracks along top of beams. If new stirrups are required for shear strength enhancements should be followed.

5.2.2 Deflection due to Strengthening of slabs

The strengthening of slab is taken up only after the strengthening of beams is completed. A reinforced structural concrete topping over the existing slab can be used which provides a composite construction of old and new slabs, with additional depths to slab and beam.

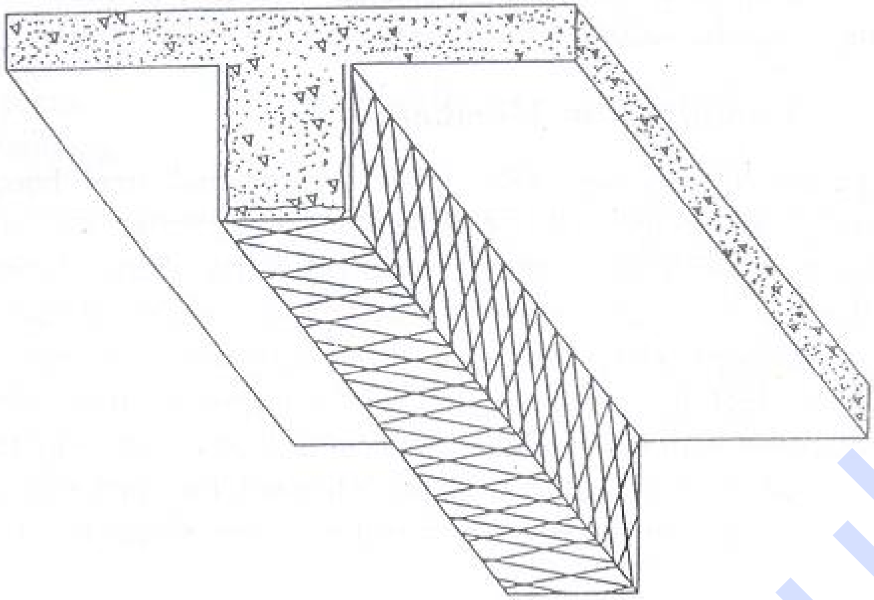
To ensure a good bond between new and old concretes, mechanical anchorage consisting of steel bolts inserted in holes drilled into the slab at suitable intervals may be provided. The spaces surrounding the holes are filled with epoxy grout.

A shear connector is embedded for half of its length in old concrete and the remaining half which is projected will subsequently b embedded in new concrete.

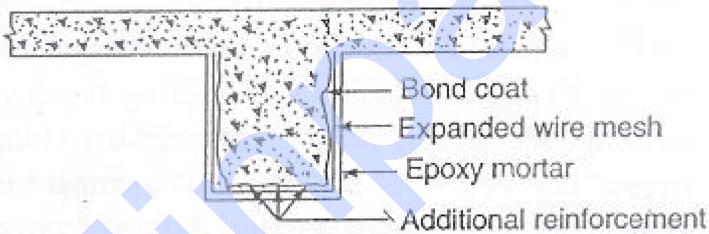
Before applying topping the surface of old floor slab should be thoroughly scabbled and cleaned. Additional reinforcement may be required over the supports, because the old reinforcement at supports acquires a position which is near to the neutral axis of compositors section.

After the preparation of old concrete surface, epoxy bond coat is applied on it and while this coat is still touch-dry 25 to 50mm thick M20 grade concrete topping is laid. The thickness of topping is governed by the strength and thickness of old floor slab.

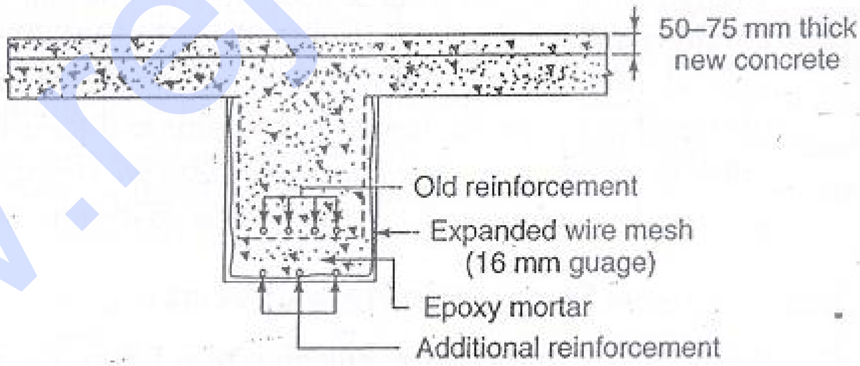
However application of topping increases the dead weight on the slab. With suitable treatment the top layer of topping maybe utilized as floor finish etc, After curing the beam and slab for 14 to 21 days props can be removed.



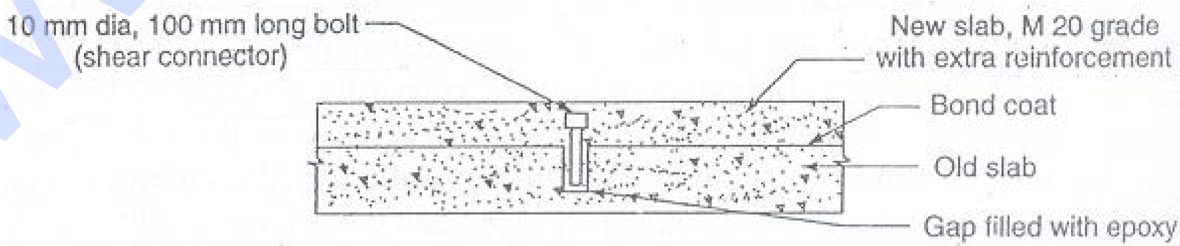
(a) Expanded wire mesh in position



(b) Repair scheme of the beam



(c) Strengthened section of the beam

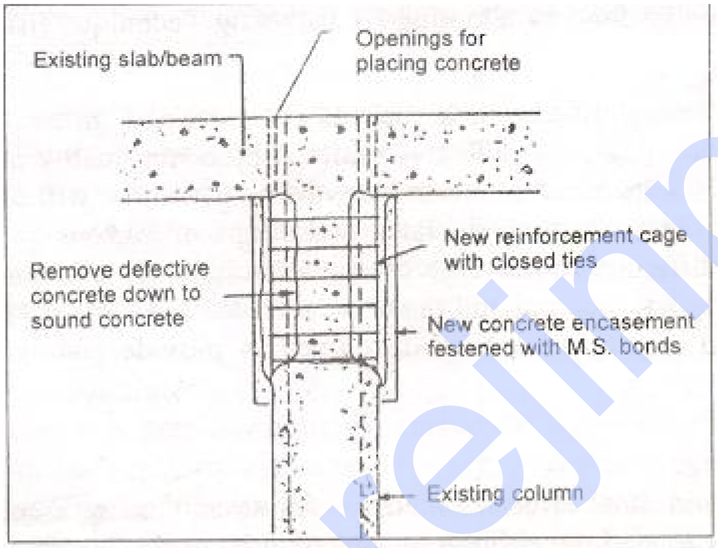


(d) Strengthening scheme of slab

5.2.3 Deflection due to Strengthening of columns

Jacketing is the process of fastening a durable material over concrete and filling the gap with a grout that provides needed performance characteristics.

