CE 2031 : Repair and Rehabilitation of Structures

VIII Semester Elective

Prepared by

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CE 2071 REPAIR AND REHABILITATION OF STRUCTURES

OBJECTIVES:

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

UNIT I MAINTENANCE AND REPAIR STRATEGIES 9

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

UNIT II SERVICEABILITY AND DURABILITY OF CONCRETE 9

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

UNIT III MATERIALS FOR REPAIR 9

Special concretes and mortar, concrete chemicals, special elements for accelerated strength gain, Expansive cement, polymer concrete, sulphur infiltrated concrete, Ferro cement, Fibre reinforced concrete.

UNIT IV TECHNIQUES FOR REPAIR AND PROTECTION METHODS 9

Rust eliminators and polymers coating for rebars during repair, foamed concrete, mortar and dry pack, vacuum concrete, Gunite and Shotcrete, Expoxy 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

UNIT V REPAIR, REHABILITATION AND RETROFITTING OF STRUCTURES 9

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

TOTAL: 45 PERIODS

TEXT BOOKS:

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

REFERENCES:

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

Unit – I

MAINTENANCE AND REPAIR STRATEGIES

Maintenance, repair and rehabilitation, Facets of Maintenance, importance of Maintenance, various aspects Inspection, Assessment procedure for evaluating a damaged structure, causes of deterioration.

1.0 Maintenance :

Maintenance is preventive in nature. Activities include inspection and works necessary to fulfill the intended function or to sustain original standard of service. The maintenance of structure is done to meet the following objective

- Prevention of damages due to natural agencies and to keep them in good appearance and working condition.
- Repair of the defects occurred in the structure and strengthen them, if necessary.

1.0.1 The Maintenance work is broadly classifies as

a) Preventive Maintenance
b) Remedial Maintenance
c) Routine Maintenance
d) Special Maintenance

a) Preventive Maintenance

- The maintenance work done before the defects occurred or damage developed in the structure is called preventive maintenance.
- It includes thorough inspection, planning the programs of maintenance and executing the work
- It depends upon the specifications, condition and use of structure.

b) Remedial Maintenance

- It is the maintenance done after the defects or damage occurs in the structure. It involves the following basic steps.
  - Finding the deterioration
  - Determining the causes

- Evaluating the strength of the existing structure
- Evaluating the need of the structure
- Selecting and implementing the repair procedure

c) Routine Maintenance

- It is the service maintenance attended to the structure periodically.
- The nature of work done and interval of time at which it is done depends upon specifications and materials of structure, purpose, intensity and condition of use.
- It includes white washing, parch repair to plaster, replacement of fittings and fixtures, binding of road surface.

e) Special Maintenance

- It is the work done under special condition and requires sanction and performed to rectify heavy damage.
- It may be done for strengthening and updating of the structure to meet the new condition of usage or to increase its serviceability.
- It may include particular or complete renewal occurring at long interval, such as floors, roofs etc.

1.0.2 Necessity of maintenance

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

a) Atmospheric agencies
b) Normal wear and tear
c) Failure of structure

a) Atmospheric agencies

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

Physical:

- Dissolving and carrying away minerals as it is universal solvent.
- Expansion and contraction – The materials is subjected to repetitive expansion and contraction while they become wet and dry and develops the stresses.
- Expansion of water – The variation of temperature causes the expansion and contraction absorbed water and affects the micro-structures of the materials.

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

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

- **Wind:** It is the agent, which transports the abrasive material and assists the physical weathering Its action is aggravated during rains and, When it is moving with high speed, it may contains acidic gases like CO_2 fumes which may act over the material and penetrates quite deeply in materials and structure.
- **Temperature:** The seasonal and annual variation of the temperature, difference in temperature in two parts of the materials and the surface of material causes expansion and contraction, this movement of the material bond and adhesion between them is lost when it is repeated. This responsible for the development of cracks and the rocks may break away into small units.

Exploitation or peeling off the shell takes place if exterior layer are heated externally with respect to internal layers. The temperature variation may also cause change in the structure and chemical composition of the material.

b) Normal Wear and tear

During the use of structure it is subjected to abrasion and thereby it looses appearance an serviceability.

c) Failure of structure

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

The causes of failure may be broadly grouped as:

- Improper Design: Due to incorrect, insufficient data regarding use, loading and environmental conditions, selection of material and poor detailing.
- Defective Construction: Poor materials, poor workmanship, lack of quality control and supervision.

- Improper use of structure: Overloading, selecting the structure for the use for which they are not designed such as deteriorating environment due to impurities from industrial fuel burning, sea water minerals, chemicals, storage of chemicals etc.
- Lack of maintenance: Lack of upkeep, proper protection, precaution and preservation, deteriorated the structure, which may result in the failure.

1.0.3 Facets of maintenance:

Maintenance operations have many facets such as

a) Emergency maintenance: Necessitated by unforeseen breakdown drainage or damage caused by natural calamity like fire, floods, cyclone earthquake etc.
b) Condition Based maintenance: Work initiated after due inspection
c) Fixed time maintenance: Activities repeated at predetermined intervals of time.
d) Preventive maintenance: This is intended to preserve by preventing failure and detecting incipient faults (Work is done before failure takes place)
e) Opportunity maintenance: Work did as and when possible within the limits of operation demand.
f) Day-to-Day care and maintenance
g) Shut down maintenance: Thorough overhaul and maintenance after closing a facility.
h) Improvement plans: This is essentially maintenance operation wherein the weak links in the original construction are either replaced by new parts or strengthened.

1.0.4 Importance of Maintenance

- Improves the life of structure
- Improved life period gives better return on investment
- Better appearance and aesthetically appealing
- Better serviceability of elements and components
- Leads to quicker detection of defects and hence remedial measures
- Prevents major deterioration and leading to collapse
- Ensures safety to occupants
- Ensures feeling of confidence on the user
- Maintenance is a continuous cycle involves every element of building science namely

- Structural
- Electrical wiring
- Plumbing-water-supply-sanitation
- Finishes in floors and walls
- Roof terrace
- Service platform/verandah
- Lifts
- Doors windows and other elements

1.1 Various aspects Inspection:

The following are the various maintenance aspects,

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

a) Daily Routine Maintenance

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

b) Weekly Routing Maintenance

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

c) Monthly Routing Maintenance

- Cleaning doors, windows' latches etc
- Checking septic tank/ sewer

- Observation for cracks in the elements
- Cleaning of overhead tanks
- Peeling of plaster, dampness, floor cracks

d) Yearly Routing Maintenance

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

1.2 Repair

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

1.2.1 Stages of repair

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

a) Removal of damaged concrete
b) Pre treatment of surfaces and reinforcement
c) Application of repair materials
d) Restoring the integrity of individual sections and strengthening of structure as a whole.

a) Removal of damaged concrete

- Prior to the execution of any repair, one essential and common requirement is that the deteriorated or damaged concrete should be removed.
- Removal of defective concrete can be carried out using tools and equipment the types of which depend on the damage.
- Normally, removal of concrete can be accomplished by hand tools, or when that is impractical because of the extent of repair, it can be done with a light or medium weight air hammer fitted with a spade shaped bit.
- Care should be taken not to damage the unaffected concrete portions.
- For cracks and other narrow defects, a saw-toothed bit will help achieve sharp edges and a suitable under cut.

b) Pre treatment of surfaces and reinforcement

The preparation of a surface/pretreatment for repair involved the following steps:

- Complete removal of unsound material.
- Undercutting along with the formation of smooth edges.

- Removal of the cracks from the surface.
- Formation of a well defined cavity geometry with rounded inside corners.
- Providing, rough but uniform surface for repair.

The cleaning of all loose particles and oil and dirt out of the cavity should be carried out shortly before the repair. This cleaning can be achieved by blowing with compressed air, hosing with water, acid etching, wire brushing, scarifying or a combination. Brooms or brushes will also help to remove loose material.

c) Application of repair materials

- After the concrete surface has been prepared, a bonding coat should be applied to the entire cleaned exposed surface.
- It should be done with minimum delay.
- The bonding coat may consist of bonding agents such ass cement slurry, cement sand mortar, epoxy, epoxy mortar, resin materials etc.
- Adequate preparation of surface and good workmanship are the ingredients of efficient and economical repairs.

d) Repair procedure:

The repair of cracked or damaged structure is discussed under two distinct categories, namely, ordinary or conventional procedures; and special procedures using the latest techniques and newer materials such as polymers, epoxy resins etc.

A repair procedure may be selected to accomplish one or more of the following objective:

1. To increase strength or restore load carrying capacity.
2. To restore or increase stiffness.
3. To improve functional performance.
4. To provide water tightness.
5. To improve appearance of concrete surface.
6. To improve durability.
7. To prevent access of corrosive materials to reinforcement.

1.2.2 Durability of concrete Repair

The objective of any repair should be to produce rehabilitation – which means a repair carried out relatively low cost, with a limited and predictable degree of change with time and without premature deterioration and/or distress throughout its intended life and purpose. To achieve this goal, it is necessary to consider the factors affecting the durability of a repaired structural system as part of a whole, or a component of composite system. Summarized some of the findings and recommendations may be grouped into three categories:

1. Durable Repair Design
2. Durable repair application and
3. Evaluation of the repairs

1**. Durable Repair Design**

Modulus of elasticity and strength of repair material:

The modulus of elasticity of the repair material not only affects the resultant flexural stiffness of the repair members, but also the tensile stress present within the repair material and the debonding stress at the interface when differential movement occurs between the repair material and substance. A higher difference in modulus of elasticity between the repair material and substrate may adversely affect the stress distribution within the repaired composite material's cross section and may lead to considerable stress concentration. Therefore, the repair material selected should have as similar modulus of elasticity as the substrate as possible. Thus considering the strength of material alone seems less fact, an overemphasis on strength may cause repairs to experience cracking arising from drying shrinkage, creep and heat of hydration.

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Coefficient of thermal expansion of repair material:

Tensile stresses in the repair material caused by changes in the temperature of the surround environment are proportional to the differences in the coefficient of thermal expansion and the change temperature. Therefore, the repair material selected should have as similar as coefficient of then expansion as the substrate as possible.

Thickness of Repair:

The internal stresses within the repair material and substrate are affected not only by differential movements, but also by the relative thickness. A thinner repair layer is more easily cracks or debonded by the higher tensile stress which occurs in the repair material. For most available repair materials, there seemed to be an optimum thickness of repair material which results in the lowest tense stress occurring within the repair material for a given amount of differential movement between the repair material and substrate. This optimum value is affected by the ratio of the modulus of elasticity the repair material to substrate and thickness of repair material to substrate.

Shrinkage and creep of repair material:

Differential shrinkage of the repair material and substrate is another important consideration a durable repair. The most common damages in concrete between substrate and repair materials and it proportional to the differential shrinkage. Therefore, the repair material selected should have fi shrinkage properties that are as low as possible. For the repair material under tension, creep mamitigate against the tensile stresses caused by differential shrinkage. However, for the repair material under compression, creep may decrease the compressive stress within the repair material and aggrava the compressive stress in the substrate caused by the different shrinkage. The creep of the repair material should be controlled based on the state of stress that the repair material will be subjected to service.

2. Durable Repair Application:

Preparation of the repaired surface

The most important surface characteristics of the receiving substrate are its roughness soundness, cleanliness and moisture condition prior to application of the repair material. The first step in the repair to be carried out is the removal of the damaged concrete. It is very important to select a method most appropriate for the specific in-situ condition. Any method that weakness the sound concrete and create micro cracking should be avoided. Otherwise, the durability and bond will be decreased by these defects. Commonly used methods in-situ include: sand blasting, chipping with jack hammers, and hydro demolition among which, the last is highly recommended. A sound surface if adequate roughness can be created by this method.

Higher plastic shrinkage of the repair material near the interface should be avoided. This requires that the substrate be pre wetted for atleast 7 hours prior to the application of the repair material in order to decrease the absorption and expansion of substrate caused by the uptake of moisture from the repair material. Otherwise, the higher uptake of moisture by the substrate after the repair material is cast may lead to higher plastic shrinkage of the repair material near the interface and higher expansion of the substrate, and there by resulting in the possible debonding of the repair material at an early age.

The application method and surface preparation are equally important considerations with regards to the performance of the repaired structures. The repair method adopted not only affects the resultant quality of the repair material, but also the quality of the interfacial transition zone, shotcrete seems to be an ideal method because it has good compatibility with the substrate concrete. Further ore, good compaction with a relatively lower water/cement ratio of the repair material can be achieved using the shotcreting process. This ensures good/high mechanical properties of the component parts and durability of the repair structure.

Bonding agents:

Use of polymer bonding agents is not recommended as their modulus of elasticity is substantially different from that of the substrate. However, use of a cementitious bonding agent with a low water/cement ratio may be considered. This type of bonding agents not only has good compatibility with the substrate and repair material, but can also alleviate the effects of differential shrinkage and thermal movement between the repair material and concrete substrate thus enhancing the bond strength and durability.

Curing of Repair Material:

Excessive loss of water may result in higher shrinkage (Plastic and drying) and cause debonding failure of therepair material at an earlier age. Therefore, specification of proper curing after completion of the repair is very important. Curing time should be atleast the same as that adopted for usual concrete practice or in accordance to manufacturers recommendations if a commercially available material is used due to the restraint afforded by the substrate.

3. Evaluation of the Repairs

Behavior of the interfacial transition phase

The formation of the interfacial transition phase is affected by many factors. Defects such as micro-cracks and pores may be formed within this phase caused by the differential movements between the substrate and repair material and a lack of aggregate interlock action between the two materials. Its mechanical behavior and durability affects directly the performance of the repaired members in service. Thus the mechanical properties and durability of this phase should be evaluated after the completion of the repair work.

Behavior of the repaired structure:

Differential movements between the repair material and the may result in the cracking of the repair material and thereby decrease the flexural stiffness and durability of the repaired members. The degradation in flexural stiffness of the required beams under static and cyclic loading was related to the appearances and development of cracks. However, the presence of steel fibres within the repair materials may improve resistance against cracking and fatigue resistance. Therefore, the flexural stiffness can be enhanced and the deflection of the repaired members reduced. At the same time, the fatigue resistance of the interface between the repair material and substrate may also be evaluated by cyclic loading test of representative samples. The test results can also form a database for the formulation of guidelines for use in practice.

1.3 Assessment Procedure for Evaluating Damages in Struture and Repair techniques:

For assessment of damage of a structure the following general considerations have to be take accout.

1) Physical inspection of damaged structure.
2) Presentation and documenting the damage.
3) Collection of samples and carrying out tests both in situ and in lab.
4) Studying the documents including structural aspects.
5) Estimation of loads acting on the structure.
6) Estimate of environmental effects including soil structure interaction.
7) Diagnosis.

