CE3005- Rehabilitation/ Heritage Restoration

Unit - I

Maintenance & Repair Strategies

Maintenance, Repair and Rehabilitation, Facets of Maintenance, importance of maintenance. Various aspects of inspection, - Assessment procedure for evaluating damaged structure - Causes of deterioration

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Maintenance :-

* It is the act of maintaining the building in its serviceable condition.

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

Objectives of maintenance:-

* To preserve building
* To restore building
* To make improvements in serviceability.

Repair :-

* It refers to the modification of a structure, Partly or wholly which is damaged in appearance or serviceability.

* It is the process of restoring something that is damaged or deteriorated or broken to good condition.

Rehabilitation:-

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

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

Scope of maintenance:-

* Petty repairs, replacements and structural repairs of buildings, White and color washing, distempering and painting at prescribed intervals

* Repair and renewal of furniture.

* operation, periodical maintenance, repairs renewals of machinery and equipment for electric, etc.,

* Repair of roads, culverts and resurfacing the roads.

Facets (or) Facts of maintenance:-
(Distinct features)

* (i) Prevention
* (ii) Repair

* Aims of maintenance work classified as
    * The avoidance of accidents, which may harm people or plant.
    * The continued operation of a facility.

* The protection of the capital investment is the asset.
* Emergency Maintenance
* Condition based maintenance
* Fixed time maintenance
* Preventive maintenance.
* opportunity Maintenance
* Day to day care and maintenance
* Corrective maintenance
* Shutdown maintenance
* improvement Plans

Importance of maintenance various aspects of Inspection:

* Improves the life of structure
* Improved life period gives better return on investment
* Better appearance and aesthetically appealing
* Better serviceability of elements & components.
* Prevents major deterioration that leads to collapse
* Ensures safety to occupants.
* Ensure feeling of confidence by the user.
* Maintenance is continuous cycle and involves every elements of building science namely structural, Electrical wiring, Plumbing, water supply, sanitation, finishes in floors & walls Roof terrace, lifts, doors & windows etc.

Factors influencing maintenance

* cost
* Age of building
* Availability of physical resourles
* Urgency
* Future use
* Social consideration.

Necessity of maintenance:-

* Preventions of damage
* Decay due to natural agencies, wear & tear
* Good appearance & working condition.
* Reduce the causes against building.
* Increase the life of the building.
* Reduce the risk for occupants.
* Reduce the outgoing expenses.
* Maintain the value of building.
* Save the building at all weathering actions.
* Protect the whole structure.

Causes of maintenance:-

* Atmospheric agencies — Rain, wind, Temp.
* Normal wear & tear
* Failure of structure → collapse the tower, sliding or overturning dam, settlement of foundation, crushing of columns.
* Improper design → due to incorrect, insufficient data, reg. use loading & environmental condition, selection material & poor detailing
* Defective Construction → Poor materials, poor workmanship lack of quality Control & supervision
* Improper use of structure → overloading, unexpected structure environment due to impurities from industrial fuel burning, sea water minerals, chemicals storage structure
* Lack of maintenance → which result may failure

classification of maintenance :-

* Preventive Maintenance
* Remedial maintenance → Finding the deterioration,
  Determining the causes
  Evaluating the strength of the existing Structure
  Evaluating the need of the structure
  Selecting & implementing the repair procedure
* Routine Maintenance
* Special Maintenance

Various aspects of Inspection

* Daily Routine Maintenance → inspection of all essential item by visual observation (crack)
* Weekly Routine Maintenance → Electrical accessories, flushing Sewer line, leaking of water line
* Monthly Routine Maintenance → cleaning doors & windows, checking septic tank, cleaning OHT, dampness
* Yearly Routine maintenance → Painting, small repairs etc.