The column jacket can also be used for increasing the punching shear strength of column slab connections by using it as a column capital. When the jacket is provided around the periphery of the column, it is termed a collar. In most of the applications, the main function of the collar is to transfer vertical load to the column. Circular reinforcement can be used for load transfer. The practice of transferring load through dowel bars embedded into columns or shear keys has a disadvantage in that they require drilling of holes for dowels or cutting shear keys which are costly and time consuming, and can damage the existing column. Reinforcement encircling the column can be used to transfer the load through shear friction. The expansion of collar as it slides along the roughened surface causes the tensioning of circular reinforcement resulting in radial compression, which provide normal force needed for load transfer. The shear transfer strength is provided by both frictional resistance to sliding and dowel action of reinforcement crossing the crack.



. Process of jacketing technique

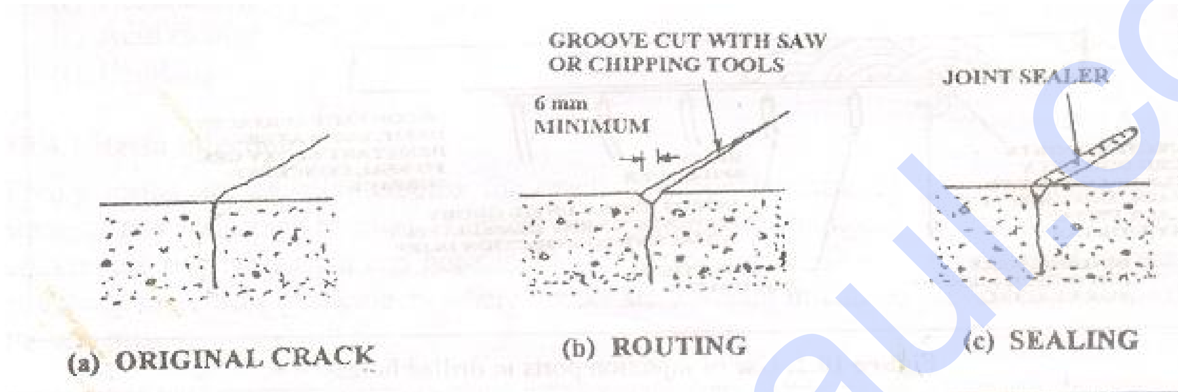
The collar is subjected to shear and bending along the collar circumference as well as direct bearing stress under concentrated load. In addition shear transfer reinforcement, the collar should be provided with reinforcement for shear and moment within collar. Column collars can be provided below the slab to act as column capital to improve punching shear strength of the slab column connection

5.3 Cracking

5.3.1Routing and sealing

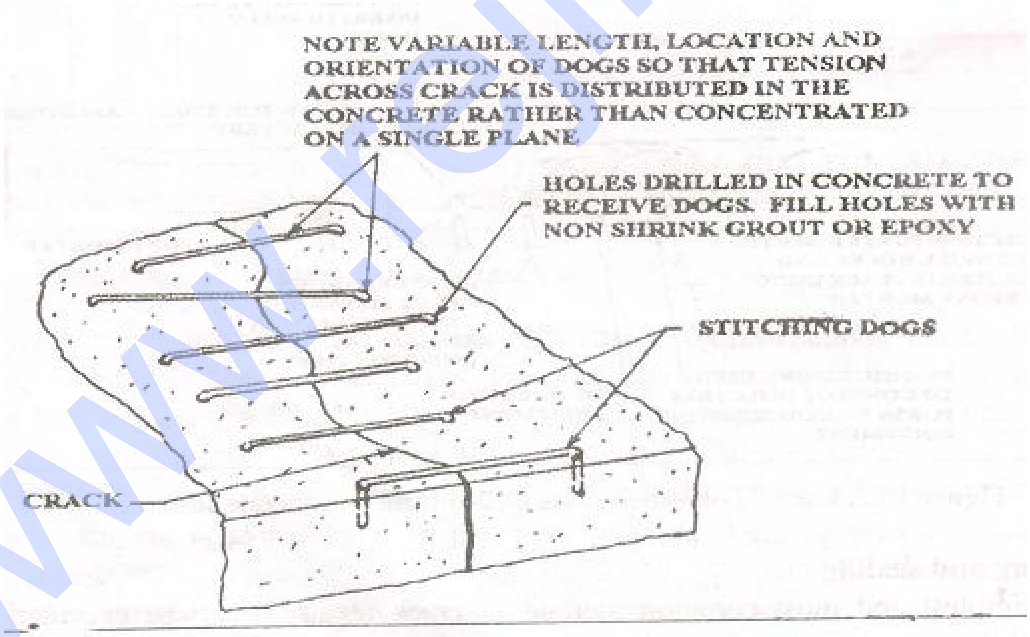
This is the simplest and most common method of crack repair. It can be executed with relatively unskilled personnel and can be used to seal both fine pattern cracks and larger isolated cracks.

The system can be used to repair dormant cracks that are of no structural significance, and is used to seal the cracks against the ingress of moisture, chemicals and carbon dioxide. This involves enlarging the crack along its exposed face and sealing it with crack fillers as shown fig. Care should be taken to ensure that the entire crack is routed and sealed.



5.3.2 Stitching

In this technique, the crack is bridged with U-shaped metal units stitching dogs before being repaired with a rigid resin material. This can establish restoration of the strength and integrity of cracked section; due care is to be given to make analysis check to ensure that this will perform well under applied loads shown fig.



Repair of crack by stitching

A non-shrink or an epoxy resin based adhesive should be used to anchor the legs of the dogs. Stitching is suitable when tensile strength must be reestablished across major cracks, although

stitching will not close the crack, and it is way of stopping the movement of active crack and thereby preventing it from spreading. Stitching dogs should be of variable length and orientation and so located that the tension transmitted across the crack is not applied to a single plane within the section but us spread over an area.

5.3.3Bonding

Cracks in concrete may be bonded by the injection of epoxy bonding compounds under pressure. A usual practice is to drill into cracks from face of the concrete at several locations. Water or a solvent is injected to flush out the defect. The surface is than allowed to dry. The epoxy is injected into the drilled holes until it flows out through the other holes.

The epoxy is injected into the drilled holes until it flows out through the other holes. Bonding with epoxies-cracks as narrow as 0.0.75mm can be sealed with epoxy compounds, usually pressure injection is restored to in sealing the cracks.

5.3.4 Bandaging

A flexible strip is fixed over the crack with only the edged of the strip bonded. Where movement is not all in one plane, where is excessive movement beyond that which can be accommodated by a recess of convenient size, or if there are factors which prohibit the cutting of a recess, a surface bandage can be used. In areas which are subject to traffic, the flexible bondage will be coated over with a wearing course

5.4 Chemical disruption

Resistance of concrete to chemical attack:

- ✓ The cement composition used in the concrete.
- ✓ Conditions under which the cement paste hardened
- ✓ All determine properties of concrete

5.4.1 Sulphate Attack

Mechanism-sulphates are found in most of the soils as calcium, potassium, sodium and magnesium sulphates. Sulphate attack occurs when pore system in concrete is penetrated by solution of sulphates.