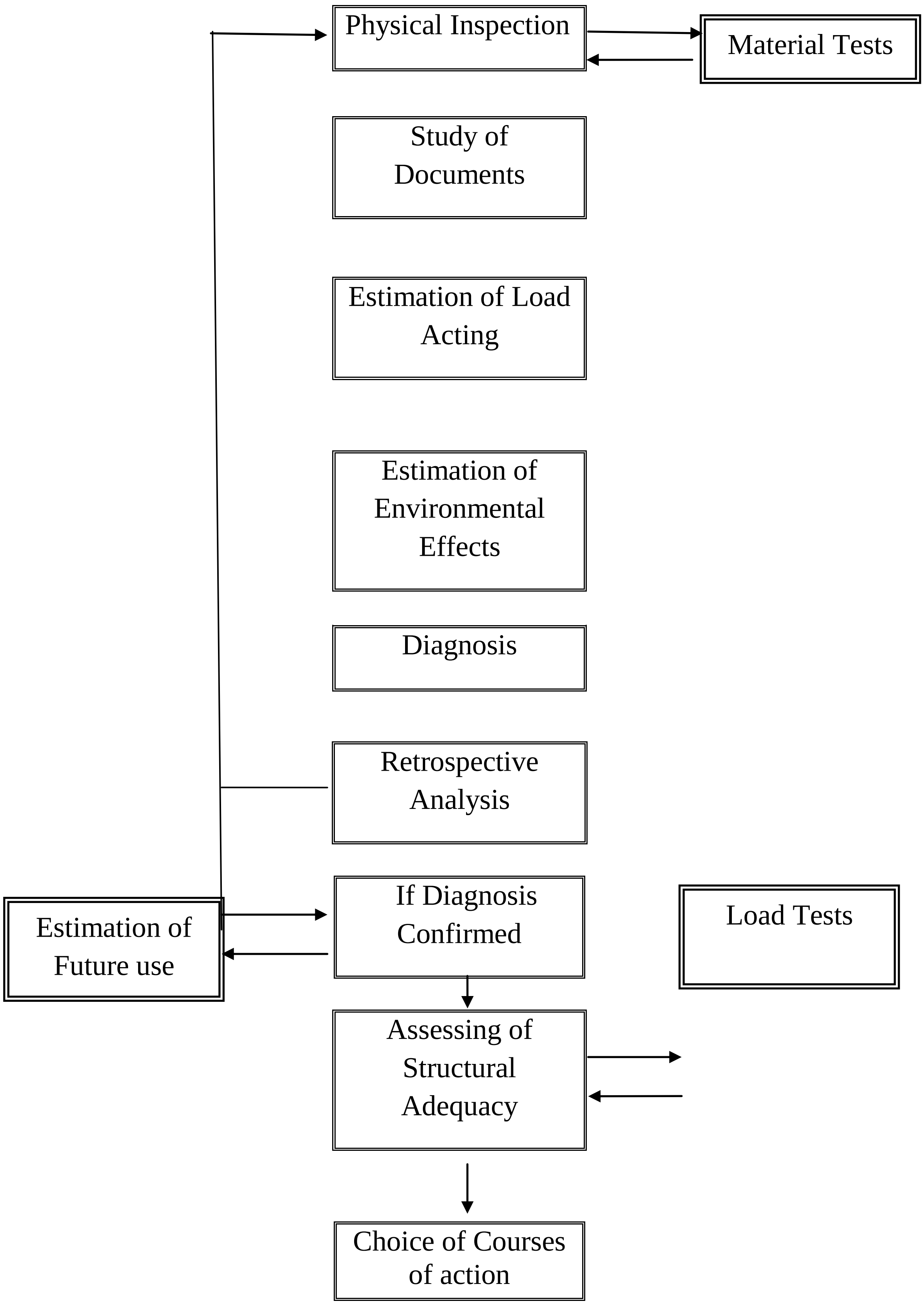

Fig. 1.1 Assessment Procedure of Damage

8) Taking preventive steps not to cause further damage.

9) Retrospective analysis to get the diagnosis confirmed.

10) Assessment of structural adequacy.

11) Estimation of future use.

12) Remedial measures necessary to strengthen and repairing the structure.

13) Post repair evaluation through tests.

14) Load test to study the behavior.

15) Choice of course of action for the restoration of structure.

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

1.3.1. Testing Techniques

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

1.3.1.1. Strength Tests

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

1.3.1.2 Durability Tests

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

1.3.1.3 Performance and Integrity Tests

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

1.3.1.4 Chemical Tests

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

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

Details of few of the tests, which are commonly used in practice, are described below,

1. Schmidt Hammer Test

Schmidt Hammer Test is a quick method for assessing the quality of concrete based on su hardness indicated by the rebound number. If the strength of concrete is high, then the rebound number is also high.

The principal of this test is that when the plunger of rebound hammer is pressed against surface of the concrete the spring controlled mass rebounds and the extent of such rebound depends upon the surface hardness of the concrete. The surface hardness and therefore the rebound number is taken to be related to compressive strength of the concrete. Rebound number values also depend on angle of measurement.

Ultrasonic Pulse Velocity test

Ultrasonic Pulse Velocity (USPV) method is being extensively used to assess the quality concrete. This test is generally used for measurement of concrete uniformity, determination of cracking and honeycombing, and assessment of concrete deterioration. Strength estimation is qulititative assessed.

The principal of USPV measurement involves sending electro-acoustic pulse through a concrete path and measuring the transit time taken, for a known distance. Pulse velocity is then, computed. Tn pulse velocity depends mainly on elastic modulus of concrete. Any factor, which influences the modulus of elasticity of concrete, will also affect its pulse velocity. The direct method of testing is the more reliable from the point of view of transmittance measurement, as maximum pulse energy is transmit at right angles to the face of transmitter.

2. Carbonation Test

Concrete is having micro-pores and these pores are filled with liquid, having PH –value as high 12.5. Thus, concrete is alkaline in nature. This alkaline of the concrete is due to (OH) ions in pore water, which are produced by the dissolution of $Ca(OH)_2$ from the solid phase of the cement gel into pore water and from the caustic alkalis present namely potassium and sodium oxides. Carbonation of the concrete is the reaction of $Ca(OH)_2$ with the atmospheric CO_2, and its conversion into $CaCO_3$. The reaction lowers the pH-value of the pore water to about 8.3. The outer zone of concrete is affected first out due to the passage of time, carbonation proceeds deeper into the mass as carbon dioxide diffuses inwards from the surface. If carbonation depth becomes equal to cover of concrete, steel reinforcement is then prone to corrosion damage.

By carbonation test, we measure the carbonated depth of concrete. To determine the depth of carbonation drilling of a hole is done in stages and the phenolphalein solution is sprayed in it after every stage. As soon as the color of the concrete becomes pink, drilling is stopped and the depth of the hole measured.

3. Core Test

Core test is one of the best methods to assess the strength of the concrete in reinforced concrete construction. Compression testing and petrographic examination of cores, cut from hardened concrete, is a well established and most reliable method enabling visual inspection of the interior regions and direct estimation of the strength. The results obtained from the other nondestructive tests are generally verified using core test.

Rebar Locator Test

By this test, bar diameter, cover to reinforcement, spacing of reinforcement, number of reinforcing bars and any discontinuity in the reinforcing bars can be detected. This test is performed using cover meter which is based on electro-magnetic theory.

Chloride Determination Test

Small amount of chlorides will normally be present in the concrete. Higher amount of chlorides may give rise to potential of corrosion risk. Quantity of chlorides in the concrete is generally determined chemically and is expressed in terms of percentage of chlorides by weight of concretes.

Thermo gravimetric and Dilatometric test, differential thermal analysis tests, Thermolumine scene test etc are some of the sophisticated tests for assessment of the residual concrete strength.

Thermo gravimetric and Dilatometric Tests

Thermo gravimetric and Dilatometry may be used to assess temperature attained by concrete. As the concrete undergoes irreversible chemical changes during fire there would be weight loss at about 500^0C. Using thermogravity curces the temperature attained during fire can be obtained. In dilatometric test, shrinkage of concrete due to process of dehydratrion is detected. By compaction expansion with temperature lines that represents dialometric curves for fire damaged concrete and unaffected concrete, the probable temperature to which concrete was subjected can be established.

Thermoluminescene Test

Thermoluminescene test was proposed by placid and elaborated by chew. This method is useful in finding out the temperature history of concrete exposed to a temperature range from 300^0C to 500 ^{0}C. This method utilizes the concept that the intensity of emission of visible light on heating versus temperature curve for a particular material depends on its thermal and radiation history. Temperature versus thermoluminescence curve of the fire affected sample may be compared with that of unaffected sample for comparison of exposures to the given temperature.

Differential thermal Analysis Tests

Differential thermal Analysis test is based on measurement of temperature curve of the concrete samples accompanying the irreversible physic, chemical transformation at a temperature, heated in surface. This method consists of heatng of sample in platinum crucible with a thermocol embedded in it. The time temperature curve of sample is compared with that of crucible containing in material or without my samples. The differential thermal analysis of concrete samples are conducted pulverized sample of mortar obtained from sound and unsound concrete with granular size of the concrete passing a sieve of 150 microns and retained on 75 microns sieve.

1.4 Causes of Deterioration:

The following are the causes of failure of structure:

a) Occurrences incidental to construction stage. This could be attributed to

1. Local settlement of sub grade.
2. Movement of formwork.
3. Vibrations.
4. Internal settlement of concrete suspension.
5. Setting Shrinkage.
6. Premature removal forms.

b) Drying Shrinkage

c) Temperature stresses – This may be due to

1. Difference in temperatures between the inside of the building with its environment.
2. Variation in internal temperature of the building or structure.

d) Absorption of moisture by concrete

e) Corrosion of reinforcement – This could be caused by

1. Entry of moisture through cracks or pores.
2. Electrolytic action

f) Aggressive action of chemical

g) Weathering action

h) Action of shock waves

i) Erosion

j) Poor design details at

1. Re-entrant corners
2. Changes in cross section
3. Rigid joints in precast elements
4. Deflections

This lead to

1. Leakage through joints
2. Inadequate drainage
3. Inefficient drainage slopes
4. Unanticipated shear stresses in piers, columns and abutments etc
5. Incompatibility of materials of sections
6. Neglect in design

k) Errors in design

l) Errors in earlier repairs

m)Overloading

n) External influences such as

1. Earthquake
2. Wind
3. Fire
4. Cyclones etc.

Some of the major causes of deterioration of concrete structure are discussed in detail here.

1.4.1 Design and construction flows

Design of the 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 upto the reinforcement, thus increasing the risk of corrosion of reinforcement.

1.4.2 Environmental Effects

Micro-cracks present in the concrete are the source of ingress of moisture and atmospheric carbon diozide 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 structure will be severely reduced.

1.4.3 Poor Quality material used

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

1.4.4 Quality of supervision

Construction work should be carried out as per the l aid sown specification. 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.

1.4.5 Deterioration 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 of reinforcement

1.5 Rehabilitation

Rehabilitation consists of restoring the structure to service level; it once 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.

Unit – II

SERVICEBILITY AND DURABILITY OF CONCRETE

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

2.1 Quality assurances for concrete construction

Quality management ensures that every component of the structure keeps performing throughout its life span. In fact, quality is a measure of the degree of excellence and is indeed related to fulfillment enjoyed by the user. In concrete construction, even if rigid quality is not followed, the material performs for a short while without loss of strength. On account of this forgiving property of concrete, many in the construction industry have been operating under the illusion that rigid quality management, which is essential for mechanical industries, is not so important for concrete manufacture. This is not correct. The quality management in the current day context is based on the fact that the probability of failure of structure must be as low as possible and definitely lower than a prefixed accepted limit. Hence, quality management in essence is the management of uncertainties inherent in the construction industry.

Need for Quality Assurance

- All involved with the construction and use of a concrete structure are concerned that the quality is necessary to give good performance and appearance throughout its intended life.
- The client requires it in promoting his next engineering scheme.
- The designer depends on it for his reputation and professional satisfaction.
- The material producer is influenced by the quality 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 considerably complicated by the problems of time scheduling and costs.
- Finally the user is rewarded by a functionally efficient structure of good appearance. It would seem to follow therefore that since all responsible parties gain by quality it should be automatically achieved.
- Yet this is not so, and a considerable positive effort must be employed to achieve it.

- This effort can best be expanded by instituting a quality assurances scheme which involves each of the above parties.

  The quality management system in a true sense should have the following three components

  1) Quality assurance plan(QAP)
  2) Quality control process(QC)
  3) Quality Audit(QA)

2.1.1 Quality assurance plan

The following aspects should be addressed by any QAP:

- Organizational Set-up
- Responsibilities of personnel
- Coordinating personnel
- Quality control measure
- Control norms and limit
- Acceptance/rejection criteria
- Inspection program
- Sampling, testing and documentation
- Material specification and qualification
- Corrective measure for noncompliance
- Resolution of disputed/difficulties
- Preparation of maintenance record

The quality assurance plan starts right from the planning and design stage itself, and it can be defined as a procedure for selecting a level of quality required for a project.

2.1.2 Quality Control Plan

- It is a system of procedures and standards by which the contractor, the product manufacture and the engineer monitor the properties of the product.
- Generally the contracting agency is responsible for the QC process

- A contractor responsible for quality control incurs a cost for it, which is less than the uncontrolled cost for correcting the defective workmanship or replacing the defective material.
- Hence it is prudent to introduce effective quality control.

2.1.2 Quality Audit

- This is the system of tracing and documentation of quality assurance and quality control program.
- It is the responsibility of the process owner.
- Both design and construction processes comes under this process.
- The concept of QA encompasses the project as a whole.
- Each element of the project comes under the preview of quality audit.

2.2 Concrete Properties

2.2.1 Strength

Strength of concrete is one of the most important factors. Concrete is used as a structural element, and all structural uses are associated with its compressive strength. Strength of concrete is defined as the resistance that concrete provides against load so as to avoid failure. It depends on the water-cement ratio, quality of aggregates, compaction, curing etc. The primary factor that affects the strength of concrete is the quality of cement paste, which in turn, depends on the quality of water and cement used.

Sometimes it is economical to add pozzolana or use Portland pozzolana cement instead of ordinary cement concrete. Pozzolanas are materials that have little cementing value but rich with calcium hydroxide to form compounds that are cementitious. This reaction contributes to the ultimate strength and watertightnesss of concrete. Pozzolanas also increases the plasticity and workability of concrete. Excessive addition of pozzolanas affects durability. So it should be used along with cement as a partial replacement or in small percentage.

Generally construction industry needs faster development of strength in concrete so that the projects can be completed in time or before time. This demand is catered by high early strength cement, use of very low W/C ratio through the use of increased cement concrete and reduced water content. But this result in higher thermal shrinkage, drying shrinkage, modulus of elasticity and lower creep coefficients. With higher quantity of cement content, the concrete exhibits greater cracking tendencies because of increase in thermal and during shrinkage. As the creep coefficient is low in such concrete there will not be much slope for relaxation of stresses. Therefore high early strength concretes are more prone to cracking than moderate or low strength concrete.

Of course, the structural cracks in high strength concrete can be controlled by use of sufficient steel reinforcement. But this practice does not help the concrete durability, as provision of more steel reinforcement; will only results in conversion of the bigger cracks to smaller cracks. And these smaller cracks are sufficient to allow oxygen, carbon dioxide and moisture get into the concrete to affect the long term durability of concrete.

Field experience have also corroborated that high early strength concrete are more cracks-prone. According to a recent report, the cracks in pier caps have been attributed to use of high cement content in concrete. Contractors apparently thought that a higher than the desired strength would speed up the construction time, and therefore used high cement content.

Similarly, report submitted by National Cooperative Highway Research Programme(NCHRP) of USA during 1995, based on their survey showed that more than, 100000 concrete bridge decks in USA showed full depth transverse cracks even before structures were less than one month old. The reasons given are that combination of thermal shrinkage and drying shrinkage caused most of the cracks. It is to be noted that deck concrete is made of high strength concrete. These concrete have a high elastic modulus at an early age. Therefore, they develop high stresses for a given temperature change or amount of drying shrinkage. The most important point is that such concrete creeps little to relieve the stresses.

It is interesting to see that the above point of view is not fully convincing when seen from many other consideration.

Firstly, the high strength concrete has high cement content and low water content. On account of low water content, only surface hydration of cement particle will have taken place leaving considerable amount of unhydrated core of cement grains. This unhydrated core of cement grains has strength in reserve. When micro cracks have developed, the unhydrated core gets hydrated, getting moisture through micro cracks. The hydration products so generated seal the cracks and restore the integrity of concrete for long term durability.

Secondly, as per aiticin, the quality of products of hydration formed in the case of low W/C ratio is superior to the quality of gel formed in the case of high W/C ratio.

Thirdly, the micro structure of concrete with low W/C ratio is much stronger and less permeable. The interconnected networks of capillaries are so fine that water cannot flow any more through them. It is reported that when tested for chloride ion permeability, it showed 10-50 times slower penetration than low strength concrete.

2.2.2 Permeability

Concrete is a permeable and a porous material. The rates at which liquids and gases can move in the concrete are determined by its permeability. Permeability affects the way in which concrete resists external attack and the extent to which a concrete structure can be free of leaks. The permeability is much affected by the nature of the pores, both their size and the extent to which they are interconnected. There can therefore be no one measure of porosity which fully describes the way in which the properties of concrete or of hardened cement paste are affected.

If a material were judged, the decision would rest primarily on the choice of medium used for testing.

For (ex) Vulcanized rubber would be found impervious and nonporous if tested with mercury, but if tested with hydrogen it would be found to be highly porous. Early work on the permeability of concrete was generally related to its use in dam construction.

In 1946 Powers and Brownyard examined the permeability of cement pastes and came to the conclusion that well-cured neat paste of low w/c ratio is practically impermeable and that the permeability of cement pastes depends almost entirely on the amount of capillary water present, since the gel pores are extremely small. Earlier work of Ruettgers resulted that the permeability of concrete is generally much higher than the theoretical permeability owing to the fissures under the aggregate that permit the flow partially to bypass the paste and owing to the capillaries in the paste that permit the flow in the paste to bypass the gel. Numerical values for permeability of concrete need to be examined with care.