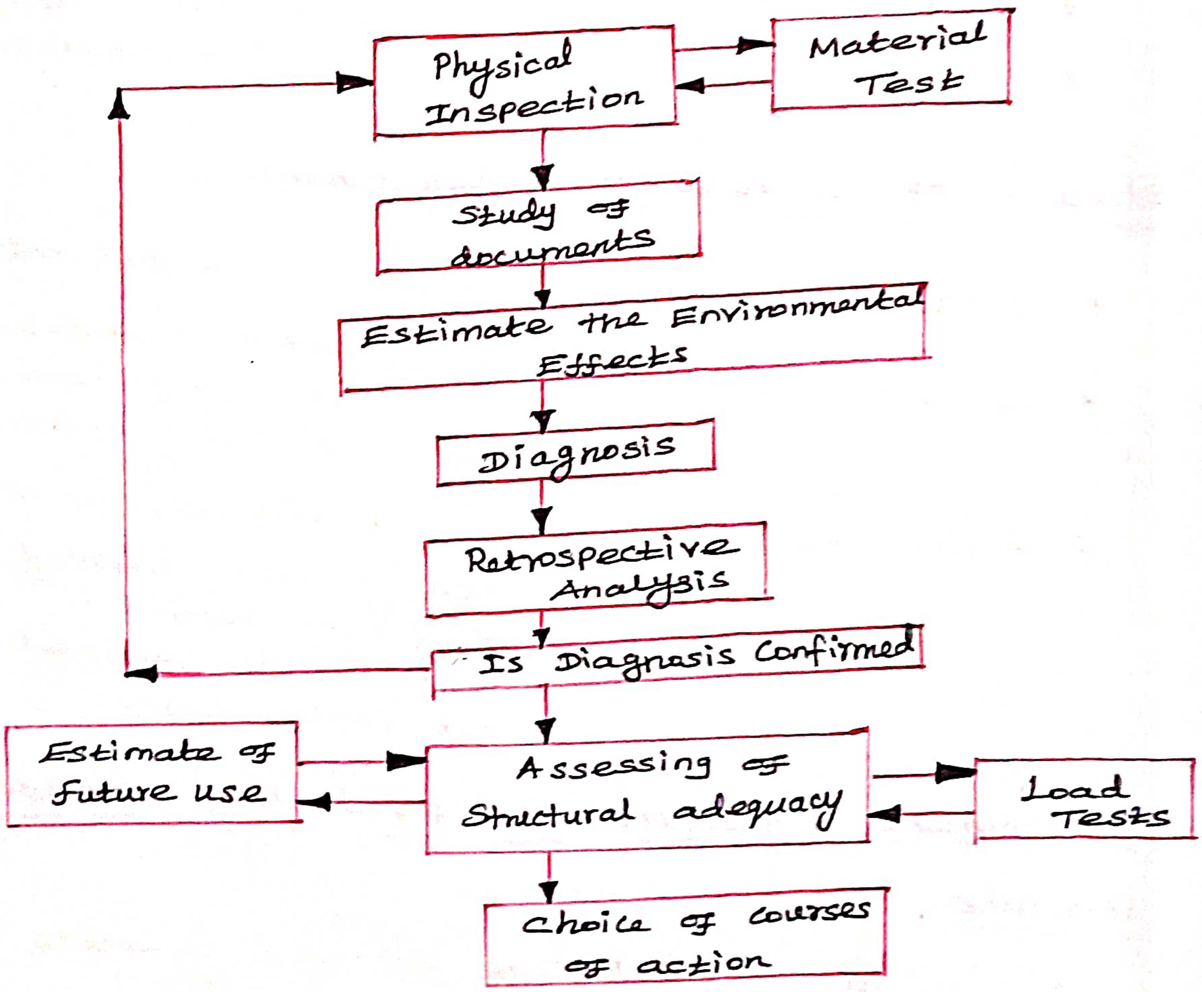
Stages of Inspection & Maintenance :-

* Inspection → collect data at specified intervals.
* Analysis → Add latest information to database - earlier information
  examine progression of defects
  relate defects to action criteria
* Action possibilities → Note & wait for the next inspection
  Alter inspection frequency
  Institute repairs
  Further detailed investigation
  Put saftey procedures in place

Assessment procedure for evaluating damages in a structure :-

* physical inspection of damaged structure.
* Preparation and documenting the damage.
* collection of samples & carrying out tests both insitu and in Lab.
* studying the documents including structural aspects.