5.4.1.1 Chemical mechanism

The effect of sulphate on concrete can be mainly, chemical and physical and they are closely related. The sulphate attack or reaction is indicated by the characteristic whitish appearance on the surface. As a result of the chemical reactions between sulphate and hydration products, changed in the microstructure and pore size distribution of the cement paste takes place. Sulphate converts calcium hydroxide into large of calcium sulphate.

$$Na_2So_4.10H_2O + Ca(OH)_2 \longrightarrow CaSO_4.2H_2O + 2NaOH + 8H_2O$$

The second hydration hydration produc, tricalcium aluminates hydrate reacts with sulphate solution to form sulpho aluminates hydrate, which has a greater volume than that of the original compound.

$$2(3CaO.Al_2O_3.12H_2O) + 3(Na_2So_4 .10H_2O) \longrightarrow 3CaO.Al_2O_3.3CaSo_4.31H_2O + 2Al(OH)_3 + 6NaOH + 17H_2O$$

When concrete cracks, its permeability increases and the aggressive water penetrates more easily in to the interior, thus accelerating the process of deterioration.

5.4.2Alkali reaction

The reaction of some forms of silica and carbonates inaggregates with the alkalis in cement produces a gel, which causes expansion and cracks.

5.4.2.1Mechanism of Alkali-aggregate reaction

This is called alkali carbonate reaction. Certain carbonate rock aggregates have been reative in concrete. The results of these reactions have been characterized as ranging from beneficial to destructive.

The destructive category is apparently limited to reactions with impure dolomitic aggregates and are silt of either dedolomitization reactions. Visual examination of those reactions that are serious enough to disrupt the concrete in a structure will generally show map or pattern cracking and a general appearance, which indicates that the concrete swelling. A distinguishing feature which differentiates alkali-carbonate rock reaction from alkali-silica reaction is the lack of silica gel exudations at cracks. Typical alkali aggregate reaction damage is as shown fig.

Factors:

- ✓ Size of the aggregate particles
- ✓ Alkali content in cement
- ✓ Fineness of cement particles
- ✓ Porosity of the aggregate particles

5.5 weathering corrosion

5.5.1 Sulphate Attack

Mechanism-sulphates are found in most of the soils as calcium, potassium, sodium and magnesium sulphates. Sulphate attack occurs when pore system in concrete is penetrated by solution of sulphates.

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When concrete cracks, its permeability increases and the aggressive water penetrates more easily in to the interior, thus accelerating the process of deterioration.

5.5.2 Salt attack/Weathering

Solid salts do not attack concrete, but when present in solution they can react with hardened concrete. It is a more general problem in masonary structures. Efflorescense is awhitish crystalline deposit on the surface. Efflorscence is the formation of calcilum carbonate precipitate on the concrete surface owing to carbonation

Prevention measures

- ✓ Using sound materials free from salts
- ✓ Proper concrete proportioning
- ✓ Consolidation and Curing
- ✓ Preventing the access of moisture to the structure

5.6wear

The concrete has been damaged by erosion it is almost certain that any repaired section will again be damaged unless the cause of the erosion is removed. The best concrete made will not withstand the forces of cavitation or severe abrasion for a prolonged period. It may be more economical to replace the concrete periodically rather than to reshape the structure to produce streamlined flow or to eliminate the solids which are causing abrasion.

5.6.1Mechanism

Abrasion-erosion damage is caused by the action of debris rolling and grinding against a concrete surface. In hydraulic structures, the areas most likely to be damaged are spillway aprons, stilling basin slabs, and lock culverts and laterals.

The sources of the debris include construction trash left in a structure, riprap brought back into a basin by eddy currents because of poor hydraulic design and riprap or debris thrown into a basin by the public. Also barges and towboats impacting on lock wells and gide wells can cause abrasions erosion damage.

5.6.2 Symptoms

- ✓ Concrete surfaces abraded by waterborne debris are generally smooth and may contain localized depressions.
- ✓ Mechanical abrasion is usually characterized by long shallow grooves in the concrete surface and spelling along monolith joints.

- ✓ Armor plates is often torn away or bent.

5.6.3 Common materials

Metallic types

- ✓ Pearlitic iron turnings
- ✓ Crushed cast iron chilled grit

Non-metallic types:

- ✓ Silicon carbide grains
- ✓ Fused alumina grains
- ✓ Natural emery grains

5.7fire

A fire in a concrete structure causes damage. The extent of which depends upon the intensity and duration of the fire.

The principle types of damages are

- ✓ Reduction in strength of concrete
- ✓ Cracking and spalling of concrete
- ✓ Deflection and deformation of members
- ✓ Discolouration

Concrete structures are determined by three main factors:

- ✓ The capacity of concrete itself to withstand heat
- ✓ The conductivity of the concrete to heat
- ✓ The coefficient of thermal expansion of concrete

A large number of reinforced concrete structures salvaged from destruction in fires by timely fire fighting operations can be put to further service after strengthening and providing some cosmetic repairs since the cost of restoration of such structures less than

that for dismantling and construction of new ones. The fire may cause different degrees of damage to the structure: the structure may be completely burnt or destroyed; its surface may be slightly damaged or slight deformation may occur. In the first case, the whole of damaged portion has to be replaced during restoration of structure while in the latter, only repair and finishing may be required. The extent of damage caused th the structure during a fire depends on the duration of fire, and the temperature to which the structure was subjected during the fire.

High temperature during a fire reduces the strength of reinforced concrete structures due to change in the strength and deformability of materials, reduction in cross sectional dimensions, weakening of bond between the reinforcement and concrete which determines structural action under the load.

When assessing the effects of a fire on a building structure, it is important to recognize that the huge expansion that occurs in the members subjected to the fire temperature may cause damage in other members remote from the fire.

Shear cracking can occur in columns and cracking resulting from inversion of moment may occur if detailing is not adequate

Restoration of fire Damaged Elements

The eccentrically loaded columns fail when reinforcement bars in tension heat up. The fire resistance of such elements can be increased by increasing the thickness of protective layer. Heat transmission and temperature of bottom reinforcement are keys to the behavior of reinforced concrete slab exposed to fire. The reinforcing bars are assumed to retain one half of their original strength. Carrying capacity of slabs can be enhanced by increasing their thickness. For beams, depth and width can be increased. It should be kept in mind that in beams, weakening of bond between transverse reinforcement and concrete on account of heating reduces the residual shear load carrying capacity considerably.

The carrying capacity of axially loaded depends upon the cross section of the column coefficient of change in strength of concrete under high temperature and corresponding critical temperature. The carrying capacity can be restored by increasing the cross section with suitable increase in the longitudinal steel.

5.8 leakages

Leakage in the concrete structures causes inevitable damage to the reinforcement. Construction joints, shrinkage and restraint cracks may form leak paths. The amounts of water involved vary from damp-patches which tend to evaporate as they are formed, to running –leaks which may eventually form undrained surfaces. Damp patches may also be formed when water passes through the voids along reinforcing bars formed due to **plastic settlement.**

The other common routes for larger volume leaks are **honeycombed concrete, movements joints** like expansion and contraction joints. In case of water-retaining structures, the extent of leakage may be measured by monitoring loss of liquid from the structure.

Techniques

- ✓ **Conventional leak-sealing methods**
- ✓ **Leak-sealing by injection techniques**

Conventional methods

Some sources of minor leakage may dry up by autogenously healing which is an accumulation of calcium salts along the leak path. This will obstruct the passage of water over period of time and reduce the leakage to negligible proportions.

Once leak spots have been identified, the remedial action may involve the application of local or complete surface seal in the form of a coating system.

- ✓ Surface preparations
- ✓ Filling of surface imperfections with resin-based grouts

- ✓ Application of primer
- ✓ Application of two coats of high-build paint

The procedure may require quite extensive preparatory work including the injection of suspect joints and random shrinkage cracks with allow viscosity resin.