The coefficient of permeability K1 is obtained from applying Darcy's law for low velocity flow,

$$(dr/dt).(1/A)=K1.(\hat{}h/L)$$

dr/dt= The rate of volume flow ($m^3s\text{-}^1$)

A= Area of porous medium normal to the direction of flow (M^2)

^h= Drop in hydraulic head across the thickness of the medium (m).

L= Thickness of the medium (m).

K1=Coefficient of permeability depending on the properties of the medium and of fluid ($ms\text{-}^1$)

For any set of tests, the value of K1 depends on both the medium and the fluid and therefore represents the permeability of the medium to a specified fluid at specified temperature. As pointed out by the concrete society working party, a number of factors can account for widespread of permeability results for a specific w/c ratio concrete, due primarily to aspects of the test method for eg:

a) Varying and continuing hydration of the specimen.
b) Incomplete and variable initial saturation.
c) Lack of absolute water cleanliness.
d) Chemical reaction of specimen with the test fluid
e) Effect of dissolved gases where high pressure air is used to pressurize the water.
f) Silting due to movement of fines.
g) Micro structural collapse and macroscopic instability when very high flow pressures are used.
h) Lack of attainment of steady state condition.

The composition of the water and the presence of dissolved materials can also have a substantial effect. The drying was found to increase the permeability and for the particular specimens examined, drying at 79% relative humidity increased the permeability about 70-told. The flow tests are appropriate for testing material which has a high permeability but for concrete of low permeability a method in which the depth of penetration is measured is usually a core practical proposition. The water tightness of a concrete structure is not determined by the permeability of the hardened cement paste or even by the measured permeability of laboratory specimens of the concrete. The permeability of concrete, both to moisture and to gas is important in relation to the protection afforded to embedded steel. The initial surface absorption test measures the rate at which water is absorbed in to the surface of the concrete for a brief period under a head of 200mm. The Figg test subsequent modifications of its measure the permeability of the concrete at the bottom of a fine hole drilled to some depth below the concrete surface. The depth to which water which is absorbed into concrete under little head has been shown to be initially a linear function of the square-root of time. The slope of this function is called Sorptivity. The sorptivity is a measure for assessing the protection that will be a afforded to embedded reinforcing steel, particularly after it has become activated.

Penetration of concrete by materials in solution may adversely affect its durability. For instance, when $Ca(OH)_2$ is being leaching out or an attack by aggressive liquids takes place. This penetration depends o the permeability of the concrete. Since permeability determines the relative ease, with which concrete can become saturated with water, permeability has an important bearing on the vulnerability of concrete to frost. Furthermore, in case of reinforced concrete, the ingress of moisture and of air will result in the corrosion of steel. Since this leads to an increase in the volume of the steel, cracking and spalling of the concrete cover may well follow.

The high permeability of concrete in actual structures is due to the following reasons:

- The large microcracks with generated time in the transition zone.
- Cracks generated through higher structural stresses.
- Due to volume change and cracks produced on account of various minor reasons.
- Existence of entrapped air due to insufficient compaction.

2.2.3 Thermal Properties

Concrete is a material used in all climatic regions for all kinds of structures. Thermal properties are important in structures in which temperature differentials occur including those due to solar radiation during casting and the inherent heat of hydration. Knowledge of thermal expansion is required in long span bridge girders, high rise buildings subjected to variation of temperatures, in calculating thermal strains in chimneys, blast furnace and pressure vessels, in dealing with pavements and construction joints, in dealing with design of concrete dams and in host of other structures where concrete will be subjected to higher temperatures such as fire, subsequent cooling, resulting in cracks, loss of serviceability and durability.

The thermal properties of concrete are more complex than those of most other materials because these are affect ted by moisture content and porosity.

Threee types of tests are commonly used to study the effect of transient high temperature on the stress-strain properties of concrete under compression. These are the following,

(a) Unstreesed Tests: Where specimens are heated under no initial stress and then loaded until the point of failure.

(b) Stressed Tests: Where a fraction of the compressive strength capacity at room temperature is applied and sustained during heating. When the target temperature is reached, the load is increased until the point of failure.

(c) Residual Unstressed Tests: Where the specimens are heated without any load, cooled to room temperature, and then loaded until the point of failure.

To study about the thermal properties of concrete the following properties needs to be known,

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

Thermal Conductivity:

This measures the ability of material to conduct heat. Thermal conductivity is measured in joules per second per square meter of area of body when the temperature deference is 1^0C per meter thickness of the body.

The conductivity of concrete depends on type of aggregate, moisture content, density and temperature of concrete. When the concrete is saturated, the conductivity ranges generally between about 1.4 and 3.4j/m^2s ^{0}c/m.

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.

$$\text{Diffusivity} = \frac{\text{Conductivity}}{\text{CP}}$$

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

Specific Heat:

It is defined as the quantity of heat required to raise the temperature of a unit mass of a material by one degree centigrade. The common range of values for concrete is between 840 and 1170 j/kg per ^{0}C.

Coefficient of thermal expansion:

Coefficient of thermal expansion is defined as the change in 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 $11*10^{-6}$ and $20*10^{-6}$ per ^{0}C. Coefficient of thermal expansion of aggregate varies between $5*10^{-6}$ and $12*10^{-6}$ per ^{0}C. Limestone and gabbors will have low values and quartzite will have high values of coefficient of thermal expansion. Therefore the kind of aggregate and content of aggregate influences the coefficients of thermal expansion of concrete.

2.2.4 Cracking

Plastic shrinkage cracks

Water from fresh concrete can be lost by evaporation, absorption of sub grade, formwork and in hydration process. When the loss of water from the surface of concrete is faster than the migration of water from interior to the surface dries up. This creates moisture gradient which results n surface cracking while concrete is still in plastic condition. The magnitude of plastic shrinkage and plastic shrinkage cracks are depending upon ambient temperature, relative humidity and wind velocity.

Rate of evaporation of water in excess of 1 kg/m^2 per hour is considered critical. In such a situation the following measures could be taken to reduce or eliminate plastic shrinkage cracks.

- Moisten the sub grade and formwork
- Erect temporary wind breakers to reduce the wind velocity over concrete.
- Erect temporary roof to protect concrete from hot sun.

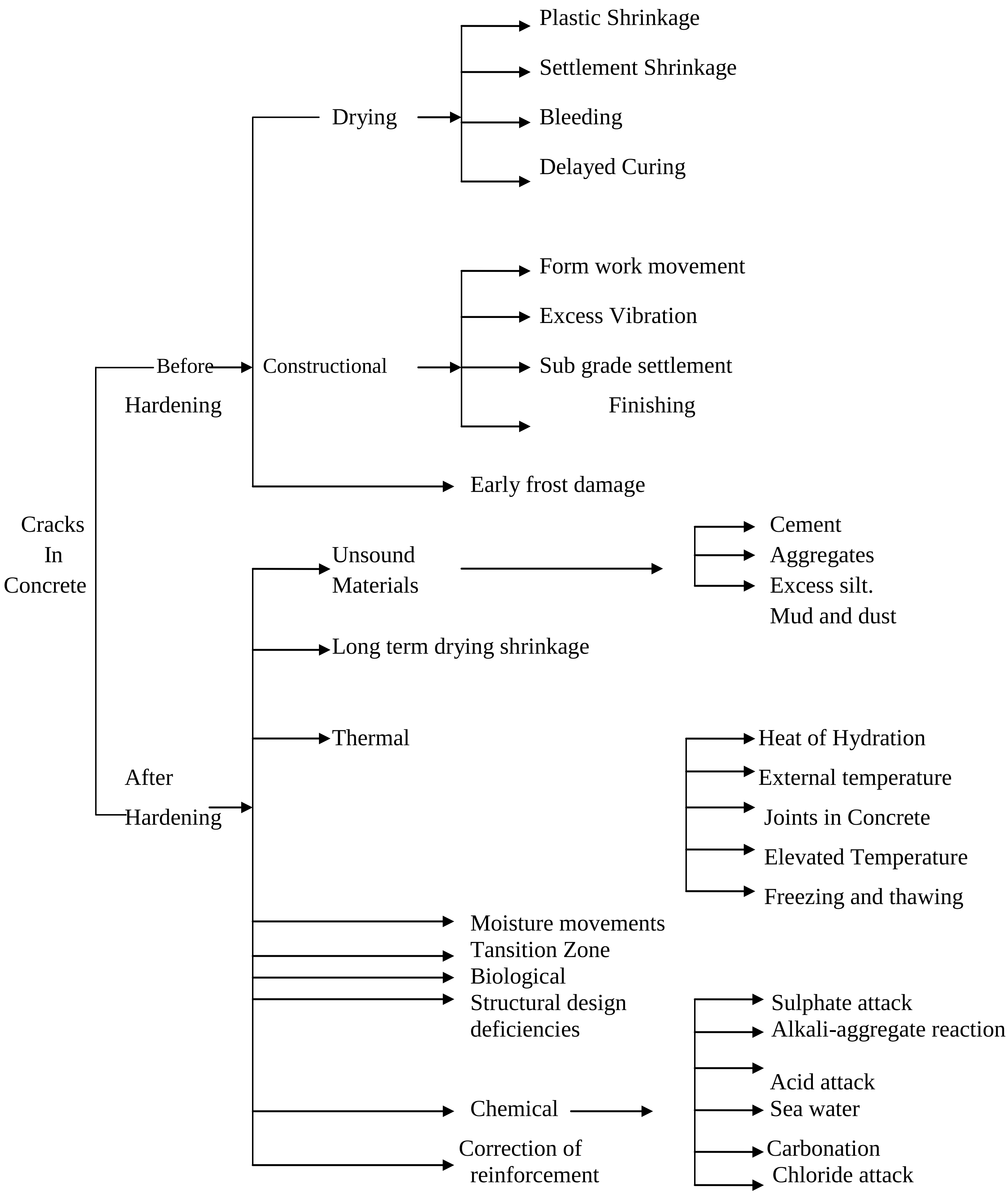

Fig 2.1 Various Types and Causes of cracks in Concrete

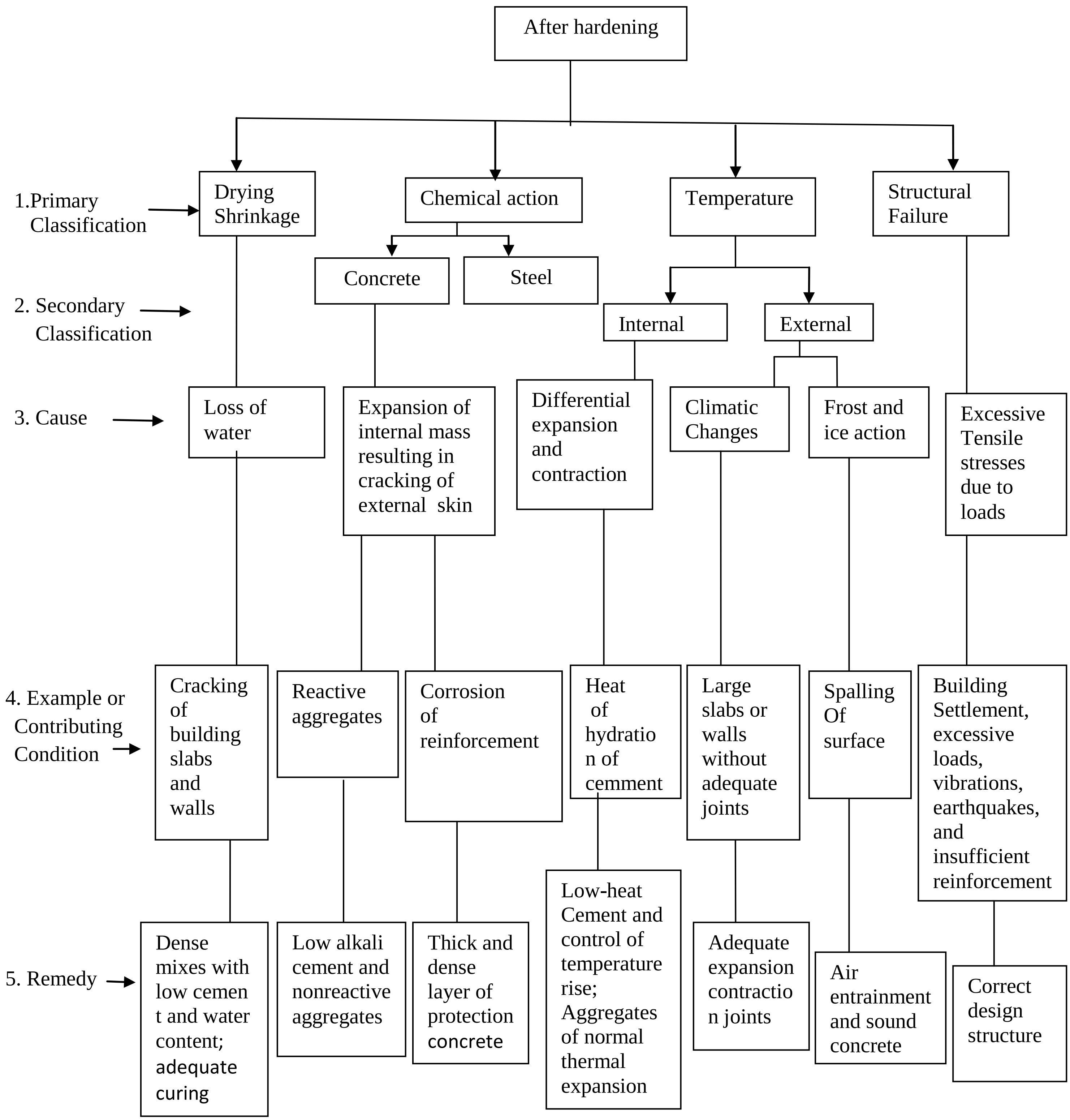

Fig2.3 Other Properties, types and causes of concrete cracking

- Reduce the time between placing and finishing. If there is delay cover the concrete with polyethylene sheets.
- Minimize evaporation by covering concrete with burlap, fog spray and curing compound.

Plastic shrinkage cracks are very common in hot weather conditions in pavements floor and roof slab concrete.

Once they are forms it's difficult to rectify. In case of prefabricated units, they can be heated by controlled revibration, if the concrete is in plastic condition. In roof and floor slab it is difficult to repair. However, sometimes, thick sluury is poured over the cracks and well worked by trowel after striking each side of the cracks to seal the same. The best way is to take all precautions to prevent evaporation of water from the wet concrete, finish it fast, and cure it as early as feasible.

In Mumbai – Pune express highway, the fresh concrete is protected by 100 meter long low tenterected on wheel to break the wind and also to protect the green concrete from hot sun. In addition curing compound is sprayed immediately after finishing operations.

Plastic shrinkage cracks, if care is not taken, will affect the durability of concrete in many ways.

Settlement Cracks

If the concrete is free to settle uniformly, then there is no crack. If there is any obstruction to uniform settlement by way of reinforcement or larger piece of aggregate, then it creates some voids or cracks. This is called settlement cracks. This generally happens in a deep beam.

Concrete should be poured in layers and each layer should be properly compacted. Building up of large quantity of concrete over a beam should be avoided.

Sometimes, the settlement cracks and voids are so severe it needs grouting operators to seal them off. Revibration, if possible is an effective step. Otherwise they affect the structural integrity of the beam or any other member and badly affect the durability.

Bleeding

Shrinkage of concrete is one of the important factors contributing to lack of durability of concrete. Shrinkage is mainly responsible for causing cracks of larger magnitude or minor micro cracks. The aspect of cracking in concrete is very complex, involving many factors such as magnitude of shrinkage, degree of restraint, extensibility of concrete, extent of stress relaxation by creep and at what age the shrinkage is appearing etc. Cracks can be avoided only if the stress induced by shrinkage strain, after relaxation by creep, is at all time less than the tensile strength of concrete. The above situation is not happening in most of the cases and as such generally shrinkage causes cracks in concrete.

2.3 Durability:

Definition:

Durability of concrete may be defined as the ability of concrete to resist weathering action, chemical attack, and abrasion while maintaining its desired engineering properties. Different concretes require different degrees of durability depending on the exposures environment and properties desired.

For example, concrete exposed to tidal seawater will have different requirements than an indoor concrete floor. Concrete ingredients, their proportioning, interactions between them, placing and curing practices, and the service environment determine the ultimate durability and life of concrete.