* Estimation of loads acting on the structure.
* Estimate of environmental effects including soil struct. interaction.
* Diagnosis.
* Taking preventive steps not to cause further damage.
* Retrospective analysis to get the diagnosis confirmed.
* Assessment of structural adequacy.
* Estimation of future use.
* Remedial measures necessary to strengthen and repairing the structure.
* Post repair evaluation through tests.
* Load test to study the behaviour.
* choice of course of action for the restoration of structure.



Strength Tests

* Schmidt Rebound Hammer Test
* Ultrasonic pulse velocity
* Pull out and Pull off Tests
* Break off
* Core Test
* Windsor probe
* Pulse Echo Technique

Durability Tests

* Corrosion Test
* Absorption and permeability
* Test for Alkalai Aggregate Reaction
* Abrasion Resistance Tests
* Rebar Locator Test

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

Chemical Tests

* corbonation Test
* Sulphate Determination Test
* chloride Determination Test
* Thermo-luminescence Test
* Thermo gravimetric analysis Test
* Differential Thermal analysis
* Diatometric Test.

Deterioration

* The process that adversely affects the performance of a structure over time due to defects and damages occured by naturally occuring chemical, physical or biological actions, repeated actions such as those causing fatigues, normal or severe environmental influences and wear due to use, abuse & others.

Causes of Deterioration :-

* Design and construction flaws
* Environmental effects
* Usage of poor quality material
* Quality of supervision
* Deterioration due to corrosion
* + Spalling of concrete cover
  + cracks parallel to the reinforcement
  + spalling at edge
  + swelling of concrete
  + Dislocation
  + Internal cracking & reduction in area of steel reinforcement.

Causes of failure of Structure:-

* occurrences incidental to construction stage.
  - Local settlement of subgrade
  - Movement of formwork
  - Vibrations.
  - Internal settlement of concrete suspension
  - Setting shrinkage
  - Premature removal forms
* Drying shrinkage
* Temperature stresses.
  - Difference in Temp. b/w inside the building

* Absorption of moisture by concrete
* Corrosion of reinforcement
  - Entry of moisture through cracks (or) pores.
  - Electrolytic action.
* Aggressive action of chemical
* Weathing action
* Action of shock waves.
* Erosion
* Poor design details
  - Re entrant corners
  - changes in cross section
  - Rigid joints in precast elements
  - Deflections
  + leakage through joints
  + Inadequate drainage
  + Insufficient drainage slopes
  + Neglect in design
  + Unanticipated shear stress in piers, columns, abutments, etc.,
  + Incompatibility of materials, of sections
* Errors in design
* Errors in earlier repairs
* overloading.
* External influence
  - Earthquake,
  - wind
  - Fire
  - cyclones.

Repair & Rehabilitation :-

* It refers to the modification of a structure Partly or wholly which is damaged in appearance or serviceability.

Factors Considered for repair of Concrete Structure

* cause of damage
* Type, Shape and function of the structure
* The capabilities & facilities available with builders
* The availability of repair materials.

Stages of concrete repair

* Removal of damaged Concrete
* Pre-treatment of surfaces & reinforcement
* Application of repair material
* Restoring the integrity of individual sections & strengthening of structure as a whole.

Repair procedure :-

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

* To increase strength or restore load carrying capacity.

* To restore or increase stiffness
* To improve functional Performance
* To provide Water tightness.
* To improve appearance of concrete surface
* To improve durability

* ~~To improve~~

* To Prevent access of Corrosive materials to reinforcement.

Types of repair

* cosmetic treatment on surfaces
* Parial replacement of surface & subsurface material.
* Additional of reinforcements & bonding materials to strength the element.

Classification of repairs.

class of damage	classification of repair	Repair requirements.
1.	Superficial	cement mortar bonding by trowelling.
2	General	Non-Structural or minor Structural; restoring cover to rebars
3	Principal	significant loss of concrete strength, shotcreting for Slab & beams etc.
4	Major	Demolition and recasting required.

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 agent → cement slurry, cement Sand mortar, epoxy, expoxy mortar, epoxy + epoxy mortar, resin materials etc.,
* Adequate preparation of surface and good workman ship are the ingrediants of efficient + economial repairs.

Repair of cracks – Techniques.