Honey combed concrete if not particularly extensive may be filled out using a resin based mortar. Laitance and surface contaminants may be removed by sand blasting and power wire brush

Injection Sealing

From liquid flow and pressure considerations the simplest and most cost effective way is to seal the leakage from the water-retaining side of the structure. When the wet side is inaccessible, the leakage must be tackled from the dry side which is considerably more difficult.Successfull leak sealing requires injection of sealant to fill water passages completely, and it is necessary to attain a relatively high flow velocity to achieve this, because of short pot-life or working time of the typical repair material.

The first basic step is to restrict or confine the water flow to tubee through which the sealant any be introduced.

Due to possibility of concrete being stressed during injection, it is preferable to maintain lower pressures. The direct methods are very slow due to sealant being pumped slowly through very narrow passages against pressure, and the pressure cannot be maintained for long enough to achieve complete penetration. In many cases water may find another finer pathway leading from the same source. In contrast the indirect methods enable the work to be completed quickly because surface seals are not required and mechanical anchorages can be used.

5.9 Marine exposure

Durability of concrete exposed to sea-water again stresses that of all chemical and physical properties, permeability of concrete is the most important factor influencing performance. Concrete are achieved by using mixes having high cement contents and low water: cement ratios, through consolidation and control of thermal and shrinkage cracking, and limiting cracks due to mechanical loading.

5.9.1Physic-chemical effects of sea water on hydrated cement as follows:

- ✓ Chemical attack by sea water on cement only occurs in the case of permeable concrete
- ✓ C4AF, in contrast to C3A has no deleterious effects
- ✓ Portland cements with C3A contents lower than 10% resist chemical attack in sea-water
- ✓ Cements containing more than 65% slag are most resistant to sea-water attack
- ✓ The effects of pozzolan depend on their mineralogical composition and reactivity
- ✓ Compressive or flexural strengths are not a good basis for assessing durability once reactions commence; a much b etter basis is the measurement of expansions as they continue

5.9.2 Application of materials

- ✓ Mortar placement
- ✓ Injection into cracks
- ✓ Large-scale Repair

QUESTION BANK
UNIT I
MAINTENANCE AND REPAIR STRUCTURE

TWO Marks

1. Define Maintenance

Maintenance is the act of keeping something in good condition by checking or repairing it regularly. f

2. Define Repair.

Repair is the process of restoring something that is damaged or deteriorated or broken, to good condition.

3. Define Rehabilitation.

Rehabilitation is the process of returning a building or an area to its previous good conditions.

4. What are the two facets of maintenance?

The two facets of maintenance are

- ✓ Prevention
- ✓ Repair

5. What are the causes of deterioration?

- ✓ Deterioration due to corrosion
- ✓ Environmental effects
- ✓ Poor quality material used
- ✓ Quality of supervision
- ✓ Design and construction flaws

6. Define 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 warrant urgent execution.

7. How deterioration occurs due to corrosion?

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

8**. What are the steps in selecting a repair procedure?**

- ✓ Consider total cost
- ✓ Do repair job in time
- ✓ If defects are few & isolated repair on an individual basis. Otherwise do in generalized manner
- ✓ Ensure the repair prevents further development of defects

- ✓ In case of lost strength, repairs should restore the strength
- ✓ If appearance is a problem, the number of applicable types of repairs become limited & the repairs must be covered
- ✓ Repair works should not interface with facilities of the structure
- ✓ Take care in addition of section to a member and in restributing live loads and other live load moments. After selecting a suitable method of repairs, and after considering all the ramifications of its application, the last step is to prepare plans & specification and proceed with the work.

9. Discuss about the environment effects which leads to deterioration of concrete structure.

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 environme4nt concrete structure will be severely reduces.

10. What is the effect of selecting poor quality material for construction?

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.

11. How can we determine the cause for deterioration of concrete structure?

- ✓ Inspect & observe the structure
- ✓ Observe in bad & good weather
- ✓ Compare with other constructions on the area or elsewhere & be patient
- ✓ Study the problem & allow enough time to do the job

12. What are the factors to be considered by the designer at the construction site.

- ✓ Minimum and maximum temperatures
- ✓ Temperature cycles
- ✓ Exposure to ultra violet radiation
- ✓ Amount of moisture
- ✓ Wet/dry cycles
- ✓ Presence of aggressive chemicals

13. What are the steps in repair aspect?

- ✓ finding the deterioration
- ✓ determining the cause
- ✓ evaluating the strength of existing building or structure
- ✓ evaluating the need of repair
- ✓ Selecting & implementing a repair procedure

14. Define the fixed percentage method of evaluating the strength of existing structure.

It is to assume that all members which have lost less than some predetermined % of their strength are still adequate and that all members which have lost more than the strength are inadequate. It is usually from 15% onwards higher values are applicable for piling % stiffness bearing plates etc.

15. Discuss about the design and construction errors leading to deterioration of a structure.
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.

16. Discuss about the quality of supervision to be followed at a site.
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.

17. What are the possible decisions that can be made after evaluating the strength of a structure?

- ✓ to permit deterioration to continue .
- ✓ to make measures to preserve the structure in its present condition without strengthening
- ✓ to strengthen the construction
- ✓ if deterioration is exceptionally sever, to reconstruct or possibly abandonit.

18. How can we evaluate the strength of existing structure by stress analysis?
This method is to make detailed stress analysis of the structure, as it stands including allowances for loss of section where it has occurred. This is more difficult & expensive. Here also the first stop is to make preliminary analysis by fixed percentage method and if it appears that major repairs will be required, the strength is reevaluated based on detailed stress analysis, considering all contributions to such strength.

19. Define the load test method of evaluating the strength of existing structure.
Load tests may be required by the local building offered, but they should only be performed where computation indicated that there is reasonable margin of safety against collapse, lest the test bring the structure sown. Load test show strengths much greater than computed strengths when performed on actual structures. When performed on actual structures. In repair work every little bit of strength is important.

20. What are the possible decisions after finding a structure to be inadequate?

- ✓ if the appearance of the existing condition is objectionable – repair now
- ✓ if appearance is not a problem then
- ✓ Put the condition under observation to check if it is dormant or progressive.
- ✓ if dormant – no repair
- ✓ if progressive – check the feasibility & relative economics of permitting deterioration to continue and performing a repair at some later date & of making the repair right away

16 MARKS

1. with a flowchart explain the assessment procedure for evaluate damages in a structure

2. explain the various casus for detoriation of concrete structures

3. different type of maintenance to the structural elements

4. with graph explain the service life behavior of concrete structure with respect to maintenance

5. explain the importance of maintenance

UNIT-II

SERVICEABILITY AND DURABILITY OF CONCRETE

1. How can use prevent the effect of freezing and thawing in concrete?
Concrete can be restricted from frost action, damage of the structure by the entrainment of air. This entrainment of air is distributed through the cement paste with spacing between bubbles of no more than about 0.4mm.

2. Write any two tests for assessment of frost damage?
The frost damage can be assessed by several ways:
i) Assessment of loss of weight of a sample of concrete subjected to a certain number of cycles of freezing and thawing is one of the methods
ii) Measuring the change in the ultrasonic pulse velocity or the damage in the change in the dynamic modulus of elasticity of specimen is another method.