Some important degradation mechanisms in concrete structures include the following:

1. Freeze-thaw damage (physical effects, weathering).
2. Alkali-aggregate reactions (chemical effects).
3. Sulphate attack(chemical effects).
4. Microbiological induced attack(chemical effects).
5. Corrosion of reinforcing steel embedded in concrete (chemical effects).
   a)carbonation of concrete
   b) chloride induced.
6. Abrasion (physical effects).
7. Mechanical loads(physical effects).

2.3.1 Effect of freezing and thawing:

- The most severe climate attack on concrete occurs when concrete containing moisture is subjected to cycles of freezing and thawing.
- The capillary pores in the cement are of such a size that water in them will freeze when the ambient temperatures is below 0^0C.

- The gel pores are so small that water in them does not 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 distance.
- 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 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 lost moisture as the concrete dries.
- Fully saturated concrete, if permanently submerged, will not need protection against freezing, but concrete which as been saturated and is exposed to freezing, as for example in the tidal range, may not be effectively protected by air-entrainment.

2.3.2 Effect of Temperature:

- The temperature difference within a concrete structure, result in differential volume change.
- When the tensile strain due to differential volume change exceeds the tensile strain capacity of concrete, it will crack.
- The temperature differentials associated with the hydration of cement, affect the mass concrete such as in large columns, piers, footings, dams etc. Whereas the temperature differentials due to changes in the ambient temperature can affect the whole structure.
- The liberation of the heat of hydration of cement causes the internal temperature of concrete to rise during the initial curing period, so that is is usually slightly warmer than its surroundings.
- In thick sections and with rich mixes the temperature differential may be considerable. As the concrete cools it will try to contract.

- Any restraint on the free contraction during cooling will result in tensile stresses which are proportional to the temperature change, coefficient of thermal expansion, effective modulus of elasticity and degree of restraint.
- The more massive the structure, the greater is the potential for temperature differential and degree of restraint.
- Thermally induced cracking can be reduced by controlling the maximum internal temperature, delaying the onset of cooling by insulating the formwork and exposed surfaces, controlling the rate of cooling, and increasing the tensile strain capacity of the concrete.
- Special precautions need to be taken in the desing of structures in which some portions are exposed to temperature changes while the other portions of structures are either partially or completely protected.
- A drop in temperature may result in the cracking of the exposed element while increase in temperature may cause cracking in the protected portion of the strcture.
- Temperature gradients cause deflection and rotation in structural members; if these are restrained serious stresses can result.
- Allowing for movement by using properly designed contraction joints and correct detailing will help alleviate these problems. If the cracks do form.
- Remedial measures are similar to those for cracks that form after a structure in service.

2.3.3 Effect of chemical:

- The most important constituent of concrete namely cement is alkaline; so it will react with acids or acidic compounds in presence of moisture, and in consequence the matrix becomes weakened and its constituents may be leached out. The concrete may crack, as a result of expansive reactions between aggregate containing active silica and alkalies derived from cement hydration, admixture or external sources(e.g. curing water, ground water, alkaline solutions stored). The alkali – silica reaction results in the formation of a swelling gel, which tends to draw water from other portions of concrete. This causes local expansion nd accompanying tensile stresses which if large may eventually result in the complete deterioration of the structure. Control measures include proper selection of aggregate, use of low-alkali cement and use of pozzolana. Typical symptoms in unreinforced and highly reinforced concrete are *map cracking*, usually in a rough hexagonal mesh pattern and gel excluding from cracks.

- The alkali-carbonate reactions occurs with certain limestone aggregate and usually results in the formation of alkali-silica product between aggregate particiles and the surrounding cement paste. The problem may be minimized by avoiding reactive aggregate, use of smaller size aggregate and use of low-alkali cement.
- When the sulphate bearing waters come in contact with the concrete, the sulphate penetrates the hydrated paste and reacts with hydrated calcium aluminate to form calcium suphoaluminate with a subsequent large increase in volume, resulting in high tensile stresses causing the deterioration of concrete. The blended or pozzolana cements impart additional resistance to sulphate attacks.
- The calcium hydroxide in hydrated cement paste will combine with carbon dioxide in the air to form calcium carbonate which occupies smaller volume tan the calcium hydroxide resulting called *carbonation shrinkage*. This situation may result in significant surface grazing and ay be especially serious on freshly placed concrete surface kept warm during winter by improperly vented combustion heaters.

Factors which increase concrete vulnerability to external chemical attacks are,

1. High porosity
2. High permeability and absorption resulting from too high W/C ratio.
3. Unsatisfactory grading of aggregate.
4. Cement compaction.
5. Improper choice of cement type for condition of exposure.
6. Inadequate curing period.
7. Exposure to alternate cycles of wetting and drying and to the lesser extended of heating and cooling.
8. Increased fluid velocity which may bring about both replenishment of the aggressive species and increases in the rate of leaching.
9. Suction forces which may caused by drying on one or more faces of a section.
10. Unsatisfactory choice of shape and surface to volume ratio of concrete structure.

2.3.4 Effect of Corrosion:

2.3.4.1 Formation of white patches

CO_2 reacts with $Ca(OH)_2$ in the cement paste to form $CaCO_3$. The free movement of water carries the unstable $CaCO_3$ towards the surface and forms white patches. It indicates the occurrences of carbonation.

2.3.4.2 Brown patches along reinforcement

When reinforcement starts corroding, a layer a ferric oxide is formed. This brown product resulting from corrosion may permeate along with moisture to the concrete surface without cracking of the concrete.

2.3.4.3 Occurrence of cracks

The increase in volume exerts considerable bursting pressure on the surrounding concrete resulting in cracking. The hair line crack in the concrete surface lying directly above the reinforcement and running parallel to it is the positive visible indication that reinforcement is corroding. These cracks indicate that the expanding rust had grown enough to split the concrete.

2.3.4.4 Formation of multiple cracks

As corrosion progresses, formation of multiple layers of rust on the reinforcement which in turn exert considerable pressure on the surrounding concrete resulting in widening of hair cracks. In addition, a number of new hair cracks are also formed. The bond between concrete and the reinforcement is considerably reduced. There will be a hollow sound when the concrete is tapped at the surface with a light hammer.

2.3.4.5 Snapping of bars

The continued reduction in the size of bars results in snapping of the bars. This will occur in ties/stirrups first. At this stage, size of the main bars is reduced.

2.3.4.6 Buckling of bars and bulging of concrete

The spalling of the cover concrete and snapping of ties causes the main bars to buckle. This results in bulging of concrete in that region. This follows collapse of the structure. When corrosion of reinforcement starts, the deterioration is usually slow but advances in geometrical progression. Corrosion can also cause structural failure due to reduced C/S and hence reduced load carrying capacity. It is possible to arrest the process of corrosion at any stage by altering the corrosive environment in the vicinity of the reinforcement.

2.4 Design Errors and Construction Errors:

2.4.1 Design Errors

Design errors may be divided into two general types:

1. Those resulting from inadequate structural design
2. Those resulting from lack of attention to relatively minor design details.

Each of the two types of design errors is discussed below.

(1) Inadequate structural design.

(a) Mechanism. The failure mechanism is simple – the concrete is exposed to greater stress than it is capable of carrying or it sustains greater strain than its strain capacity.

(b) Symptoms. Visual examinations of failures resulting from inadequate structural design will usually show one of two symptoms.

1. First, errors in design resulting in excessively high compressive stresses will result in spalling. Similarly, high torsion or shear stresses may also result in spalling or cracking.
2. Second, high tensile stresses will result in cracking.

To identify inadequate design as a cause of damage, the locations of the damage should be compared to the types of stresses that should be present in the concrete. For example, if spalls are present on the underside of a simple-supported beam, high compressive stresses are not present and inadequate design may be eliminated as a cause. However, if the type and location of the damage and the probable stress are in agreement, a detailed stress analysis will be required to determine whether inadequate design is the cause. Laboratory analysis is generally not applicable in the case of suspected inadequate design. However, for rehabilitation projects, thorough petro graphic analysis and strength testing of concrete from elements to be reused will be necessary.

(c) Prevention.

Inadequate design in prevented by thorough and careful review of all design calculations. Any rehabilitation method that makes use of existing concrete structural members must be carefully reviewed.

(2) Poor design details

A structure may be adequately designed to meet loadings and other overall requirements, poor detailing may result in localized concentrations of high stresses in otherwise satisfactory concrete. These high stresses may result in cracking that allows water or chemicals access to the concrete. In other cases, poor design detailing may simply allow water to pond on a structure, resulting in saturated concrete. In general, poor detailing does not lead directly to concrete failure; rather, it contributes to the action of one of the other causes of concrete deterioration described in this chapter. Several specific types of poor detailing and their possible effects on a structure are described in the following paragraphs. In general, all of these problems can be prevented by a thorough and careful review of plans and specifications for the project. In the case of existing structures, problems resulting from poor detailing should be handled by correcting the detailing and not by simply responding to the symptoms.

(a) Abrupt changes in section.

Abrupt changes n section may cause stress concentrations that may result in cracking. Typical examples would include the use of relatively thin sections such as bridge decks rigidly tied into massive abutments or patches and replacement concrete that are not uniform in plan dimensions.

(b) Insufficient reinforcement at reentrant corners and openings.

Reentrant corners and openings also tend to cause stress concentrations that may cause cracking. In this case, the best prevention is to provide additional reinforcement in areas where stress concentrations are expected to occur.

(c) Inadequate provision for deflection.

Deflection in excess of those anticipated may result in loading of members or sections beyond the capacities for which they were designed. Typically, these loadings will be induced in walls or partitions, resulting in cracking.

(d) Inadequate provision for drainage.

Poor attention to the details of draining a structure may result in the ponding of water. This ponding may result in leakage or saturation of concrete. Leakage may result in damage to the interior of the structure or in staining and encrustations on the structure. Saturation may result in severely damaged concrete if the structure is in an area that is subjected to freezing and thawing.

(e) Insufficient travel in expansion joints.

Inadequately designed expansion joints may result in spalling of concrete adjacent to the joints. The full range of possible temperature differentials that a concrete may be expected to experience should be taken into account in the specification for expansion joints. There is no single expansion joint that will work for all cases of temperature differential.

(f) Incompatibility of materials.

The use of materials with different properties (modulus of elasticity or coefficient of thermal expansion) adjacent to one another may result in cracking or spalling as the structure is loaded or as it is subjected to daily or annual temperature variations.

(g) Neglect of creep effect.

Neglect of creep may have similar effects as noted earlier for inadequate provision for deflections. Additionally, neglect of creep in prestressed concrete members may lead to excessive prestress loss that in turn results in cracking as loads are applied.

(h) Rigid joints between precast units.

Designs utilizing precast elements must provide for movement between adjacent precast elements or between the precast elements and the supporting frame. Failure to provide for this movement can result in cracking or spalling.

(i) Unanticipated shear stresses in piers, columns, or abutments.

Through lack of maintenance, expansion bearing assembles are allowed to become frozen, horizon-tal loading may be transferred to the concrete elements supporting the bearings. The result will be cracking in the concrete, usually compounded by other problems which will be caused by the entry of water into the concrete.

2.4.2 Construction Errors:

Failure to follow specified procedures and good practice or outright carelessness may lead to a number of conditions that may be grouped together as construction errors. Most of these errors do not lead directly to failure or deterioration of concrete. Instead, they enhance the adverse impacts of other mechanisms. Each error will be briefly described along with preventative methods. In general, the best preventive measure is a thorough knowledge of what these construction errors are, plus an aggressive inspection program. It should be noted that errors of the type described in this section are equally as likely to occur during repair or rehabilitation projects as they are likely to occur during new construction.

(a) Adding water to concrete. Water is usually added to concrete in one or both of the following circumstances:

1. First, water is added to the concrete in a delivery truck to increase slump and decrease emplacement effort. This practice will generally lead to concrete with lowered strength

and reduced durability. As the w/c of the concrete increases, the strength and durability will decrease.

2. In the second case, water is commonly added during finishing of flatwork. This practice leads to scaling, crazing, and dusting of the concrete in service.

(b) Improper alignment of formwork.

Improper alignment of the formwork will lead to discontinuities on the surface of the concrete. While these discontinuities are unsightly in all circumstances, their occurrence may be more critical in areas that are subjected to high-velocity flow of water, where cavitations erosion may be induced, or in lock chambers where the "rubbing" surfaces must be straight.

(c) Improper consolidation.

Improper consolidation of concrete may result in a variety of defects, the most common being bugholes, honeycombing, and cold joints.

"Bugholes" are formed when small pockets of air or water are trapped against the forms. A change in the mixture to make it less "sticky" or the use of small vibrators worked near the form has been used to help eliminate bugholes.

Honeycombing can be reduced by inserting the vibrator more frequently, inserting the vibrator as close as possible to the form face without touching the form, and slower withdrawal of the vibrator. Obviously, all of these defects make it much easier for any damage-causing mechanism to initiate deterioration of the concrete.

Frequently, a fear of "overconsolidation" is used to justify a lack of effort in consolidating concrete. Overconsolidation is usually defined as a situation in which the consolidation effort causes all of the coarse aggregate to settle to the bottom while the paste rises to the surface. If this situation occurs, it is reasonable to conclude that there is a problem of a poorly proportioned concrete rather than too much consolidation.

(d) Improper curing.

Curing is probably the most abused aspect of the concrete construction process. Unless concrete is given adequate time to cure at a proper humidity and temperature, it will not develop the characteristics that are expected and that are necessary to pro-vide durability. Symptoms of improperly cured concrete can include various types of cracking and surface disintegration. In extreme cases where poor curing leads to failure to achieve anticipated concrete strengths, structural cracking may occur.

(e) Improper location of reinforcing steel.

This section refers to reinforcing steel that is improperly located or is not adequately secured in the proper location. Either of these faults may lead to two general types of problems.

1. First, the steel may not function structurally as intended, resulting in structural cracking or failure. A particularly prevalent example is the placement of welded wire mesh in floor slabs. In many case, the mesh ends up on the bottom of the slab which will subsequently crack because the steel is not in the proper location.

2. The second type of problem stemming from improperly located or tied reinforcing steel is one of durability. The tendency seems to be for the steel to end up near the surface of the concrete. As the concrete cover over the steel is reduced, it is much easier for corrosion to begin.

(f) Movement of formwork

Movement of formwork during the period while the concrete is going from fluid to a rigid material may induce cracking and separation within the concrete. A crack open to the surface will allow access of water to the interior of the concrete. An internal void may give rise to freezing or corrosion problems if the void becomes saturated.

(g) Premature removal of shores or reshores.

If shores or reshores are removed too soon, the concrete affected may become overstressed and cracked. In extreme cases there may be major failures.

(h) Settling of the concrete.

During the period between placing and initial setting of the concrete, the heavier components of the concrete will settle under the influence of gravity. This situation may be aggravated by the use of highly fluid concretes. If any restraint tends to prevent this settling, cracking or separations may result. These cracks or separations may also develop problems of corrosion or freezing if saturated.

(i) Settling of subgrade.

If there is any settling of the subgrade during the period after the concrete begins to become rigid but before it gains enough strength to support its own weight, cracking may also occur.

(j) Vibration of freshly placed concrete.

Most construction sites are subjected to vibration from various sources, such as blasting, pile driving, and form the operation of construction equipment.

Freshly placed concrete is vulnerable to weakening of its properties if subjected to forces which disrupt the concrete matrix during setting.

(k) Improper finishing of flat work.

The most common improper finishing procedures which are detrimental to the durability of flat work are discussed below.

(1) Adding water to the surface. Evidence that water is being added to the surface is the presence of a large paint brush, along with other finishing tools. The brush is dipped in water and water is “slung” onto the surface being finished.

(2) Timing and finishing. Final finishing operations must be done after the concrete has taken its initial set and bleeding has stopped. The waiting period depends on the amouts of water, cement, and admixtures in the mixture but primarily on the temperatures of the concrete surface. On a partially shaded slab, the part in the sun will usually be ready to finish before the part in the shade.

(3) Adding cement to the surface. This practice is often done to dry up bleed water to allow finishing to proceed and will result in a thin cement-rich coating which will craze or flake off easily.

2.5 Effect of Cover Thickness

There is a substantial experience which relates durability and the amount of water. The thicker the cover over the steel is, the longer it will take the chloride ions to reach the steel and reduce the pH and passivity provided by the cement. However, excessive cover can led to the development of a few wide cracks under overstress, whereas a thinner cover results in many small cracks.