* Resin injection
* Routing + Sealing
* stitching
* External stressing
* Bonding
* Blanketing
* overlays
* Dry pack
* Vacuum impregnation
* Polymer impregnation

Rehabilitation

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

Steps involved in Rehabilitation

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

* support the structural members properly as required
* Remove all cracked, spalled and loose concrete.
* clean the exposed concrete surfaces and steel reinforcement
* Provide additional reinforcing bars, if the loss in reinforcement is more than 10%.
* Apply protective coatings over the exposed or repaired surface.

Applications of Rehabilitation:-

* shotcrete / Gunite
* Resin injection
* Dry pack & epoxy bonded dry pack
* slab jacking technique
* Sprayed concrete.

Factors of Rehabilitation

The factors to be considered by the designer at the construction site are as follows.

* Minimum & maximum temperature
* Temperature cycles
* Exposure to ultra violet radiation
* Amount of moisture
* wet/dry cycles
* Presence of aggressive chemicals.

Unit- 2

Strength and Durability of Concrete

Quality assurance for concrete – strength, Durability – cracks, different types, causes – Effects due to climate, temperature, Sustained elevated temperature, Corrosion

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Quality assurance for Concrete

* It is a management system, which increases confidence that a material, product or Service will Conform to specified requirements.

* It outlines the commitments, policies, designated responsibilities and requirements of the owner.

* The construction should results in satisfactory Strength, serviceability and long term durability so as lower the overall life cycle cost.

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

* QA & QC would involve both the inputs as well as the outputs.

* Inputs are in the form of materials for concrete, workmanship in all stages of batching, mixing, transportation, placing, compaction and curing, and the related plant, machinery and equipments, resulting in the output in the form of Concrete in place.

* QA plan shall define the tasks and responsibilities of all persons involved, adequate control and checking procedures and the organization and maintaining adequate documentation of the building process and its results.

* The documentation should generally include.

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

Need for Quality Assurance :-

* 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 statisfaction.
* The material producer is influenced by the Quantity of work in his feature sales.
* The building contractor also relies on it, to promote his organization in procuring future contracts, but his task is often complicated by the problems of time scheduling and costs.

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

Causes of design faults

* Mis-interpretation of client's needs
* Lack of good communication b/w members of the design team.
* Mis-interpretation of design standards or codes of practice.
* Use of incorrect or out-of-date data.
* Production of and reference to inadequate and imprecise specifications.

Causes of faults in construction

* Mis-interpretation of design drawings or specifications.
* Lack of effective communication with suppliers and sub contractors.
* In sufficient co-ordination of subcontracted work.
* Inadequate onsite supervision.
* poor workmanship due to inadequate skills and experience of the labour force satisfactory instructions.

Components of Quality management system (QMS)

* Quality Assurance plan (QAP) (or) (QP)
* Quality Control process (QC)
* Quality Audit (QA)

Quality assurance plan (Q.AP (or) QP)

* The quality assurance plan starts right from the planning and design stage

* It can be defined as a procedure for selecting a level of quality required for a project.

* The following aspects should be addressed by Q.A.P:-

- organizational set-up
- Responsibilities & authorities of personal
- Identification of co-ordinating personal
- Quality control measures in design including field changes.
- Establishment of controlled norms acceptance and rejection criteria for material.
- Inspection programmer for verification of contractual compliance including acceptance & rejection.
- Sampling testing documentation and material qualification.
- Preparation, submission and maintenance of records at all stages.
- Quality assurance activity as to start Planning & design stage.
- The project including its design drawing & specification by an independent.

Quality Control plan:-

* It is a system of procedures & 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.

* It implements the quality plan by those actions necessary for Conformance to established requirements.

* product manufacturer material process or are the like monitor the properties of finished Work.

* QC is the responsibility of the contracting organization

* The contracting organization is also responsible for a QC activities related to its sub contractor.

* The control system to be used by it performing design, purchasing, fabrication, production of concrete & other construction activities for the contractual responsibilities.

Quality Audit (Inspection check)

* It is a system of tracking and documentation of quality assurance & QC Programs.

* Quality Audit covers both the design as per as the construction phase.

* The concept of quality management encompasses the total project and element of the project.

* concept of quality management depends on available materials & construction technology.