3. How does a concrete structure get affected by heat?

- ✓ Heat may affect cone and as a result of:-
- ✓ the removal of evaporable water
- ✓ the removal of combined water
- ✓ alteration of cement past
- ✓ alteration of aggregate
- ✓ change of the bond between aggregate and paste

4. How can you control cracks in a structure?

- ✓ Use of good coarse aggregates free from clay lumps
- ✓ Use of fine aggregate free from silt, mud & organic constituent.
- ✓ Use of sound cement.
- ✓ Provision of expansion & contraction joint.

5.. Define aggregate splitting?

This phenomenon occurs most frequently when hard aggregates are used in concrete. The thermal stresses except close to corners are predominantly compressive near to the heated surface. This stress causes the aggregate to split in this direction and the fractures may propagate through the mortar matrix leading to deterioration.

6. What the factor affecting chemical attack on concrete?

- ✓ High porosity
- ✓ Improper choice of cement type for the conditions of exposure
- ✓ Inadequate curing prior to exposure
- ✓ Exposure to alternate cycles of wetting and drying

7. Write the methods of corrosion protection?

- ✓ Corrosion inhibitors
- ✓ corrosion resisting steels
- ✓ coatings for steel
- ✓ Cathodic protection

8. List out some coating for reinforcement to prevent corrosion?

- ✓ Organic coating
- ✓ Epoxy coating
- ✓ Metallic coating
- ✓ Zinc coating

9. Define corner reparation?

This is a very common occurrence and appears to be due to a component of tensile stress causing splitting across a corner. In fire tests, corner separation occurs most often in beams and columns made of Quartz aggregate and only infrequently with light weight aggregates.

10. List any four causes of cracks?

- ✓ Use of unsound material
- ✓ Poor & bad workmanship
- ✓ Use of high water-cement ratio
- ✓ Freezing & thawing
- ✓ Thermal effects
- ✓ Shrinkage stresses

11. What are the types of cracks?

- ✓ Class-1: Cracks leading to structural failure
- ✓ Class-2: Cracks causing corrosion
- ✓ Class-3: Cracks affecting function
- ✓ Class-4: Cracks affecting appearance

12. What changes occur, when hot rolled steel is heated to 500oC?

At temp of 500oC-600oC the yield stress is reduced to the order of the working stress and the elastic modulus is reduced by one-third. Bars heated to this temp virtually recover their normal temperature.

13. List out the various types of spalling?

i) General or destructive spalling
ii) Local spalling which is subdivided as

- ✓ aggregate splitting
- ✓ comer separations
- ✓ surface spalling
- ✓ Sloughing off

14. List some faults in construction planning?

- ✓ Overloading of members by construction loads
- ✓ Loading of partially constructed members
- ✓ Differential shrinkage between sections of construction
- ✓ Omission of designed movement joints

15. Define corrosion?

The gradual deterioration of concrete by chemically aggressive agent is called “corrosion”

16. Give some examples for corrosion inhibitors?

- ✓ Anodic inhibitors
- ✓ Cathodic inhibitors
- ✓ Mixed inhibitors
- ✓ Dangerous & safe inhibitors

17. Define effective cover?

The cover to reinforcement measured from centre of the main reinforcement up to the surface of concrete in tension is called "Effective cover"

18. Define corrosion inhibitor?

Corrosion inhibitor is an admixture that is used in concrete to prevent the metal embedded in concrete from corroding.

19. What are the operations in quality assurance system?

- ✓ Feed back
- ✓ Auditing
- ✓ Review line
- ✓ Organization

20. List the various components of quality control.

Five components of a quality (control) assurance system are:

- ✓ Standards
- ✓ Production control
- ✓ Compliance control
- ✓ Task and responsibilities and
- ✓ Guarantees for users

16 MARKS

1. Explain in detail about quality assurance
2. Describe various components of quality control
3. Discuss in detail about the thermal properties of concrete
4. Elaborately explain about the effects of temperature on concrete
5. Explain the various corrosion protection methods

UNITIII

1. What is expansive cement?

A slight change in volume on drying is known as expansion with time will prove to be advantage for grouting purpose. This type of cement which suffers no overall change in volume on drying is known as “Expansive cement”.

2. What is the action of shrink comb in expansive cement?

Shrink comb grout acts like a Portland cement. It (shrinks) sets and hardens; it develops a compressive strength of about 140kg/gm^2 at 7days and 210kg/cm^2 at 28 days.

3. List the various types of polymer concrete.

i) Polymer impregnated concrete (PIC)

ii) Polymer cement concrete (PCC)

iii) Polymer Concrete (PC)

iv) Partially impregnated and surface coat v)
Polymer Concrete.
vi) Polymer impregnated concrete (PIC)

4. Give the various monomers used in polymer concrete.
   - Mehylmethacrylate (MINS)
   - Styretoc
   - Aerylonitrile
   - t-butyle slynene

5. Define polymer concrete.

Polymer concrete is a aggregate bound a polymer binder instead of Portland cement as in conventional concrete pc is normally use to minimize voids volume in aggregate mars. This can be achieve by properly grading and mixing of a to attain the max density and (mixing) the aggregates to attain (maximum) minimum void volume. The entrapped aggregated are prepacked and vibrated in a mould.

6. What are the uses of Polymer concrete?

During curing Portland cement form mineral voids. Water can be entrapped in these voids which are freezing can readily attack the concrete. Also alkaline Portland cement is easily attached by chemically aggressive materials which results in rapid determination, there as using polymers can compact chemical attack.

7. What is sulphur infiltrated concrete?

New types of composition have been produced by the recently developed techniques of impregnating porous material like concrete with sulphur. Sulphur impregnation has shown great improvement in strength

8. What are the applications of sulphur infiltrated concrete?

Sulphur – (impregnated) infiltration can be employed in the precast industries. Sulphur infiltration concrete should found considerable use in industry situation where high corrosion resistant concrete is required. This method cannot be conveniently applied to cast- in place concrete Sulphur impregnation has shown area improvement in strength.

9. What is drying shrinkage?

Concrete made with ordinary Portland cement shirts while setting due to less of water concrete also shrinks continuously for long true. This is known as "drying shrinkage".

10. What is self stressing cement?

This cement when used in concrete with restrained expansion includes compressive stresses which approximately offset the tensile stresses induced by shrinkage "self Stressing cement"

11. What is polymer impregnated concrete?

PIC is a widely used polymer composition concrete, cured and dried in over or dielectric heating from which the air in the (pipes) open cell is removed by vacuum. Then low density manpower is diffused through a open cell and polymerized by using radiation, application of heat or by chemical initiation.

12. Define polymer partially impregnated concrete.

Polymer partially impregnated or coated in dep(CID) and surface coated (SC) control partially polymer impregnated concrete is used to in the strength of concrete. Partially impregnated concrete is sufficient in situations there the major required surface persistent against chemical and mechanical attacks.

13. How can we manufacture sulphur infiltrated concrete?

Sculpture is heated to bring it into molten condition to which coarse and fine aggregates are poured and mixed together. On cooling, this mixture gave fairly good strength, exhibited acid resistance and also other chemical resistance, but it proved to be either than ordinary cement concrete.

14. What is the difference between ordinary cement and expansive cement?

Ordinary concrete shrinks while setting whereas expansive cement expands while setting

15. What are the uses of gas forming and expansive chemicals?

Gas formation and expansive chemicals to produce light weight concrete as well as to cause expansion on application such as grouts for anchor bolts. They are non strinking type. Principal chemicals used are Hydrogen peroxide, metallic aluminium or activated or activated carbon. Sometimes bentonite clays and natural gum are also used.