As opposed to the above mentioned facts, which appear to justify the rigid rules on cover, are the fallowing facts.

- Ships built during World War I and II had covers of only about 20mm, yet they did not suffer corrosion steel.
- In the erstwhile USSR, many floating dry-docks have been built with covers of 15 and 20mm with highly successful durability over many years of adverse exposure.

It is confirmed opinion that the impermeability of the cover is of major importance. The thickness should be related to the steel bar diameter and the maximum size of the coarse aggregate.

The general factors affecting permeability, such as cement content, water/cement ratio, compaction and consolidation of the concrete, and curing are important. While many fee that prestressing steel should have a greater cover than non-stressed steel, because of the more serious consequences of corrosion. Prestressed concrete pilling by hundreds of thousands are rendering completely successful service with only 4-6cm of cover. Other factors affecting cover are the tolerances of placement of steel and forms, and the depths of honeycombs and bug holes and other surface defects.

Lack of adequate cover contributes much to corrosion in an aggressive environment. A well compacted and continuous, even if thin, cover of good quality concrete on reinforcement is sufficient to protect it from corrosion. The following are the reinforcement thickness of covers for various levels of exposure.

- For normal exposure : At least 50mm thickness
- For moderate exposure : At least 40mm thickness
- For mild exposure : At least 30mm thickness
- For normal exposure : At least 20mm thickness

Cover Meter

When a metallic object is placed in the varying magnetic field of coil, the field induces eddy currents in the object. These eddy currents in turn produce an additional magnetic field in the vicinity of the magnetic object. A magnetic field gets superimposed and the magnetic field near the coil also gets modified in the presence of metal. This modification has the same effect as would be obtained if the characteristic of the coil itself had been changed. The change depends upon the electrical conductivity, dimension, magnetic permeability, presence of discontinuity such as crack, frequency of the field of the coil, size and shape of the coil, and the distance of the coil from the metallic object.

It is possible to measure the cover thickness for a known diameter by keeping all other parameters constant. By placing the soil at two different distances from the rebar, both the cover thickness and the diameter of the rebar can be found.

2.6 Effect of Cracking

The formation of cracks is dangerous for protection against corrosion. Once concrete cracks, the external depassivating agents can penetrate deep into concrete and set off the process of corrosion. Cracks running transversely to the reinforcement are less harmful than the longitudinal cracks along the reinforcement.

Thus in the order to induce the process of corrosion and to keep it going, at least one of the following conditions must exist in any RC structure.

- Chloride ion concentration in excess of the threshold value at the interface of the reinforcement and concrete or sufficient advancement of the carbonation front to destroy the passivity of the ferric oxide surface layer of the reinforcement.
- Adequate moisture in the concrete to facilitate the movement of chloride ions and provide a conduction path between the anodic and the cathodic areas on the steel.
- Sufficient oxygen supply to the cathodic areas in order to maintain such areas in a depolarized condition.
- Difference in electrochemical potentials at the surface of the reinforcement.
- Low values of electrical resistivity of concrete.
- Relative humidity in the range 50-70%.
- Higher ambient temperature.

Unit – III

MATERIALS AND TECHNIQUES FOR REPAIR

Special concretes and mortar, concrete chemicals, special cements for accelerated strength gain, Expansive cement, polymer concrete, sulphur infiltrated concrete, ferro cement, Fibre reinforced concrete.

3.1 Special Concretes:

Note: For more Special Concretes please refer “Concrete Technology” by M.S. Shetty. From Page 444 with the topic “Special concrete and concreting methods.

3.2 Special Mortar:

The following are the different types of special mortars available, they are

- Cement-clay mortar
- Light-weight and heavy mortars
- Decorative mortar
- Air-entrained mortar
- Gypsum mortar
- Fire-resistance mortar
- Packing mortar
- Sound absorbing mortar
- X-ray shielding mortar

3.2.1 Cement-clay mortar

- Here clay is introduced as an effective finely ground additive in quantities ensuring a cement-clay proportion of not over 1:1. The addition of clay improves the grain composition, the water retaining ability and the workability of mortar and also increases the density of mortar.
- This type of mortar has better covering power and can be used in thin layers.

3.2.2 Lightweight and Heavy mortars

Light weight mortars:

- These are prepared form light porous sands fro pumice and other fine aggregates. They are also prepared by mixing wood powder, wood shavings or saw dust with cement mortar or lime mortar.
- In such mortars, fibres of jute coir and hair, cut into pieces of suitable size, or asbestos fibres can also be used.
- These mortars have bulk density less than 15KN/m^3.

Heavy weight mortars:

- These are prepared from heavy quartz or other sands.
- They have bulk density of 15 KN/m^3 or more.
- They are used in load bearing capacity.

3.2.3 Decorative mortars:

These mortars are obtained by using-

- Colour cements or pigments and
- Fine aggregate of appropriate color, texture and surface.

3.2.4 Air-entrained Mortar

- The working qualities of lean cement-sand mortar can be improved by entraining air in it(air serves as a plasticizer producing minute air bubbles which helps in flow characteristics and workability)/
- The air bubbles increase the volume of the binder paste and help to fill the voids in the sand.
- The air entraining also makes the mortar weight and a better heat and sound insulator.

3.2.5 Gypsum Mortar

- These mortars are prepared from gypsum binding materials such as building gypsum and anhydrite binding materials.

3.2.6 Fire Resistant Mortar

- It is prepared by adding aluminous cement to a finely crushed power of fire-bricks(Usually proportion being one part of aluminous cement to two parts of powder of fire-bricks).

- This mortar being fire resistance, is used with fire-bricks for lining furnaces, fire places, ovens etc.

3.2.7 Sound Absorbing mortar

- These mortarts may have binging materials such as cement, lime, gypsum slag etc and aggregate(light weight porous materials(such as pumice, cinders etc.
- The bulk density of such a mortar varies from 6 to 12KN/m^3.
- Noise level can be reduced by using sound absorbing plaster formed with the help of sound absorbing mortar.

3.3 Concrete Chemicals

Admixtures are used to modify the properties of fresh and hardened concrete. They are classified as chemical and mineral admixtures. Chemical admixtures are used in construction industry for building strong, durable and waterproof structures. Depending on their use, chemical admixtures are used for the following four main purposes.

1. Some chemicals are mixed with concrete ingredients and spread throughout the body of concrete to favorably modify the moulding and setting properties of the concrete mix. Such chemicals are generally known as *chemical admixtures* Admixtures are added to concrete to give it certain desirable properties in either the fresh or the hardened state. Most admixtures result in modifying more than one intended property.
2. Some chemicals are applied on the surfaces of moulds used to form concrete to effect easy mould-releasing operation.
3. Some chemicals are applied on the surfaces of concrete to protect it during or after its setting.
4. Some chemicals are applied to bond or repair broken or chipped concrete.

3.3.1 Accelerators:

Accelerators reduce the setting time, generally produce early removal of forms and early setting of concrete repair, and patch work. They are helpful in cold weather concreting. The most common accelerator for plain concrete work Is calcium chloride ($CaCl_2$). Its quantity in the concrete mix is limited to 1-2% by weight of cement. The presence of $CaCl_2$ can cause corrosion of embedded steel. It reduces resistance against sulphate attack an may cause an alkali-aggregate reaction. For prestressed and reinforced concrete $CaC\ l_2$ cannot be used. Instead, calcium formate is preferred as an accelerating admixture for such caoncretes. The properties and types of accelerating admixtures are shown in fig. 3.1.

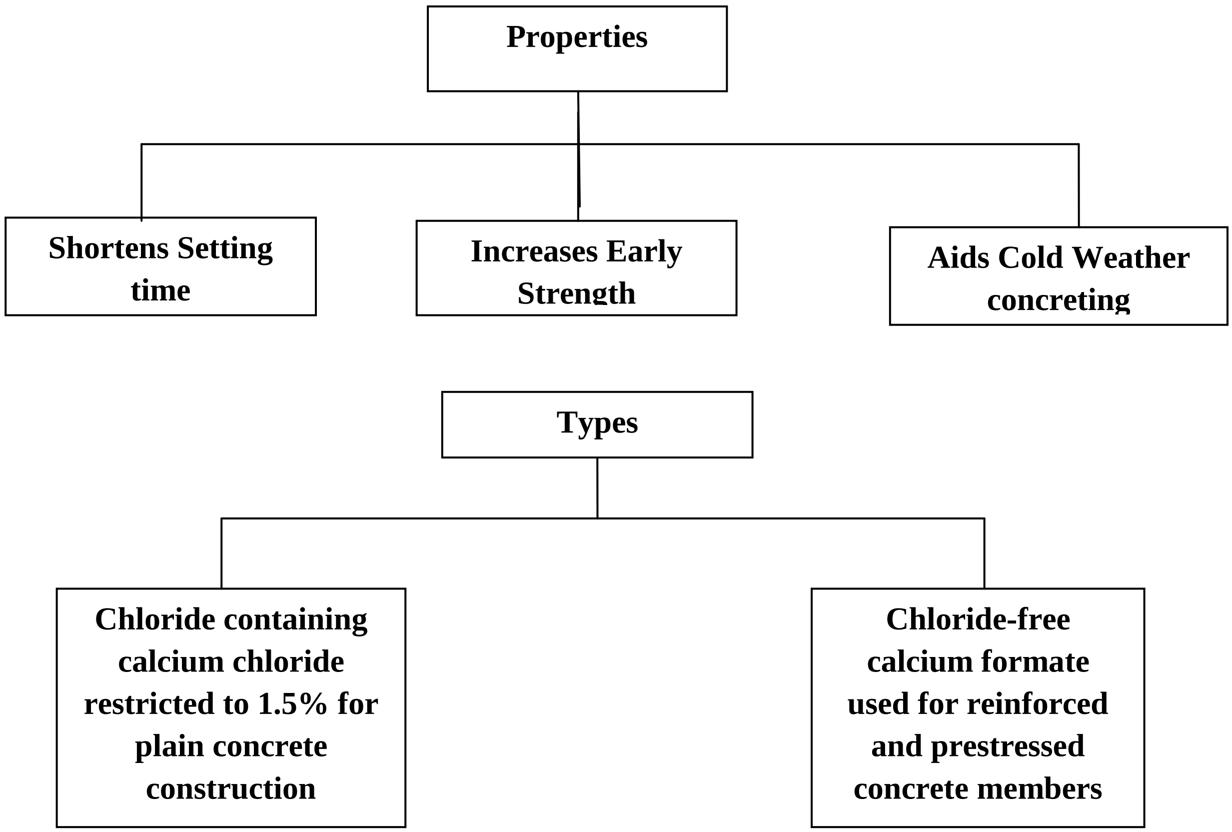

Fig. 3.1 Accelerating Admixture

3.3.2 Retarders

Retarders increase the setting time of the concrete mix and reduce the water-cement ratio. Usually up to 10% water reduction can be achieved. A wide range of water-reducing and set retarding admixture s are used in ready mixed concrete. Usually, these chemicals are derived from lignosulphonic acids and their salts, hydroxylated carboxylic acid and their salts and sulphonated melamine or naphthalene formaldehyde.

They have a detergent like property. They work on the principle that water-reducing agent migrate to the surface of water as shown in fig. this increases the surfaces activity and hence imparts a soapy property to the mix and delays setting.

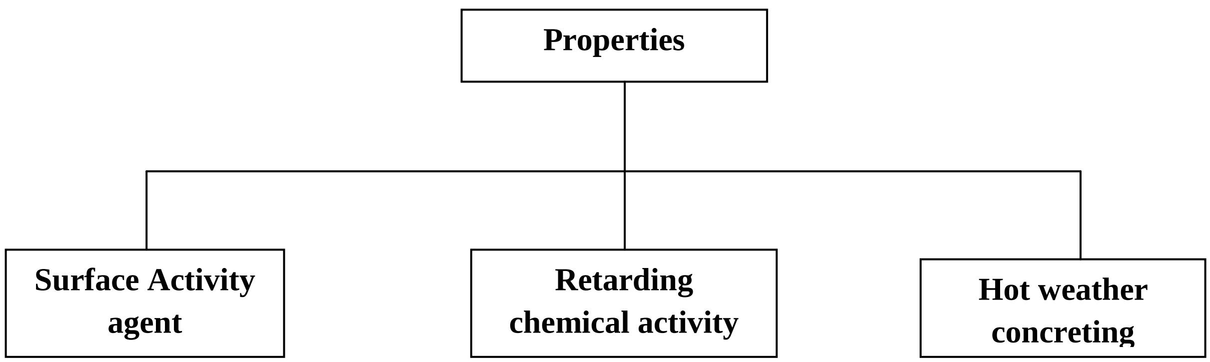

Fig.3.2 Retarders

3.3.3 Plasticizers

A plasticizers is defined as an admixture added to wet concrete mix to impart adequate workability properties. As shown in fig. plasticizers can be of the following three types.

1. finely divided minerals
2. air-entraining agents
3. Synthetic derivatives

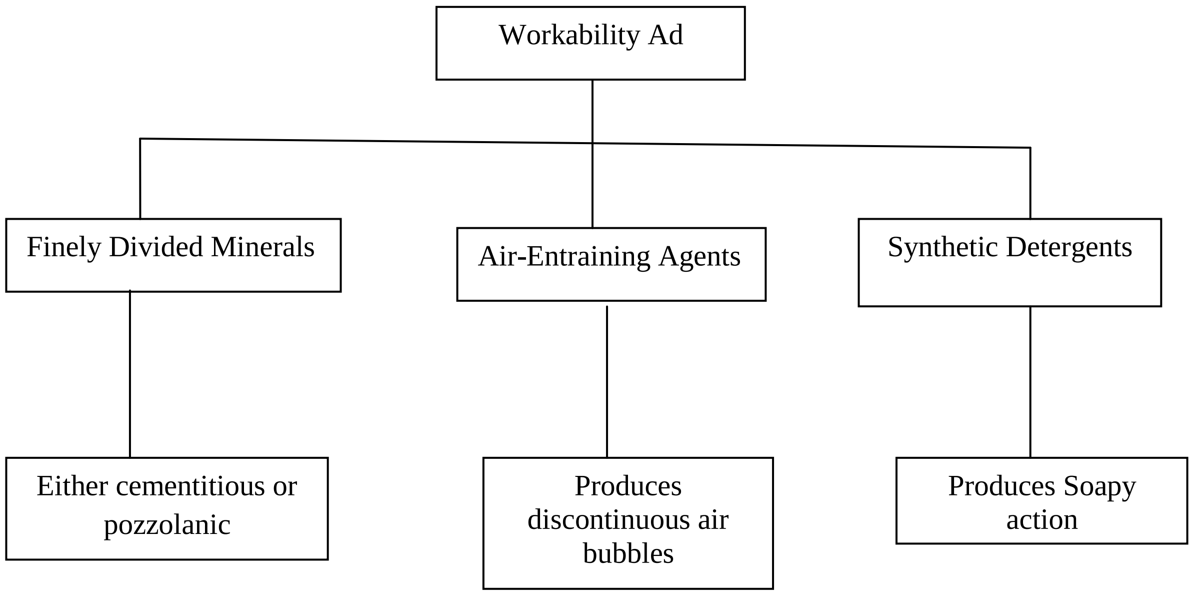

Fig.3.3 Types of Plasticizers

3.3.3.1 Finely divided minerals

They are either cementitious or pozzolanic. Natural cements, hydraulic lime and slag cement belong to the former category, whereas fly ash and heat-treated clays belong to the latter. They are used as workability aids. They help in reducing bleeding by way of adding finer particiles to the mix.

3.3.3.2 Air-entraining agents

These help in protecting concrete subjected to repeated freeze thaw cycles. Concrete with entrained air has higher workability and cohesiveness. Segregation and bleeding are reduced by using air-entraining agents. These agents are generally used to ensure durability against frost.

Air-entraining agents are derived from synthetic detergents, salts of sulphonated lignin, fatty acids, organic salts of sulphonated hydrocarbons or salts of wood resins.

These agents create millions of tiny air bubbles which relieve the expansion pressure. They result inn 9% increase in the volume of water, and osmotic pressure develops as water diffuses from gel pores into the capillaries.

The stability of the air voids between the cement gel and aggregate is also shown in the figure. Some air-entraining agents react and produce adverse effects when used along with accelerating ot set-retarding admixtures.