* 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

Reasons for Poor Quality construction

* Poor materials & workmanship
* Poor architectural or structural design
* Poor detailing of reinforcement
* cement content → It should be minimum of 300 kg/m^3 of concrete
* Excess water to cement ratio → It should not exceed about 50% of the weight of cement
* Inadequate compaction of concrete
* Inadequate curing of concrete
* Inadequate cover to reinforcement.
* Poor or no supervision
* Lack of technical knowledge of the building contractor & his supervising team.
* poor maintenance

Design errors & construction errors:

Design Errors

* Inadequate structural design
  + Failure Mechanism → concrete exposed to greater stress & strain
  + Symptoms → visual inspection
    - 1st error in design — high compressive stress (or) torsion — Result → spalling or cracking
    - 2nd → high tensile stress — result cracking.

* Lack of attention to relatively minor design details.

(Poor Design Details)

- Poor design → high Loading & high stresses, its Results cracking — allow water then create leakage & finally chemical or deflected the structure
- Abrupt changes in section
- Insufficient reinforcement at reentrant corners & openings
- Inadequate provision for deflection
- Inadequate provision for drainage

- In sufficient travel in expansion joints
- Incompatibility of materials.
- Neglect of creep effect.
- Rigid joints b/w precast unit
- Unanticipated shear stresses in piers, column or abutments.

Construction Errors :-

* Adding water to concrete
* Improper alignment of formwork
* Improper consolidation of concrete
* Improper movement of formwork
* Improper curing
* Improper location of reinforcing steel.
* premature removal of shores or reshores
* setting of the concrete
* setting of subgrade
* Vibration of freshly placed concrete
* Improper finishing of flat work

Properties of concrete

* strength of concrete
* permeability of concrete
* Durability of concrete
* Thermal property of concrete
* Micro cracking of concrete
* Stress and strain characteristics of concrete
* shrinkage & temperature effects
* creep of concrete
* Acid attack , fire resistance
* Efflorescence

Strength of concrete:-

* Strength of concrete is defined as the resistance that concrete provides against load so as to avoid failure.

* It depends on the W/c 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.

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

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

* 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 water tightness of concrete.

* Increases the plasiticity & worability of concret

* excessive addition of pozzolanas affects durability.

* It should be used along with cement as partial replacement or small percentage.

* Construction industry need faster development of strength.

* ~~Wo~~ W/c increases the strength will be reduced

* results in — drying shrinkage, thermal shrinkage, modulus of elasticity & lower creep coeffic

* cement content is high → the concrete exhibits greater cracking. (increase thermal & drying shrinkage)

* high early strength — more cracking

* Structural cracks in high strength concrete can be controlled by use of sufficient steel reinforcement.

* It practice does not helps durability of concrete, as provision of more steel reinforcement.

* will only results in ~~[illegible]~~ conversion of the bigger cracks to smaller cracks.

* Smaller cracks are to allow oxygen, CO_2 + moisture get into concrete to affect long term durability of concrete.

Strength of a material

— Ratio of cement to mixing water

— Ratio of cement to aggregate

— Grading, surface texture, shape, strength stiffness of aggregate particles.

— Maximum size of aggregate.

Characteristic strength of a Concrete :-

* Compressive Strength
  - cube → 150 x 150mm (or) 100 mm x 100 mm
  - cylinder → 150 mm dia + 300 mm height
  - Test specimens are cast, cured & tested as per the standards
  - compressive strength given by different specimens for the same concrete mix are different

$f_{ck\ cylinder} = 0.8\ f_{ck\ cube}$

* **Flexural Strength**

- Prism → 100×100×500 mm (or) 150×150×700 mm
- Determination of flexural tensile strength is essential of estimate the load at which the concrete members may crack.
- Flexural tensile strength of concrete by conducting a direct tension test
- At failure or rupture, to dermine the modulus of rupture by standard test.

* The results are affected by the size of the specimen casting, curing & moisture condition, rate of loading & manner of loading.

Flexural Strength $F_{cr} = \sqrt{0.7 f_{ck}}$

Tensile strength

(i) Direct method

* To determine the tensile strength of concrete can be broadly classified as direct & indirect method.