16) What is the use of corrosion inhibiting chemicals

They resist corrosion of reinforcement .in adverse environment sodium benzonate , calcium lingo sulphonate and sodium nitrate have good results

17) Write the use of antifungus admixtures

These are added to control and inhibit growth of bacteria or fungus in surfaces expressed t moisture. Polyhalogenated phenol, Dieldrin emulsion and copper compounds are some of the chemicals used for this

18) What i s u s e of curing compounds

They are either wax based or resin based. When coated in freshly laid concrete they form a temporary film over the damp surface which stops wter evaporation and allows sufficient moisture retention in concrete for curing

19) What are the uses of sealants?

They are used to seal designed joints. They are formulated from synthetic rubbers or polysulphides. The choice of a sealant depends on the location of the joint, its movement capability and the function the sealant is expected to perform.

20) What are the uses of flooring

These are usually toppings based on metallic or non metallic aggregates which are mixed with cement and placed over freshly laid concrete sub floor. These compounds in high viscosity liquid, form mixed with recommended filters at site, are based on resins and polymers such as epoxy, acrylic, polyuretheneor polysulphide.

UNIT lV : TECHNIQUES FOR REPAIR AND DEMOLITION

TWO Marks

1.What is Vacuum concrete?

Only about half of the water added in concrete goes into chemical combination and the remaining water is used to make concrete workable. After laying concrete, water which was making concreting workable is extracted by a special method known as "vacuum method".

2. What are the equipments used in vacuum concrete?

The equipment essentially consists of:-i. vacuum pump
ii. water separator and

3.What is Gunite?

Gunite can be defined as mortar conveyed through a hose and pneumatically projected at a high velocity on to a surface.

4. What are the two types of process in Shotcrete?

a. Wet mix process
b. Dry mix process

5. What are the stages in dry mix process in shotcrete?

i. In this process, the concrete is mixed with water as for ordinary concrete before conveying through the delivery pipeline to the nozzle, at which point it is jetted by compressed air, onto the work in the same way as that if mix process.
ii. The wet process has been generally desired in favour of the dry mix process, owing to the greater success of the latter.

6. What is shotcrete?

Shotcrete is a recent development on the similar principle of guniting for achieving greater thickness with small coarse aggregate.

7. What are the preliminary investigations before demolition of a structure?

The demolition contractor should have ample experience of the type of work to be offered;

- Fully comprehensive insurance against all risks must be maintained at all times;
- An experienced supervisor should be continuously in charge of the work;
- The contract price should include all safety precautions included in the relevant building regulations;
- The completion date should be realistic, avoiding and need to take risks to achieve the date

8. Write about protective clothing given before demolition.

Buildings where chemicals have been stored or where asbestos, lead paint, dust or fumes may be present will require specialized protective clothing, e.g.

9. Give a brief note on shoring and underpinning in demolition.
The demolition contractor has a legal obligation to show technical competence when carrying out the work. When removing sections of the building which could have leave other parts unsafe, adequate temporary supports and shoring etc. must be provided.

10. What are the major factors in selecting a demolition procedure?
Majors factors to be considered in selecting an appropriate technique include:-

- Safety of personnel and public
- Working methods
- Legislation applicable
- Insurance cover

11.Give the categories of demolition techniques.
Demolition techniques may be categorized as:-

- Piecemeal demolition, using hand-held tools or machines, to reduce the height of the building or structure gradually;
- Deliberate controlled collapse, demolition to be completed at ground level.

12.Write short notes on demolition by hand.
Demolition of buildings or structure by hand-held tools such as electric or pneumatic breakers, sometimes as a preliminary to using other methods, should be carried out, where practicable, in the reverse order to the original construction sequence. Lifting appliances may be necessary to hold larger structural members during cutting and for lowering severed structural members and other debris.

13. In what cases demolition by machine can be done?
Simple roof structures supported on wall plates should normally be demolished to the level of wall plates by hand, but if this may involve unsafe working, then demolition totally by machine may be appropriate.

14.Write short notes on balling machine.
Balling machines generally comprise a drag-line type crawler chassis fitted with a lattice crane jib. The demolition ball, with a steel anti -spin device, is suspended from the lifting rope and swung by the drag rope.

15.How are explosives used for demolition of a structure?
If explosives are to be used for demolition, the planning and execution, include pre-weakening, should be under the control of a person competent in these techniques. For large demolition, the competent person is likely to be an experienced explosive engineer; for smaller work, a shot-firer may be sufficient.
16 What is a hydraulic pusher arm?
Articulated, hydraulically-powered pusher-arm machines are normally mounted on a tracked or wheeled chassis, and have a toothed plate or hook for applying for applying a horizontal force to a wall. The machine should stand on a firm level base and apply force by a controlled movement of the pusher arm.

17. What is pre-weakening?

Buildings and structures normally have structural elements designed to carry safely the loading likely to be imposed during their life. As a preliminary to a deliberate controlled collapse, after loads such as furnishings, plant and machinery have been removed, the demolition contractor may be able to weaken some structural elements and remove those new redundant. This pre weakening is essentially a planned exercise and must be preceded by an analysis of its possible effects on the structure until it collapses, to ensure that the structural integrity of the building is not jeopardized accidentally. Insufficient information and planning relating to the structure may result in dangerous and unsafe work.

18. What is deliberate collapse?

The deliberate collapse of the whole or part of a building or structure requires particularly high standards of planning, supervisions and execution, and careful consideration of its effect on other parts of the structure or on adjacent buildings or structures. A surrounding clear area and exclusion zone are required to protect both personnel and property from the fall of the structure itself and debris which may be thrown up by the impact.

19. How can you develop a demolition strategy?

The strategy will need to take into account the method of construction used for the original building and its proximity to other buildings, structures and the general public. These factors, together with location, the cost and availability of tipping and disposal and the desirability and economics of reuse, must be taken into account in the development of an appropriate strategy for the demolition of a structure.

20. What are nibblers?

Nibblers use a rotating action to snap brittle materials such as concrete or masonry. In either case, material should be removed from the top of walls or columns in courses not greater than 600mm in depth, steel reinforcement should be cut separately as necessary.

21. What are the considerations before demolition?

Considerations should be given to:-

- Conducting a site and building survey, with a structural bias;
- The examination of drawings and details of existing construction where available;
- The preparation of details and drawings from site survey activities where no such information is available;
- Establishing previous use of premises, especially with regard to flammable substances or substances hazardous to health or safety;
- Programming the sequence of demolition work;
- The preparation of a Method Statement.

16 MARKS

1. Briefly explain about the vaccum concrete.

2. Explain the process of epoxy injection. Also explain routing, guniting.

3. Explain in detail about the corrosion protection methods

4. Explain demolition process of a damaged structure

5. Explain in detail about various demolition technique

UNIT V : REPAIRS, REHABLITION AND RETROFITTING OF STRUCTURES

1.What are the techniques required for repairing cracks?

- Bonding with epoxies
- Routing and sealing
- Stiitching
- Blanketing
- External stressing
- Grouting
- Autogenous healing

2.Define stitching.

The tensile strength of a cracked concrete section can be restored by stitching in a manner similar to sewing cloth.

3. What do you mean by blanketing?

This is the simplest and most common technique for sealing cracks and is applicable for sealing both fine pattern cracks and larger isolated. The cracks should be dormant unless they are opened up enough to put in a substantial paten in which case the repair may be more property termed as “Blanketing”.