3.3.3.3 Synthetic Derivatives

Synthetic derivatives introduce soapy into the mix. These are surface-active agents and are primarily added to increase workability. The best example of a synthetic derivative is benezene sulphonate. Chemically they comprise the same chemicals as found in retarders and hence they also generally retard the setting time.

These derivates may react differently with different types of cement. Hence, a careful study of the type of cement is required before choosing a particular synthetic derivative.

3.3.3.4 Superplasticizers

Superplasticizers produce extreme workability and thus flowing concrete. They achieve reduction in the water content without loss of workability. Their use generally leads to an overall reduction in the cost.

Superplasticizers molecules and cement grains are oppositely charged and hence repel each other. This increases the mobility and hence makes the concrete flow. Superplasticizers enables savings in cement for a given strength and are ideal for pumping concrete, casting heavily reinforced concrete members, and the precast elements of concrete.

3.4 Special Cements for accelerated Strength Gain

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

Formerly high doses of 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 aluminate cement. Because of problems associated with the conversion, under hot humid conditions, of the calcium aluminate hydrates from one form 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 fluoro-aluminate. The cement meal contains a substantial amount of fluorite as a substitute for limestone. The burning process has a problem due to the release of small amounts 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 to 45 minutes.

The strength level is adjusted by controlling the amount of calcium fluoro aluminate in the cement. The time of set is reduced and the compressive strength gain increased in regulated cement mortars and concrete by an increase in the cement content of the mix, reduction of the water/cement ratio, increases 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 is also advantageous, as the heat of hydration is considerably higher than that of Portland cement concrete.

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 aluminium –phosphate cements, which when used for concrete patching for pavements allow traffic flow after only 45 minutes.

3.5 Expansion cement

Concrete made with ordinary Portland cement shrinks while setting due to loss of free water. Concrete also shrinks continuously for long time. This is known as drying shrinkage. Cement used for grouting anchor bolts or grouting machine foundations or the cement used in grouting the prestress concrete ducts, if shrinks, the purpose for which the grout is used will be some extent defeated. There has been a search for such type of cement which will not shrink while hardening and thereafter. As a matter of fact, a slight expansion with time will prove to be advantageous for grouting purpose.

This type of cement which suffers no overall change in volume on drying is known as expansion cement. Cement of this type has been developed by using an expanding agent and a stabilizer very carefully. Proper material and controlled proportioning are necessary in order to obtain the desired expansion.

Generally, about 8-20 parts of the sulphoaluminate clinker are mixed with 100 parts of the Portland cement and 15 parts of the stabilizer. Since expansion takes place only so long as concrete is moist, curing must be carefully controlled. The use of expanding cement requires skill and experience.

One type of expansive cement is known as shrinkage compensating cement. This cement when used in concrete, with restrained expansion, induces compressive stresses which approximately offset the tensile stress induced by shrinkage. Another similar type of cement is known as self stressing cement. This cement when used in concrete induces significant compressive stresses after the drying shrinkage has occurred. The induced compressive stresses not only compensate the shrinkage but also give some sort of prestressing effects in the tensile zone of the flexural member.

3.6 Polymer Concrete:

Polymer concrete is an aggregate bound with a polymer binder instead of Portland cement as in conventional concrete.

The main technique in producing PC is to minimize void volume in the aggregate mass so as to reach the quantity of polymer needed for binding the aggregates. This is achieved by properly grading and mixing the aggregates to attain the maximum density and minimum void volume. The graded aggregates are prepacked and vibrated in a mould. Monomer is then diffused up through the aggregates and polymerization is initiated by radiation or chemical means. A silane coupling agent is added to the monomer to improve the bond strength between the polymer and the aggregate. In case polyester resins are used no polymerization is required.

An important reason for the development of this material is the advantage it offers over conventional concrete where the alkaline Portland cement on curing, forms internal voids. Water can be entrapped in these voids which on freezing can readily crack the concrete. Also the alkaline Portland cement is easily attacked by chemically aggressive materials which results in rapid deterioration, whereas polymers can be made compact with minimum voids and are hydrophobic and resistant to chemical attack. The strength obtained with PC can be as high as 140 MPa with a short curing method.

However, such polymer concretes tend to be brittle and it is reported that dispersion of fibre reinforcement would improve the toughness and tensile strength of the material. The use of fibrous polyester concrete in the compressive region of reinforced concrete beams provides a high strength, ductile concrete at reasonable cost. Also polyester concretes are viscoelastic in nature and will fail under sustained compressive loading at stress levels greater than 50% of the ultimate strength. Therefore, polyester concrete should be considered for structures with a high ratio of live load to dead load and for composite structures in which the polymer concrete may relax during long-term loading. Experiments conducted on FPC composite beams have indicated that they are performance effective when compared to reinforced concrete beam of equal steel reinforcement percentage. Such beams utilize steel in the region of high tensile stress, fibrous polyester concrete (FPC) with its favorable compressive behavior, in the regions of high compressive stress and Portland cement concrete in the regions of relatively low flexural stress.

Advantages

Advantages of polymer concrete include:

- Rapid curing at ambient temperatures
- High tensile flexural, and compressive strengths
- Good adhesion to most surfaces
- Good long-term durability with respect to freeze and thaw cycles
- Low permeability to water and aggressive solutions
- Good chemical resistance
- Good resistance against corrosion
- Lightweight
- May be used in regular wood and steel formwork
- May be vibrated to fill voids in forms
- Allows use of regular form-release agents
- Dialectric

Disadvantages

Some safety issues arise out of the use of polymer concrete. The monomers can be volatile, combustible, and toxic. Initiators, which are used as catalysts, are combustible and harmful to human skin. The promoters and accelerators are also dangerous. Polymer concretes also cost significantly more than conventional concrete.

3.7 Sulphur-Infiltrated concrete

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

In the past, some attempts have been made to use sulphur as a building material instead of cement. Sulphur is heated to bring it into molten condition to which coarse and fine aggregates are pored 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 day’s time.

The following **procedure** has been reported in making sulphur-Infiltrated concrete.

The concrete to be infiltrated should be produced using normal aggregate with aggregate-cement ratios between 3:1 to 5:1 and having water-cement ratio preferably in the range 0.60 to 0.80. The infiltration procedure normally used consists of moist-curing of concrete elements for 24 hours at about 23^0C followed by drying (at 121^0C) for a period of 24 hours, immersing dried element in molten sulphur at 121^0C under vacuum for two hours, releasing the vacuum and soaking for an additional half an hour, and then removing the elements from molten sulphur to cool. In case of low water-cement ratio, concretes which are relatively dense external pressure may be applied following the release of vacuum to force sulphur into concrete. The foregoing procedure may be modified to suit individual job conditions. However, the following points should be kept in mind.

(i) For concretes with a water-cement ratio of the order of 0.65, the one-day-old elements must be handled with care to avoid damage.

(ii) the drying temperature should be kept as high as possible but not exceeding 150^0C since a higher temperature may damage the gel-structure of the young hydrated cement paste. The period of drying will depend on the type and size of element.

(iii) The period of vacuum, (evacuation time) appears to be less critical than the immersion time in molten sulphur after evacuation. For concrete with water-cement ratio of about 0.55, increased immersion time is essential to achieve full infiltration.

Durability:

Generally, the performance of sulphur-Infiltrated concrete is satisfactory against freezing and thawing, seawater attack and wetting and drying. The sulphur-Infiltrated concrete is more durable than conventional concrete in higher concentrations of H_2So_4 and HCl. When left submerged in stagnant water over extended periods of time, slight leaching of sulphur may take place and concrete may eventually show undesirable expansion followed by some cracking. The instability of SIC in aqueous media is apparently related to the presence of polysulphide anions formed during infiltration and found to be highly soluble in alkaline pore solutions of wet concrete. The polysulphide and calcium ions (dissolved from concrete) form concentrated calcium polusulphide, a yellow orange leachate. Under moist aerated conditions, it reacts with oxygen to form sulphur efflorescence.

The strength properties of SIC are not significantly affected when it is exposed to short-term temperature up to 100^0C. at this temperature SIC exhibits certain amount of ductile behavior before failure.

The magnitude of increase in abrasion resistance of SIC depends on the sulphur loading of the test specimens. However, the sulphur filling of the pores in concrete provides an uninterrupted path for heat flow resulting in increased values of thermal conductivity over that of normal dry concrete.

The sulphur-Infiltrated concrete provides a corrosive protection to embedded steel. The sulphur loading required for a given corrosion protection depends upon water-cement ratio used in concrete. Higher the water-cement ratio, higher the sulphur loading required. The minimum sulphur loading varies from 10% for 0.70 water-cement ratio to 5% for 0.40 water-cement ratio.

Applications:

The sulphur-Infiltrateed concrete is ideally suited for precast units such as

- Patio slabs
- Sidewalks
- Kerbs and
- Sewer pipes

3. FerroCement

Ferrocement is a type of thin reinforced concrete, constructed of cement mortar reinforced with closely spaced layers of continuous and small diameter wire mesh.

It is well known that conventional reinforced concrete members are too heavy, brittle, which cannot be satisfactorily repaired if damaged, develop cracks and reinforcements are liable to be corroded. These disadvantages of normal concrete make it inefficient for certain types of work.

Ferrocement is a relatively new material consisting of wire meshes and cement mortar. 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 or 1:3 with water/cement ratio of 0.4 to 0.45. The ferrocement elements are usually of order of 2 to 3 cm in thickness with 2 to 5mm external cover to the reinforcement. The steel content varies between 300 kg to 500 kg per cubic metre of mortar. The basic idea behind this material is that concrete can undergo large strains in the neighbourhood of the reinforcement and the magnitude of stains depends on the distribution and subdivision of reinforcement throughout of the mass of concrete.

The main advantages are simplicity of its construction, lesser dead weight of the elements due to their small thickness, its high tensile strength, less crack widths compared to conventional concrete, easy repairability, noncorrosive nature and easier mouldability to any required shape. This material is more suitable to special structures like shells which have strength through forms and structures like roofs, silos, water tanks and pipelines.

Reinforcement

Skeletal reinforcement with closely spaced wires is the most commonly used reinforcement in ferrocement. In the ferrocement a wire mesh is required to control the cracking and skeleton steel to support the wire mesh. Use of fine meshes with thin wires at closer spacings for effective crack control.

3.11.1 Types of Wire mesh reinforcement used in Ferrocement:

1) Hexagonal wire mesh
2) Square mesh
3) Three dimensional mesh

3.11.1.1 Hexagonal Wire Mesh:

Meshes with hexagonal openings are called chicken wire mesh. Diameter of wires varies Between 0.5mm to 10mm, the grid size varies between 10mm to 25mm these meshes are more flexible and easier to work with it, which means we can make it easily into desired shape.

3.11.1.2 Square Mesh:

Square mesh is made out of straight wires in both the longitudinal and transverse directions. Thus welded-mesh thickness is equal to two wire diameters. Welded meshes are weak at welded spots. Diameter varies between 1mm to 1.5mm. Grid size varies between 15 to 25mm.

3.11.1.3 Three Dimensional Mesh:

A three dimensional mesh is also available. A crimpled keeper wire frictionally locks together three alternating layers of straight wire. The mesh is sufficiently thick so that in some applications, only one layer is required.

3.11.2 Types of mortar for ferrocement:

1. Ordinary Cement Mortar
2. High Performance Mortar
3. Lightweight Aggregate Mortar
4. Fiber Reinforced Mortar
5. Polymer Mortar

3.11.2.1 Ordinary Cement Mortar:

Portland cement is used to make ordinarily cement mortar. The filter material is usually a well-graded sand capable of passing 2.36mm sieve. However depending upon the characteristics of the reinforcing material mortar may contain some small-size gravel.

The mix proportion ranges of the mortar for ferrocement are sand-cement ratio by weight, 1.4 to 2.5, water-cement ratio by weight, 0.3 to 0.5.

3.11.2.2 High Performance Mortar:

This mortar is similar to conventional cement mortar but it contains mineral admixture to produce impermeable matrix. This enhances the durability of ferrocement by providing greater protection to the steel reinforcement. By proper selection of chemical and mineral activities and W/C ratio, FC mortar can reduce pore size considerably and thereby achieving very high strength levels, which are not possible conventionally.

It having comprehensive strengths in the range of 50 to 100Mpa.

3.11.2.3 Light Weight Aggregate Mortar:

It is used to construct low-cost housing, Lightweight aggregate reduces the density of the mortar. It helps in reduction of dead load, Lightweight aggregate are introduced replacing the sand in the mortar, Lightweight aggregates reduce the thermal conductivity.

3.11.2.4 Fiber Reinforcement Mortar Composites

Fiber reinforcement mortar composites are produced by introducing small diameter discontinuous fibers during mixing of mortar matrices, Fibers which have been produced from steel, carbon, glass, nylon etc in various shapes & sizes thy posses high modulus of elasticity and lead to strong and stiff composites.

In ferrocement applications very short length of 2mm to 12mm were used to increase their properties. The short fibers was used in the composite, with the objective of improving the crack resistance of the matrix. Short fibers can control micro cracking before the actual mortar cracks. The long fibers were used to improve the post cracking behavior of the composites.

The length of these fibers allows them to bridge the cracks. The fibers can then transmit the loads from the cracked matrix to uncracked matrix, which results in more ductility of composite.

3.11.2.5 Polymer Mortar:

To overcome the disadvantage of cement mortars and concretes, such as delayed hardening, low tensile strength, high drying shrinkage and low chemical resistance, polymer cement or polymer modified cement mortars are being used for man industrial application in the form of protective coating for concrete.

Polymer modified mortar is obtained by the addition of polymer material to cement mortar during resulting in a polymer modified mortar. The polymer fills of the capillary pores makes the concrete impermeable.

Applications

- Boats Construction
- Sun Screens
- Cylindrical shell roof
- Folded plate roof
- Water tank

3.12 Fibre Reinforced Concrete

FRC can be defined as a composites material, consisting of mixtures of cement mortar or concrete and discontinuous, discrete uniformly dispersed suitable fibres.

Fibre is a small piece of reinforcing material that can be circular or flat.

Properties of FRC:

- It have more tensile strength.

- Fibres improve the impact and abrasion resistance of concrete.
- It posses high compressive strength.
- It posses low thermal and electrical conductivity.

Aspect ratio

The fibre is often described by a convenient parameter called “aspect ratio”. The aspect ratio of the fibre is the ratio of its length to its diameter. Typical aspect ratio ranges from 30 to 150.

Types of Fibres:

1. Steel Fibres
2. Glass Fibres
3. Polypropylene Fibres
4. Slurry Infiltrated Fibre Concrete (SIFCON)
5. Asbestos
6. Carbon

1. Steel Fibres

Steel fibre is one of the most commonly used fibre. Generally round fibres are used. The diameter may vary from 0.25 to 0.75mm. The steel fibre is likely to get rusted and lose some of its strength. But investigations have shown that the rusting of the fibres take place only at the surface. Use of steel fibre makes significant improvements in flexural, impact and fatigue strength of concrete. It has very high tensile strength of 1700N/mm^2. Steel fibres are incorporated in the shotcrete to improve its crack resistance, ductility and energy absorption and impact resistance characteristics.

Applications

- Industrial Flooring
- Warehouses
- Overlays
- Tunneling

2. Glass Fibre

Glass fibre is a recent introduction in making fibre concrete. It has very high tensile strength of 1020 to 4080 N/mm^2 glass fibre which is originally used in conjunction with cement was found to be affected by alkaline condition of cement. Therefore, alkaline resistant glass fibre by trade name “CEM-FIL” has been developed and used.

- AR glass fibres have a density that is similar to that of concrete.
- It gives better bond between the concrete matrix and the reinforcement.
- It prevents crack.

The fibres also have elastic modulus which is significantly higher than concrete. This enables the fibres to provide an effective reinforcement during the hardened stage of concrete.

Application

- Noise Barriers
- Water ducts and channels
- Tunnel lining
- Railways.

3. Polypropylene fibre:

They are having good resistance against shrinkage and temperature cracks. It is having low modulus. They have longer elongation under a given load, which means they can absorb more energy without fracture.

The low modulus fibres can be combined with steel fibres which is the latest trend what we call hybrid technology. Its applicable for structure exposed to atmosphere. These fibres can take care of the drying shrinkage where as steel cannot perform in wet condition.

Applications:

Area of application: Polypropylene fibres can be used for slabs on grade, airport, highways, pavement, parking areas, bridge deck overlays, sewer pipes, precast concrete products.