* Direct method suffers from a number of difficulty related to holding the specimen properly in the testing machine without (inducing) introducing stress concentration and to the application of uniaxial tensile load which is free from eccentricity ~~to~~ the specimen.

* Very small eccentricity of load will induce bending and axial force condition and the concrete fails at apparent tensile stress other than the tensile strength because of difficulties involved in conducting the direct tension test.

(ii) Indirect method (splitting test)

* The number of indirect method has been developed to determine the tensile strength.
* Direct compressive force is applied to a concrete specimen in such a way that the specimen fails due to tensile stresses induced in the specimen.

$$\sigma_{sp} = \frac{2P}{\pi d l}$$

Advantages of splitting Test

* It is simple to perform and given more uniform results. than other tension test.
* The strength determines is closer to the actual tensile strength of the concrete that given by modulus of rupture test
* The same mould can be used for casting specimen for both compression tension tests.

Factors affecting Strength of Concrete

* size of the test specimen
* size of aggregate & type of aggregate
* support conditions of the specimen
* Moisture conditions
* Types of testing machine
* Type of cement
* Degree of compaction
* Type of curing & temperature of curing
* Nature of loading.

Durability

* It is defined as the ability of concrete to resist weathering action, chemical attack & abrasion while maintaining its desired engineering properties.

* Different concretes require different degrees of durability depending on the exposures environment and properties desired.

* Example :- concrete exposed to tidal sea water
  - concrete ingredients their proportioning, interactions b/w them, placing & curing practices & the service environment determine the ultimate durability & life of concrete

* some important degradation mechanism in concrete structures includes the following
  + Freeze - thaw damage (Physical effects, weathering)
  × Alkalai - aggregate reactions (chemical effects)
  × sulphate attack (Chemical effects)
  × Microbiological induced attack (chemical effect)
  × Corrosion of reinforcing steel embedded in concrete (chemical effects)
  × Corbonation of concrete
  × chloride induced
    - Abraision (physical effects)
    - Mechanical loads (Physical effects)

Effects due to climate

* The lack of durability of concrete on account of freezing & thawing action of frost is not of great importance to Indian standards.

* It is of greatest considerations in most part of the world.

* The most severe climatic attack on concrete occurs, when concrete containing moisture is subjected to cycle of freezing and thawing.

* The capillary pores in the cement paste will freeze, when the ambient temperature is below 0°C

* The gel pores are so small, that water freeze at normal winter temperatures.

* Freezing expands by 9% of its volume, exess water in the cappillaries has to move.

* Cement paste impermeable high pressures are necessary to move the exess water even over quite small distances.

* Normal Strength concrete, that movement of order of 0.2mm is sufficient to tensile strength of the paste.

* Concrete can be protected from freeze-thaw damage by the entrainment of the air distributed through the cement paste, with spacing b/w bubbles not more than 0.4mm.

* For effective protection Air entraining Agent (AEA) must be added in the mix.

* It is only the amount of air entrained, which can be measured in wet concrete.
* Amount of air 4 to 8%
* Depend on maximum size of aggregate
* Air is entrained even no AEA is added.
* The effect is stabilize the air bubbles.
* More air is entrained with a large dose of AEA
* Higher Slump more air is entrained.
* Fine aggregate have a very marked effect
* sand is the most important single factor in air entrainment.
* If concrete is so dense, no inter connected capillary pores & freeze-thaw deteroration will exists.
* Use of high cement content & low w/c ratio will lead in this direction as will the introduction of silica fume, it would be wise to dispence with air entrainment, if freeze & thaw resistance is wanted.

Effects due to temperature

* The temperature difference with in 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.
* It contains the hydration of cement, affect the mass concrete such as in large columns, piers, footings, dams etc.,

* The heat of hydration of cement causes the internal temperature of concrete to rise during the initial curing period, that is usually slightly warmer than its surroundings.

* In thick sections & with rich mixes the temperature differential may be considerable. As the concrete cools it will try to contraction

* The free contraction during cooling will result in tensile stresses which are proportional to the temperature change, co-efficient of thermal expansion, effective modulus of elasticity and degree of restraint.

* The more massive 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.

* 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 problem. If the cracks do form.