4. Define external stressing.

Development of cracking in concrete is due to tensile stress and can be arrested by removing these stresses. Further the cracks can be closed by including a compressive force sufficient to over come the tension a residual compression.

5. Write short notes on Autogenous healing.

The inherent ability of concrete to heal cracks within “autogenous healing”. This is used for sealing dormant cracks such as precast units cracked in handling of cracks developed during the precast pilling sealing of cracks in water hands and sealing of cracks results of temporary conditions.

6.. What is overlay?

Overlays may be used to restore a spelling or disintegrated surface or to protect the existing concrete from the attack of aggressive agents. Overlays used for this purpose include concrete or mortar, bituminous compounds etc. Epoxies should be used to bond the overlays to the existing concrete surface.

7. Give short note on Jacketing.

Jacketing consists of restoring or increasing the section of an existing member by encasing it in a new concrete. This method is useful for protection of section against further deterioration by providing additional to in member.

8. Give an account on how metal bonding is done on concrete member.

On the tension side of the beam 2 to 3mm steel plates are to the existing beam to increase its capacity. The glue or adhesive should compatible with the existing concrete with behavioral characteristics under load addition to providing integrity with parent member.

9. How clamps are used to overcome low member strength?
The distress is due to inadequate stirrups either due to deficiency in the of provision of C- stamps, U-clamp fixed externally along the length of beam to provide adequate these will be protected by covering with rich mortar or concreting as the a later stage.

10. Define grouting.
Grouting can be performed in a similar manner as the injection of an epoxy. However the use of an epoxy is the better solution except where considerations for the resistance of cold weather prevent such use in which case grouting is the comparable alternative.

11. Give a short note on epoxy coatings.
These are organic compound which when activated with suitable hardening agents form strong chemically resistant structures having excellent adhesive properties. They are used as binders or adhesives to bond new concrete patches to existing surfaces or hand together cracked portions. Once hardened, this compound will not melt, flow or bleed. Care should be taken to place the epoxy within the pot life period after mixing.

12. What are protective surface coatings?
During of concrete can be substantially improved by preventive maintenance in the form of weather proofing surface treatments. These treatments are used to seal the concrete surface ad to inhibit the intrusion of moisture or chemicals.

13. List some materials used as protective surface coatings.
Materials used for this purpose include oils such as linseed oils, petroleum etc.

14. Define dry pack.
Dry packing is the hand placement of a very dry mortar and subsequent tamping or ramming of the mortar into place producing an intimate contact between the old and new concrete work.

15. Give a brief account on routing and sealing.
This method involves enlarging the cracks along its exposed surface, filling and finally sealing it with a suitable material. This is the simplest and most common technique for sealing cracks and is applicable for sealing both fine pattern cracks and larger isolated.

16. List any four causes of cracks?
- Use of unsound material
- Poor & bad workmanship
- Use of high water-cement ratio
- Freezing & thawing
- Thermal effects
- Shrinkage stresses

17. What are the types of cracks?

a) Class-1: Cracks leading to structural failure

b) Class-2: Cracks causing corrosion

c) Class-3: Cracks affecting function

d) Class-4: Cracks affecting appearance

18. What is pneumatically applied mortar?

Pneumatically applied mortar is used for the restoration of when the location of deterioration is relatively at shallow depth. It can be used on vertical as well as on horizontal surfaces and is particularly restoring surfaces spalled to corrosion of the reinforcement. Damaged concrete elements also retrofitted using this method. This also has known as gunning or shotcreting techniques.

19. What is caging with steel?

A steel caging is prepared and made to surround the existing masonry so that lateral expansion when it is loaded in compression. The confinement of masonry will steel cage increases its capacity and ductility.

20. Give a brief note on dogs in stitching.

The dogs are thin and long and to cannot take much of compressive force. The dogs must be stiffened and strengthened by encasement in an overlay or some similar means.

21. Give some concrete materials used to overcome weathering action on concrete.

The two concrete repair materials used were

(i) a flow able concrete with 16 mm aggregate and containing a plasticizer and a shrinkage-compensating additive, to be cast against forms in heights up to 1.5m, and

(ii) a patching mortar to be applied brendering, for areas less than .01 m_2

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16 MARKS

1. explain the various strengthening technique to overcome low member strength

2. explain the various techniques for repair of cracks

3. explain in detail about chemical disruption on concrete

4. explain about the weathering action on concrete

5. explain various technique for repair spalling and disintegration of concrete

Reg. No. : | | | | | | | | | | | | |

Question Paper Code : 20186

B.E./B.Tech. DEGREE EXAMINATION, MAY/JUNE 2012.

Eighth Semester

Civil Engineering

CE 2071/080100066 — REPAIR AND REHABILITATION OF STRUCTURES

(Regulation 2008)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Distinguish between Repair and Rehabilitation.

2. Write the importance of maintenance.

3. Explain the importance of "coefficient of thermal expansion" with respect to strength of concrete.

4. Discuss briefly the effects due to "climate".

5. Classify cracks based on its thickness.

6. What are the applications of expansive cement?

7. What do you mean by critical length of fibre?

8. What is a dry pack?

9. What are the characteristics of good coatings?

10. What do you mean by weathering corrosion?

PART B — (5 × 16 = 80 marks)

11. (a) With a graph explain the service life behavior of a concrete structure. Also explain in detail about time based maintenance.

Or

(b) Explain the causes and effects of any four defects in concrete structures.

12. (a) With chemical equations, explain the mechanism of corrosion.

Or

(b) With sketches explain the possible design and constructional errors.

13. (a) Explain in detail about the special materials manufacturing procedure and application of polymer modified concrete.

Or

(b) With respect to fibre reinforced concrete explain aspect ratio and volume fraction. Also explain their effects on fresh and hardened concrete properties. Explain with its stress – Strain curve

14. (a) Explain in detail :

(i) Foamed concrete (8)

(ii) Vacuum concrete. (8)

Or

(b) Explain in detail any two corrosion protection methods. (8 + 8 = 16)

15. (a) With sketches explain how do you improve the load carrying capacity of columns and beams.

Or

(b) How do you repair and rehabilitate a structure distressed due to fire?

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Question Paper Code : 66213

B.E./B.Tech. DEGREE EXAMINATION, APRIL/MAY 2011.

Eighth Semester

Civil Engineering

CE 1035 — REPAIR AND REHABILITATION OF STRUCTURES

(Regulation 2004)

(Common to B.E. (Part-Time) Seventh Semester, Regulation 2005)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Define the term 'Maintenance'.

2. What are the causes of deterioration of concrete?

3. Write the needs of quality assurance?

4. Define 'corrosion'.

5. What are the applications of polymer cement concrete?

6. Define the terms : (a) Shoring and (b) Underpinning.

7. What is meant by weathering corrosion?

8. Write short notes on leakage in structures.

PART B — (5 × 16 = 80 marks)

11. (a) Discuss briefly the various causes of deterioration.

Or

(b) Explain in detail about the assessment procedure for evaluating a damaged structure.

12. (a) Write short note on :

(i) Quality assurance for concrete construction. (8)

(ii) Acceptance criteria. (8)

Or

(b) (i) What are the design and construction errors? (3)

(ii) Explain the effects of cover thickness in a concrete structure. (5)

(iii) Explain in detail about any two corrosion protection methods. (8)

13. (a) (i) What is fibre reinforced concrete? How is it produced? (8)

(ii) What are applications fibre reinforced concrete? (8)

Or

(b) (i) Explain the types and applications of polymer concrete. (8)

(ii) Explain the manufacturing process of foamed concrete and its application. (8)

14. (a) Write short note on :

(i) Ferro cement. (8)

(ii) Sulphur infiltrated concrete. (8)

Or

(b) Explain in detail construction chemicals for water proofing.