4. Slurry infiltrated fibre Concrete (SIFCON)

SIFCON is a high-strength, high performance concrete. It contains high volume percentage of steel fibres. It is also called as high-volume fibrous concrete. The volume of steel varies from 4 to 20 percent. SIFCON has no coarse aggregates. It contains fine sand and additives such as fly ash, micro-silica and latex emulsions. Proportions of cement and sand generally used for making SIFCON are 1:1, 1:1.5, or 1:2. Cement slurry alone can also be used for some application. Generally, fly ash or silica fume equal to 10% to 15% by weight of cement is used in the mix. The water cement ratio varies between 0.3 to 0.4.

Applications:

Proportions like ductility, crack resistance and penetration and impact resistance are very high for SIFCON when compared to other materials, it is best suited for application in the following areas.

- Overlays, bridge decks
- Seismic resistance structures
- Precast concrete products
- Military applications such anti-missile hangers, under-ground shelters
- Aerospace launching platforms
- Repair, rehabilitation and strengthening of structures
- Concrete mega-structures such as offshore and long-span structures, solar towers etc.

5. Compact Reinforces Concrete (CRC)

CRC is a mixer of cementitious content and fine steel fibres and further reinforced with a high concentration of continuous and uniformly placed larger steel bars. CRC has structural similarities with reinforces concrete, but is much more heavily reinforced and exhibits mechanical behavior more like that of structural steel, having almost the same strength and extremely high ductility.

Applications:

It is best suited for the applications in the following areas:

- Load carrying parts in large machines.
- Special high-performance joints in conventional steel.

6. Asbestos

Asbestos is mineral fibre and has proved to be most successful of all fibres as it can be mixed with Portland cement. Tensile strength of asbestos varies between 560 to 980N/mm^2. The composite product called asbestos cement has considerably higher flexural strength than the Portland cement paste. For unimportant fibre concrete, organic fibres like coir, jute, cane splits are also used.

Applications

- Sheet pipe, boards, sewer pipes, wall lining etc.

7. Carbon:

Carbon fibres perhaps posses very high tensile strength 2110 to 2815 N/mm^2 and young's modulus. It has been reported that cement composite made with carbon fibre as reinforcement will have very high modulus of elasticity and flexural strength. Carbon fibres concrete are used to construct structures like cladding, panels and shells.

UNIT IV

TECHNIQUES FOR REPAIR AND DEMOLOTION

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 coatings and cathodic protection. Engineereddemolition techniques for dilapidated structures – case studies.

4.1 Rust Eliminators

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

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

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

4.2 Polymer Resin based Coating

These are generally of two types,

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

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

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

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

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

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

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

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

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

4.3. Formed Concrete

If a sufficiently portion of concrete is removed, it can best be replaced with concrete placed in forms. This concrete can be placed without a bonding agent and without grout on the prepared surface of the old concrete. US bureau of reclamation suggests that this method should be used

(i) When the depth of the repair exceeds 150 mm,

(ii) For holes extending right though the concrete section

(iii) For holes in unreinforced concrete with area greater than $0.1m^2$ and over 100 mm deep, and

(iv)For holes in reinforced concrete which have an area greater than $0.05m^2$ and which extend deeper than the reinforcement.

There are some essential requirements that apply to the use of formed concrete as a replacement material, regardless of its location in the structure.

(i) The concrete should be made from the best possible materials and with the lowest possible water/cement ratio.

(ii)To keep shrinkage to a minimum, the aggregate size should be large as can be accommodated and the water content as low as possible.

(iii)The mix should be designed so that no bleeding occurs in order to ensure that the replacement material remains in intimate contact with old concrete located above it.

(iv)The hole to be filled must be shaped so that there are no feather edges and with a depth normal to the finished seurface of atleast 40mm. It must also be shaped so that sir is not trapped.

(v)Forms must be robust and firmly fixed so that they withstand any applied pressure and do not allow grout leakage.

(vi)Old concrete, against which new concrete is to be placed, must be sound, completely clean and saturated and the surface must be free from moisture.

4.4. Mortar and Dry Pack

Dry packing is the hand placement if a low W/C ratio mortar which is subsequently rammed in to place to produce a dense mortar plug having tight contact to the existing concrete.

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

4.5. Vacuum Concrete:

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

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

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

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

4.6. 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.

- 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.
- 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.
- 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.
- The reduction in the water/cement ratio is very slightly less with mixes leaner than 6 to1, but little advantage is gained with mixes richer than this.
- The greater the depth of concrete processed the smaller is the depression of the average water/cement ratio.
- The ability of the concrete to stand up immediately after processing is improved if a fair amount of fine material is present, if the maximum aggregate size is restricted to 19mm and if a continuous grading is employed.
- Little advantage is gained y prolonging the period of treatment beyond 15 to 20 minutes and a period of 30 minutes is the maximum that should be used.

4.7. The Gunite or Concrete

Gunite can be defined as mortar conveyed through a hose and pneumatically projected at a high velocity onto a surface. Recently this method has been further developed by the introduction of small sized coarse aggregate into the mix deposited to obtain considerably greater thickness in one operation and to make the process economical by reducing the cement content. Normally fresh material with zero slump can support itself without sagging or peeling off. The force of the jet impacting on the surface 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 between guniting and shotcreting. Gunite was first used in the early 1900 and this process is mostly used for pneumatical application of mortar of less thickness, whereas shotcrete is a recent development on the similar principle of guniting for achieving greater thickness with small coarse aggregates.

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

4.7.1 Dry-mix Process

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

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

4.7.2 Wet-mix process

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

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

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

General use of Shotcrete

1. It is useful where considerable savings and peculiar adaptability is needed and it is more suitable than conventional placing methods.

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

Epoxy Injection:

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

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

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

i. **Preparation of the surface**: The contaminated cracks are cleaned by removing all oil, grease, dirt and fine particles of concrete which prevent the epoxy penetration and bonding. The contaminants should preferably be removed by flushing the surface with water or a solvent. The solvent is then blown out using compressed air, or by air drying.

   The surface cracks should be sealed to keep the epoxy from leaking out before it has cured or gelled. A surface can be sealed by brushing an epoxy along, the surface of cracks and allowing it to harden. If extremely high injection pressures are needed, the crack should be routed to a depth of about 12mm and width of about 20mm in V-shape, filled with an epoxy, and stuck off flush with the surface.

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

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

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

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

4.8. Corrosion Mechanism

Corrosion of steel reinforcement occurs by a electrochemical process which involves exchanges of electrons similar to that which occurs in a battery. The important part of the mechanism is the separation of negatively charged areas of metal or ‘anodes’ where corrosion occurs and positively charged areas or ‘cathodes’ where a harmless charge balancing reaction occurs.

At the anode the iron dissolves and then reacts to form the solid corrosion product, rust. The rust is formed at the metal/oxide interface, forcing previously formed oxide away from the steel and compressing the concrete, causing it to spall.

So in other words for corrosion to occur four basic elements are required:

- Anode – Site where corrosion occurs and current flows from
- Cathode – Site where no corrosion occurs and current flows to.
- Electrolyte – A medium capable of conducting electric current by ionic current flow(i.e Soil, Water or Concrete)

- Metallic path – connection between the anode and cathode, which allows current return and completes the circuit.

Reinforcing steel in concrete normally does not corrode because of the formation of a passive oxide film on the surface of the steel due to the initial corrosion reaction.

The process of hydration of cement in freshly placed concrete develops a high alkalinity, which in the presence of oxygen stabilizes the film on the surface of embedded steel, ensuring continued protection while the alkalinity is retained.

Normally, concrete exhibits a pH above 12 because of the presence of calcium hydroxide, potassium hydroxide – the term pH is a measure of the alkalinity or acidity, ranging from highly alkaline at 14 to highly acidic at zero, with neutrality at 7. Although the precise nature of this passive film is unknown, it isolates the steel from the environment and slows further corrosion as long as the film is intact. However, there are two major situations in which corrosion of reinforcing steel can occur.

These include:

1. Carbonation,
2. Chloride contamination

4.8.1. Deterioration through Carbonation

Carbonation is a process In which carbon dioxide from the atmosphere diffuses through the porous concrete and neutralizes the alkalinity of concrete.

$Ca(OH)_2 + CO_2 \rightarrow CaCo3 + H_2O$

Carbon dioxide, which is present in air in proportions of around 0.3 percent by volume, dissolves In water to form a mildly acidic solution. Unlike other acids that may chemically attack and etch the surface of the concrete, this acid forms within the pores of the concrete itself where the carbon dioxide dissolves in any moisture present. Here it reacts with the alkaline calcium hydroxide forming insoluble calcium carbonate.

The pH value then drops from 12.5 to about 8.5. The carbonation process moves as a front through the concrete, with a pH drop across the front. When it reaches the reinforcing steel, the passive layer decays when the pH value drops below 10.5. The steel is then exposed to moisture and oxygen and is susceptible to corrosion.

Concrete inside the building frequently carbonates totally without any sign of deterioration as the concrete dries out, leaving the steel exposed to air but not moisture. Problems are seen externally where concrete is exposed to the elements and in certain situations internally, such as kitchens and bathrooms, where the concrete is susceptible to condensation or water-leakage.

4.8.2 Deterioration due to Chloride

Salt causes corrosion by a different mechanism. When salt is dissolved in water sodium chloride forms a versatile, highly corrosive solution of sodium ions(Na+) and chloride ions(Cl-).

Salt is used for de-icing roads and its presence in sea water is a major problem for reinforced concrete structures. The very mobile chloride ions disperse through concrete pores in solution and where they come into contact with the reinforcing steel they attack the passive layer. Steel oxidizes in the presence of air and water to form rust which has a volume of up to 10 times that of the steel consumed.

As concrete has a low tensile strength it will crack when as little as a tenth of a millimeter of steel has been consumed. Horizontal cracks from, causing corners to 'SPALL' and surfaces to 'delaminate' as the reinforcement's concrete cover becomes detached and falls away in sheets.

The consequence can be seen on the underside of road bridges and many buildings and structures beside the sea.

ACI recommends the following chloride limits in concrete for new construction, expressed as a percent by weight of cement:

- Pre-stressed concrete 0.08%
- Reinforced concrete in wet conditions 0.10%
- Reinforced concrete in dry conditions 0.20%
- But in existing structures 0.026% is enough to breakdown the Passive Layer.

4.8.3 Factors Influencing corrosion of Reinforcement

Various factors initiate and sustain the process of corrosion in R.C. structures. They are broadly divided into two groups:

- General Influencing factors
- General accelerating factors

4.8.3.1 General Influencing factors

The following are the factors that generally influence corrosion of reinforcement in R.C. structures.

- pH Value
- Moisture
- Oxygen
- Carbonation
- Chlorides
- Ambient temperature
- Severity of exposure
- Quality of concrete
- Cover to the reinforcement
- Initial curing condition
- Formation of cracks

4.8.4 General Accelerating factors

The following are the factors which accelerates the process of corrosion in R.C. structures

- Chlorides
- Sulphates
- Chlorine
- Electrical Charges
- Methane Acids

4.8.4.1 Methods of Corrosion Protection

The following are some of the methods for protecting steel from corrosion

- Protective coatings for reinforcement
- Cathodic protection
- Corrosion Resistant steel
- Corrosion inhibitors

4.8.5. Protective coatings for reinforcement

This is an effective means to combat corrosion in such environment where ordinary concrete with surface coating is not able to protect reinforcement against corrosion. The surface coating for the reinforcement will increase the protection against corrosion.

There are several methods of providing protective coating to the reinforcement. The important ones are:

i. Cement Slurry Coating

- Cement Slurry Coating provides short-term protection until placement in concrete.
- Several methods have been developed for an effective corrosion protection using cement slurry.
- One such coating is a mixture of cement, condensed silica and polymer dispersion.
- This mixer found to be impermeable to water, chlorides and carbon-di-oxide.

ii. Epoxy Coating

- Epoxy coating is formed by application of an epoxy resin with appropriate curing agents catalysts, pigments and flow control agents.
- Fusion bonding using the electrostatic process is the recent development.
- Fusion bonded epoxy coating provides long-term protection against corrosion.
- Though the cost is relatively high, it is the one which is the most effective in high alkaline and chloride contaminated environment.

iii. Plastic Coating

- Similar to epoxy coating, the plastic coatings are very effective in preventing corrosion of reinforcement even in high alkaline or chloride contaminated environment.
- However, the reduction in bond between plastic coated bar and the concrete is quite substantial and hence plastic coating cannot be considered as a solution for prevention of corrosion which cannot be solved by conventional methods.

iv. Galvanizing

- Galvanizing gives protection to the reinforcement against corrosion, by means of metallic coating such as zinc.

- However, in case of corrosion due to excessive chlorides, the effect of galvanizing protection is reduce and hence is not advisable in highly chloride contaminated environments.

Cathodic protection

- Cathodic protection interferes with the natural action of the electrochemical cells that are responsible for corrosion.
- Cathodic protection can be effectively applied to control corrosion of surfaces that are immersed in water or exposed to soil.
- Cathodic protection in its classical form cannot be used to protect surfaces exposed to the atmosphere.
- The use of anodic metallic coatings such as zinc on steel(galvanizing) is, however, a form of cathodic protection, which is effective in the atmosphere.
- There are two basic methods of supplying the electrical currents required to interfere with the electrochemical cell action. They are

1. Cathodic protection with galvanic anodes.
2. Impressed current cathodic protection

4.8.5.1 Cathodic protection with galvanic anodes

- **Cathodic protection (CP)** is a technique to control the corrosion of a metal surface by making it work as a cathode of an electrochemical cell. This is achieved by placing in contact with the metal to be protected another more easily corroded metal to act as the anode of the electrochemical cell.
- This method is also called sacrificial anode cathodic protection system, where the active metal is consumed in the process of protecting the surfaces, so that corrosion is controlled.

- In sacrificial anode systems the high energy electrons required for cathodic protection are supplied by the corrosion of an active metal.

- Sacrificial anode systems depend on the differences in corrosion potential that are established by the corrosion reactions that occur on different metals or alloys.

For example, the natural corrosion potential of iron is about -0.550 volts in seawater. The natural corrosion potential of zinc in seawater is about -1.2 volts. Thus if the two metals are electrically connected, the corrosion of the zinc becomes a source of negative charge which prevents corrosion of the iron.

In application where the anodes are buried, a special backfill material surrounds the anode in order to insure that the anode will produce the despired output. Sacrificial anodes are normally supplied with either lead wires or cast-m straps to facilitate their connection to the structure being protected.

The lead wires may be attached to the structures by welding or mechanical connections. These should have a low resistance and should be insulated to prevent increased resistance or damage due to corrosion. When anodes with cast-in straps are used, the straps can either be welded directly to the structure or the straps can be used as locations for attachment.

A low resistance mechanically adequate attachment is required for good protection and resistance to mechanical damage. In the process of providing electrons for the cathodic protection of a less active metal the more active metal corrodes. The more active metal (anode) is sacrificed to protect the less active metal(cathode). The amount of corrosion depends on the metal being used as an anode but it is directly proportional to the amount of current supplied.

The anodes in sacrificial anode cathodic protection systems must be periodically inspected and replaced when consumed.

4.8.6. Impressed current Cathodic protection

In impressed current cathodic protection, an alternative source of direct electrical current, usually a rectifier that converts alternating current to direct current is used to provide the required electrical current. In this system, the electrical circuit is completed through an inert anode material that is not consumed in the process.

As shown in Figure low energy electrons that are picked up at a non-reactive anode bed are given additional energy by the action of a rectifier to be more energetic than the electrons that would be produced in the corrosion reaction.

The energy for the "electron energy pump" action of the rectifier is provided by ordinary alternating current. The effect of these electrons at the structure being protected is the same as that derived from the sacrificial anode type of cathodic protection system. However, the anode materials (such as magnetic, platinum, and newly developed ceramic materials) have been successfully used.

For buried anodes, a backfill of carbonaceous material is used to surround the anode to decrease the electrical resistance of the anode, to provide a uniform, low resistivity environment surrounding the anode and to allow gasses produced at the anode surface to vent. In practice, materials such as graphite are used for impressed current cathodic protection system anodes that are slowly consumed. Anodes in impressed current systems must be inspected and replaced if consumed or otherwise damaged.

4.9 General

4.9.1 Preliminary investigation

Demolition is a highly skilled and dangerous activity in terms of damage to life and property and there are certain basic factors to consider before a contract is placed:

- 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.