15. (a) How do you improve the load carrying capacity of columns? Explain in detail.

Or

Reg. No. :

Question Paper Code : 20186

B.E./B.Tech. DEGREE EXAMINATION, MAY/JUNE 2012.

Eighth Semester

Civil Engineering

CE 2071/080100066 — REPAIR AND REHABILITATION OF STRUCTURES

(Regulation 2008)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Distinguish between Repair and Rehabilitation.

2. Write the importance of maintenance.

3. Explain the importance of "coefficient of thermal expansion" with respect to strength of concrete.

4. Discuss briefly the effects due to "climate".

5. Classify cracks based on its thickness.

6. What are the applications of expansive cement?

7. What do you mean by critical length of fibre?

8. What is a dry pack?

9. What are the characteristics of good coatings?

10. What do you mean by weathering corrosion?

PART B — (5 × 16 = 80 marks)

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Or

(b) Explain the causes and effects of any four defects in concrete structures.

12. (a) With chemical equations, explain the mechanism of corrosion.

Or

(b) With sketches explain the possible design and constructional errors.

13. (a) Explain in detail about the special materials manufacturing procedure and application of polymer modified concrete.

Or

(b) With respect to fibre reinforced concrete explain aspect ratio and volume fraction. Also explain their effects on fresh and hardened concrete properties. Explain with its stress – Strain curve

14. (a) Explain in detail :

(i) Foamed concrete (8)

(ii) Vacuum concrete. (8)

Or

(b) Explain in detail any two corrosion protection methods. (8 + 8 = 16)

15. (a) With sketches explain how do you improve the load carrying capacity of columns and beams.

Or

(b) How do you repair and rehabilitate a structure distressed due to fire?

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Question Paper Code : 66213

B.E./B.Tech. DEGREE EXAMINATION, APRIL/MAY 2011.

Eighth Semester

Civil Engineering

CE 1035 — REPAIR AND REHABILITATION OF STRUCTURES

(Regulation 2004)

(Common to B.E. (Part-Time) Seventh Semester, Regulation 2005)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Define the term 'Maintenance'.

2. What are the causes of deterioration of concrete?

3. Write the needs of quality assurance?

4. Define 'corrosion'.

5. What are the applications of polymer cement concrete?

6. Define the terms : (a) Shoring and (b) Underpinning.

7. What is meant by weathering corrosion?

8. Write short notes on leakage in structures.

PART B — (5 × 16 = 80 marks)

11. (a) Discuss briefly the various causes of deterioration.

Or

(b) Explain in detail about the assessment procedure for evaluating a damaged structure.

12. (a) Write short note on :

(i) Quality assurance for concrete construction. (8)

(ii) Acceptance criteria. (8)

Or

(b) (i) What are the design and construction errors? (3)

(ii) Explain the effects of cover thickness in a concrete structure. (5)

(iii) Explain in detail about any two corrosion protection methods. (8)

13. (a) (i) What is fibre reinforced concrete? How is it produced? (8)

(ii) What are applications fibre reinforced concrete? (8)

Or

(b) (i) Explain the types and applications of polymer concrete. (8)

(ii) Explain the manufacturing process of foamed concrete and its application. (8)

14. (a) Write short note on :

(i) Ferro cement. (8)

(ii) Sulphur infiltrated concrete. (8)

Or

(b) Explain in detail construction chemicals for water proofing.

15. (a) How do you improve the load carrying capacity of columns? Explain in detail.

Or

Reg. No. : 9 4 3 0 9 1 0 3 0 0 6

Question Paper Code : 21195

B.E./B.Tech. DEGREE EXAMINATION, MAY/JUNE 2013.

Eighth Semester

Civil Engineering

CE 2071/080100066/CE 811 — REPAIR AND REHABILITATION OF STRUCTURES

(Regulation 2008)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. Define a defect in structures.

2. Write short notes on weekly and monthly maintenance.

3. List any four durability parameters.

4. Discuss the effect of temperature on concrete.

5. What are admixtures? Give examples.

6. What do you mean by aspect ratio?

7. What is a dry pack?

8. Explain the mechanism of cathodic protection.

9. What are the disadvantages of FRP?

10. How do you determine the temperature attained by concrete during fire?

PART B — (5 × 16 = 80 marks)

11. (a) (i) Discuss the importance of maintenance. (6)

(ii) With graph explain the service life behaviour of a concrete structure with respect to maintenance. (10)

Or

(b) With a flowchart explain the procedure for assessing the damages of a distressed structure.

12. (a) Explain the checks you will make on the day of concreting to assure quality of concrete.

Or

(b) Explain in detail about the thermal properties of concrete.

13. (a) Briefly explain about the manufacturing process and applications of expansive cement.

Or

(b) Tabulate the different types of fibres used in concrete. What are its advantages?

14. (a) Explain the process of epoxy injection. Also explain routing and scaling with sketches.

Or

(b) Explain in detail any two corrosion protection methods.

15. (a) With simple sketches explain the methods of improving the strength of existing columns and beams.

Or

(b) Explain the different methods of strengthening the concrete structures against earthquake.

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B.E./B.Tech. DEGREE EXAMINATION, APRIL 2014.

Eighth Semester

Civil Engineering

CE 2071/080100066/CE 811 — REPAIR AND REHABILITATION OF STRUCTURES

(Regulation 2008)

Time : Three hours Maximum : 100 marks

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. What is the importance of maintenance?

2. What is economic appraisal of structure?

3. List out the cause of cracks.

4. What is effect of cover thickness in concrete?

5. State the application of Ferro-cement.

6. What is the role of inhibitors in resisting corrosion in reinforcement?

7. What is meant by underpinning?

8. State the preventive measure taken during demolition.

9. What is meant by jacketing?

10. List out the repairing methods of excessive deflection of beams.

PART B — (5 × 16 = 80 marks)

11. (a) (i) Describe about the inspection to be carried out during and after the construction of structure. (10)

structure and to carry out rehabilitation work. (12)

12. (a) (i) Explain how concrete structure is affected by thermal condition. (8)

(ii) Describe about the design errors for concrete building. (8)

Or

(b) Why quality assurance for structure is needed? Explain the components of quality assurance for building. (16)

13. (a) (i) State the method adopted for accelerated strength gaining of concrete. Explain. (8)

(ii) Explain about fiber reinforcement concrete. State its applications. (8)

Or

(b) Write short notes on :

(i) Sulphur infiltrated concrete (6)

(ii) Concrete chemical (5)

(iii) Expansive cement. (5)

14. (a) (i) Explain the various methods of polymer coating applied on the surface of rebar? (8)

(ii) What is vacuum concrete? Explain the application. (8)

Or

(b) (i) Explain the method of preventing corrosion in the structure. (10)

(ii) Explain how cracks may be sealed by using epoxy injection resin. (6)

15. (a) Explain how the building is affected by.

(i) High Temperature (8)

(ii) Marine exposure. (8)

Or

(b) (i) How do you strengthen a heavily corroded RCC beam in a structure? (6)

(ii) State and explain the various options for strengthening a concrete with low member strength. (10)