4.9.2 Preliminary Considerations

Demolition operations are the subject of strict legal control – there is a substantial body of legislation and a great deal of case law relating to such operations. There may also be some regulations which impose additional restrictions: for example, action against nuisance such as noise and dust.

The BSI Code of Practice for Demolition BS 6187 exerts further influence, in that if the Demolition contractor does not observe the recommendation of the Code, this may well influence a Court's decision as to his liability in any legal proceedings.

4.9.3 General Site Provisions

A. Plant and Equipment: Must only be operated by skilled operators and must be regularly serviced.

B. Protective Clothing: Buildings where chemicals have been stored or where asbestos, lead paint, dust or fumes may be present will require specialized protective clothing, e.g. Respirators, helmets, goggles, footwear, gloves, etc. Projecting nails, pieces of metal, etc. resulting from demolition can cause accidents.

C. Shoring and Underpinning: 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.

D. Working Areas: These will need to be well signposted and clear warnings given that demolition work is in progress. This may include the necessity for some kind of lighting.

E. Debris: Sections of the building must not be overloaded with debris either on suspended floors or against party walls.

F. Weather Conditions: These can affect safety. Strong winds or drifting snow against unsafe walls. Suspended floors etc. which are unpropped may lead to collapse.

G. Flooding: The build-up of water can sometimes be hazardous.

H. Overhead Cables: A crane heights etc. must be checked against the height of any surrounding overhead cables to avoid damage and cutting off supplies etc.

I. Scaffolding and Hoarding: These must be constructed and illuminated to the relevant building regulations.

J. Security: The demolition site and any partially demolished buildings must be properly secured against entry.

K. Dust: Should be kept to a minimum by spraying with water when necessary.

L. Noise: Suppressors and silencers, particularly on compressors etc., should be used to keep noise levels to a minimum.

4.9.4 Supervision of Demolition work

A method statement showing how the demolition work is to be carried out should be prepared and the contractors should appoint a “competent person” to supervise the demolition work.

4.10 Demolition Processes

As an intrinsic part of the construction process, efficient demolition of structures is an important factors deserving careful consideration in the evolution of any redevelopment project.

Modern emphasis is on reduction of construction periods to ensure economic redevelopment, coupled with increasing town centre regenerating calling for careful demolition on constructed and restricted site, have resulted in more consideration being given to demolition as part of the process of construction and redevelopment than was typical in previous times.

4.10.1 Developing 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.

4.10.2 Building Information

Information on buildings in terms of “as built” drawings and structural details may often be unavailable or unreliable, and consequently some investigative site and desk work may be necessary, both to ascertain the way in which the building was originally constructed, and to identify the stresses and strains which exist within it.

In order to plan the most efficient method of demolition, it is important to have a full understanding of the method of construction and the stress patterns imposed upon the building. Failure to do so may result in risks to the safety of both those involved in the demolition and those in close proximity to the site.

4.10.3 Selecting Appropriate Techniques

Majors factors to be considered in selecting an appropriate techniques include:-

- Safety of personnel and public
- Working Methods
- Legislation applicable
- Insurance Cover

4.10.4 Preliminary Aspects Prior to Site Demolition Work

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.

4.10.5 Method statement

- A detailed health and safety method statement, produced before work starts, is essential for safe working. It should include a full risk assessment, identify problems and their solutions, and form a reference for the site supervision.
- The method statement should be easy to understand, agreed by and known to all levels of management and supervision, and should include such matters as:-
- The sequence and method of demolition or dismantling of the building or structure with details of personnel access, working platforms and machinery requirements;
- Details and design of any temporary supporting structures to be used during the demolition process;

- Specific details of any pre-weakening on structures which are to be pulled down or demolished with explosives;
- Arrangements for the protection of personnel and the public and the exclusion of unauthorized persons, with details of areas outside the site boundaries that may occasionally need to be controlled to improve safety during critical aspects of the work;
- Details of the removal or making safe of electrical, gas and other services and drains;
- Details of the temporary services available or required for the contractor's use;
- Details of the methods for detailing with flammable materials and gases which may have been retained or deposited as residue in process machinery, pipework or storage;
- Details of methods to establish the presence of hidden or other substances that may be hazardous to health, the methods to be used for their disposal, and any necessary protective equipment;
- Arrangements for the control of site transport used for the removal of demolition debris.

4.10.6 Demolition Methods

In many circumstances, buildings and structures should be demolished in the reverse order to their erection; although where partial demolition is involved, a more careful evaluation of the nature of the effects of the demolition is necessary.

Normally, the demolition contractor is able to adopt a method of work which:-

- Gradually reduces the height of the building; or
- Arranges the deliberate controlled collapse of the building or structure so that work can be completed at ground level.

4.10.7 Demolition Technique Selection

The choice of demolition technique will depend on the nature of the building or structure and its environment. Risks to the public, operatives involved in the demolition process and adjacent structures and buildings should be considered.

Demolition techniques may be categorized as;-

- Piecemeal demolition, using **hand-held** tools
- **Mechanical method** by
  - Hydraulic crusher with Long Boom arm

- Wrecking Ball
- Pusher Arm
- Wire Rope Pulling
- Clam Shell

- Other Methods like
  - Non Explosive Demolition Agent
  - Explosive Demolition
  - Saw cutting
  - Cutting and Lifting
  - Water jet

4.10.8 Piecemeal Demolition (Demolition by Hand):

- For demolitions of reinforced concrete buildings by hand, tools such as electric, pneumatic breakers, jack hammers etc are commonly being used.
- Oxy-acetylene torch could be used to cut the reinforcements.
- The reinforcements shall remain until all the concrete connecting to or supported by the reinforcement is broken away or when its supports are no longer required.
- Cantilever canopies, balconies and exterior walls are critical elements in building demolition.
- In congested areas, these features could critically impact on the safety of the public.
- Demolition of these features shall be performed with extreme caution.
- If rope or tie wires are used to pull down the structural elements, the pulling wire must be at least 4 times stronger than the anticipated pulling force.
- In addition, workers shall be shielded from the rope or tie wires. The rope or ties wire shall be checked at least twice per day.
- Lifting appliances may be necessary to hold larger structural members during cutting and for lowering severed structural members and other debris.
- Chutes may be used to discharge debris into a vehicle or hopper.
- Foundations would normally be grubbed up by excavation machines.

Demolition Sequence

- Demolition sequence shall be determined according to actual site conditions, restraints, the building layout, the structural layout and its construction.

- In general, the following sequence shall apply:
    a) All cantilevered structures, canopies, verandahs and features attached to the external walls shall first be demolished prior to demolition of main building and its internal structures on each floor;
    b) When demolishing the roof structure, all lift machine rooms and water tanks at high level shall be demolished in “top down” sequence to the main roof level.
    c) Demolition of the floor slabs shall begin at mid span and work towards the supporting beams;
    d) Floor beams shall be demolished in the order as follows:
        1) Cantilevered beams;
        2) Secondary beams; then
        3) Main beams.

    In the case when structural stability of beams is affected, e.g., due to loss of restraints affected beams shall be propped prior to loss of support or restraint;
    e) Non-load bearing walls shall be removed prior to demolition of load bearing walls;
    f) Columns and load bearing walls shall be demolished after removal of beams on top;
    g) If site conditions permit, the first floor slab directly above the ground floor may be demolished by machine sitting on ground level and mounted with demolition accessories.

4.10.9 Mechanical Demolition

- Mechanical demolition generally involves the use of large machinery with attachment to dismantle the building from outside.
- The common mechanical methods include the use of a **Hydraulic crusher with long Boom arm, Wrecking Ball, pusher arm, wire rope, clam shell etc…**
- These methods shall only be applied to isolated buildings on relatively flat ground.
- If it is attached to another structure, the two properties should be separated by the use of hand methods before the main demolition process begins.

- The concerns and good practices of the mechanical demolition generally included the following;
    1) The machine shall be operated on smooth and firm ground;
    2) It shall also have adequate counter-weight to prevent overturning during the operation;
    3) The equipment and accessories such as attachments and rope shall be inspected frequently and shall be repaired or whenever necessary;
    4) The impact of the collapsed structural sections on the floor or ground shall be checked to prevent the potential overloading of the suspended floor, vibration and disturbance to adjacent properties and damage to underground utilities.
    5) The site shall have full time security to prevent unauthorized personnel entering the site. No person shall stay within the working area of the machine and the building while the machine is operating.
    6) Sufficient water spray or other anti-dust precautions shall be provided to minimize air pollution by dust;
    7) The cab of the machine shall be equipped with impact proofed glass and its construction shall be robust enough to protect the operator from flying debris;
    8) A spot person shall be on site full time to provide guidance and assistance to the operator in the demolition process.

Demolition Sequence

- In general, the following sequence shall apply:

a) Prior to demolition of internal floors, all cantilevered slabs and beams, canopies, and verandahs shall first be demolished

b) The structural elements, in general, shall be demolished in the following sequence:
    - Slabs;
    - Secondary beams; then
    - Main beams

c) Mechanical plant shall descend from the floor with temporary access ramp, or be lowered to the next day floor by lifting machinery or by other appropriate means;

d) When a mechanical plant has just descended from the floor above, the slabs and beams, in two consecutive floors may be demolished by the mechanical plant simultaneously. The mechanical plant may work on structural elements on the same floor and breaking up the slabs on the floor above;

e) The wall panel, including beams and columns shall be demolished by gradually breaking down the concrete or by pulling them down in a controlled manner;

A. Hydraulic crusher with Long Boom arm

- The crusher attachment breaks the concrete and the reinforcement by the hydraulic thrust through the long boom arm system.
- The hydraulic crusher can be operated from the ground outside the building.
- This method is also suitable for dangerous buildings, silos and other industrial facilities.
- For environmental reason, it should be used wherever practicable because of its quietness.

Application Criteria

- The operation shall have a minimum clear space of 1/2 the building height as a safety zone for the falling debris;
- The equipment shall be inspected and maintained periodically to make sure the equipment is in good and safe condition.
- The excavator shall operate on firm ground that can support the machine during the crusher operation;
- Except for special applications, each section of the structure shall be demolished in a top down sequence to ensure stability of the structure;
- Debris may be used to build up a platform for the excavator to extend the range of reach. It is important that the debris is densely compacted to support the operation of the excavator. The platform must be flat and the slope must be stable. The height of the build up platform shall be limited to 3 m. The side slope of the temporary platform shall not be steeper than 1:1 (horizontal to vertical) unless the condition allows a steeper slope. The slope of access ramp for the machine shall be in accordance with the manufacturer's recommendation. The width in both directions of the platform shall be at least one and one-half the length of the machine to allow safe maneuver during the demolition operation;
- To minimize the dust impact, the structure shall be pre-soaked with water before demolition. Water shall be continuously sprayed during the crushing operation;

- Debris may fall out of the building during the demolition. The site shall be completely fenced off. There shall be 24-hour guarded security to allow only authorized personnel for site access. During the operation of the crusher there shall be no worker within the machine operating area or inside the building;
- The crusher operator shall possess the essential skills and significant experience in the crusher operation. There shall be a spot person to assist in the operation and alert the operator of any potential problem during the operation.

B. Wrecking Ball:

- The wrecking ball application consists of a crane equipped with a steel ball.
- The destruction of the building is by the impact energy of the steel ball suspended from the crawler crane. The wrecking ball operates outside the building.
- This method is suitable for dilapidated buildings, silos and other industrial facilities.
- However, the operation requires substantial clear space.
- The application also demands high level skill operators and well-maintained equipment.

Application Criteria

The recommended criteria for the use of wrecking ball are presented in the following:

- Except for special application, the balling of each section of the structure shall proceed from top to bottom. Care shall be taken to maintain the stability of the structure;
- Recommended techniques for the wrecking ball operations include:
    1) Vertical Drop – free falling of the wrecking ball onto the structure;
    2) Swing in line – swinging of the ball in-line with the jib.
- A second dragline will normally connect to the ball horizontally to control the ball motion. The ball shall be swung into the building. The ball shall strike at the top of the member so as to avoid the member from falling outside the building.
- Slewing the jib is not recommended. The motion of the ball by slewing the jib is difficult to control. It demands expert knowledge of the machine and structure as well as operating skills to safely perform the task. Slewing can potentially induce a tremendous amount of stress on the jib, as such, its use shall be avoided;

- The jib or boom shall be operated with not less than 3 m above the portion of the structure being demolished;
- Clear space for operation between the crane and the structure being demolished shall be 50% of the height of structure, the clear distance between the site boundary and the building to be demolished shall not be less than 50% of the building height plus an additional 6 m for the crane to maneuver, this criteria shall apply to all sides of the building to be demolished by wrecking ball;
- The demolition ball shall be connected with swivel type anti-spin device to prevent twisting and tangling of the wire during operation;
- The wire and boom of the machine used for balling shall have a rated capacity, at the working radius, of at least 5 times the weight of the ball;
- The strength of the wire shall be at least twice the tensile strength of the nominal steel reinforcement of the floor slab and beams. The high strength wire allows the pullout of the wrecking ball from potential traps;
- To ensure that the crane is in good condition, the wire connecting to the ball, the boom components and connecting pins shall be inspected twice daily.
- A sufficient length of the wire shall be provided to allow the ball to drop to the lowest working level plus an addition of 10% of the wire length and no less than 3 drums. For swing in-line method, there shall be sufficient length of the dragline wire to allow the ball to fall in the event that the ball is entangled with the falling debris;
- The operation shall not be performed adjacent to overhead power lines;
- The site shall be entirely fenced off to forbid public access. A 24-hour security guard shall be assigned to the site to enforce the access restriction; depending on the relative location between the fence and the building, and fence shall be designed to withstand accidental impact by the wrecking ball;
- During the use of the demolition ball, expect for the crane operator and the spot person, all other workers shall be kept away from the demolition ball's working radius. Nobody shall stay inside the building;
- To minimize the dust impact on the surrounding area, the structure to be demolished shall be pre-soaked with water before demolition. Water spraying shall continue on the structure during demolition;

- Since the safety and success of the project depend highly on the operator and site personnel, the operator must have proven experience and skill for operating the wrecking ball to the satisfaction of the approval authority; and
- A spot person shall be on site during the operation to assist the operator and to ensure site safety. The spot person shall have extensive knowledge and experience in the use of wrecking ball. The qualification and experience of the spot person shall be equivalent to those of the wrecking ball operator.

C. 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.
- Special conditions for pusher arm demolition are listed below:
  1) The pusher arm shall be constructed of steel or equivalent material and shall have adequate strength to operate on the building; a crane boom shall not be used;
  2) Minimum safety distance of 0.5 times the height of the building element being demolished shall be maintained between the machine and the building for pushing into the building.
  3) Minimum safety distance of 1.5 times the height of the building element being demolished shall be maintained if structural elements are pulling out of the building;
  4) The point of application of pushing shall not be less than 2/3 of the height and not more than 600 mm below the top of the wall; and
  5) The pusher arm method shall be limited to buildings less than 15 m high.

UNIT-I
2 Marks
1. Define Maintenance.
Maintenance is the act of keeping something in good condition by checking or repairing it regularly.
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
i) Prevention
ii) Repair
5. What are the causes of deterioration?
i) Deterioration due to corrosion
ii) Environmental effects
iii) Poor quality material used
iv) Quality of supervision
v) Design and construction flaws
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 warrent 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
Incase 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?

a) Inspect & observe the structure
b) Observe in bad & good weather
c) Compare with other constructions on the area or elsewhere & be patient
d) 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?

i. finding the deterioration
ii. determining the cause
iii. evaluating the strength of existing building or structure
iv. evaluating the need of repair
v. 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?

a. to permit deterioration to continue
b. to make measures to preserve the structure in its present condition without strengthening
c. to strengthen the construction
d. if deterioration is exceptionally sever, to reconstruct or possibly abandon it.

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
UNIT-II
2 Marks
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. Provide less water-cement ratio.

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?
i) Class-1: Cracks leading to structural failure
ii) Class-2: Cracks causing corrosion
iii) Class-3: Cracks affecting function
iv) 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?
i) Anodic inhibitors
ii) Cathodic inhibitors
iii) Mixed inhibitors
iv) 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
UNIT III
2 Marks
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/gm2 at 7days and 210kg/cm2 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
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?
Sulphur 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 are use 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

2 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

iii. filtering mat

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.

UNIT V

2 Marks

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 2to 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?

v) Class-1: Cracks leading to structural failure

vi) Class-2: Cracks causing corrosion

vii) Class-3: Cracks affecting function

viii)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 b rendering, for areas less than .01 m2.