* Remedial measures are similar to those for cracks that form after a structure in service.

Effects due to Sustained elevated temperature:-

* concrete expands with increase in temperature and contracts with decrease in temperature.

* The range of variation in temperature varies from localities, season and day to day.

* The objectionable cracks may occur in concrete due to contraction combined with the effects of shrinkage.

* Large & harmful stress develop due to deformation because temperature changes.

* The co-efficient of thermal expansion of concrete depends on the type and quantity of cement, aggregate, relative humidity & sizes of section.

(i) concrete at high temperature:-

Industrial application such as aluminium plants and brick works the conc may be frequently or occasionally subjected to temperature.

* These temperatures are likely to be applied linearly.

* Generally with & rather a long period.

* Jet craft & vertical take aircraft may subject the payment to very high temperature.

* Heat may affect concrete, as the result of
    - removal of evaporable water
    - removal of combined water
    - Alteration of cement paste

* Disruption (of beam) from disparity of expansion and resulting thermal stresses.

* Alteration of aggregate.

* change of the bond bet aggregate & paste.

* other effects on conc due to temperature.

* cycles of temperature can have a progressive effect on the reduction of strength even longer curing did not improve the loss.

* Tensile strength of cone is more effect by heat that its compressive strength.

* Rise and fall of temperature, the cone is affected by intraction of thermal expansion, drying thermal incompatibility and enhanced every at high temperature.

* heating is sufficiently rapid, high stresses can be included, hence failure & instability may result.

(ii) Effects of steel at high temperature:-

* The influence of temperature on steel appears as a change in yield stress, ultimate strength and modulus of elasticity.

* The changes depend on the type of steel and are greater in cold-weathered steel.

* The strength of hot-rolled steel bars are not reduced if the temperature does not reach to 300°C.

* At temperature 500 – 600°C the yield stress is reduced to the order of the working stress and the elastic modulus is reduced by (1/3) one-third.

* Bars heated to this temperature virtually recover their normal temperature.

* Bars heated to 800°C have a lower residual strength after cooling to room temperature.

* Pre-stressing wire and stand starts to lose strength at 150°C and may have only 50% of its room temperature strength when heated to about 400°C.

Effects of corrosion:-

(i) 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 of forms white patches.
* It inicates the occurences of carbonation.

(ii) 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

(iii) occurrence of cracks:-

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

(iv) Formation of multiple cracks

* 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 line cracks are also formed.

* The bond b/w concrete & the reinforcement is reduced.

* There will be a hollow sound when the concrete is tapped at the surface with a light hammer

(v) snapping of bars

* The continued reduction in the size of bars results in snapping of the bars.

* It will occurs in ties/stirrups first

* At this stage, size of the main bars are reduced.

(vi) Buckling of bars & 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 & 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.

Effect of Cover thickness

* substantial experience which relates durability and the amount of water.
* The thicker cover over the steel is the longer it will take the chloride ions to reach the steel & reduce the pH & passivity provided by the cement.
* Excessive cover can led to the development of a few wide cracks under overstress, whereas a thinner cover results in many small cracks.
* 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 Severe ~~normal~~ exposure → atleast 50mm thickness
    * For moderate exposure → atleast 40mm thickness
    * For Mild exposures → atleast 30mm thickness
    * For normal exposures → atleast 20mm thickness

Cracks

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

classifications of cracks :-

(i) According to location:

* Bond cracks
* mortar cracks
* Aggregate cracks

(ii) Based on their width :

* Fine → less than < 0.1 mm
* Thin → 0.1 to 0.3 mm
* Medium → 0.3 to 0.7 mm
* wide → 0.7 to 2 mm
* very wide → greater than > 2 mm

(iii) Depending upon their effects :-

* class I – cracks leading to structural failure
* class II – cracks causing corrosion
* class III – cracks affecting function
* class IV – cracks affecting appearance

(iv) classification in terms of their effects

* Those cracks which indicate immediate structural distress.
* Those cracks which may lead in the long run to a reduction of saftey, through corrosion of steel.

* by leakage, sound transfer, damage to finishes, & unsatisfactory operation of windows & doors.

* cracks are aesthetically unacceptable.

Effects of cracks

class I - structural failure

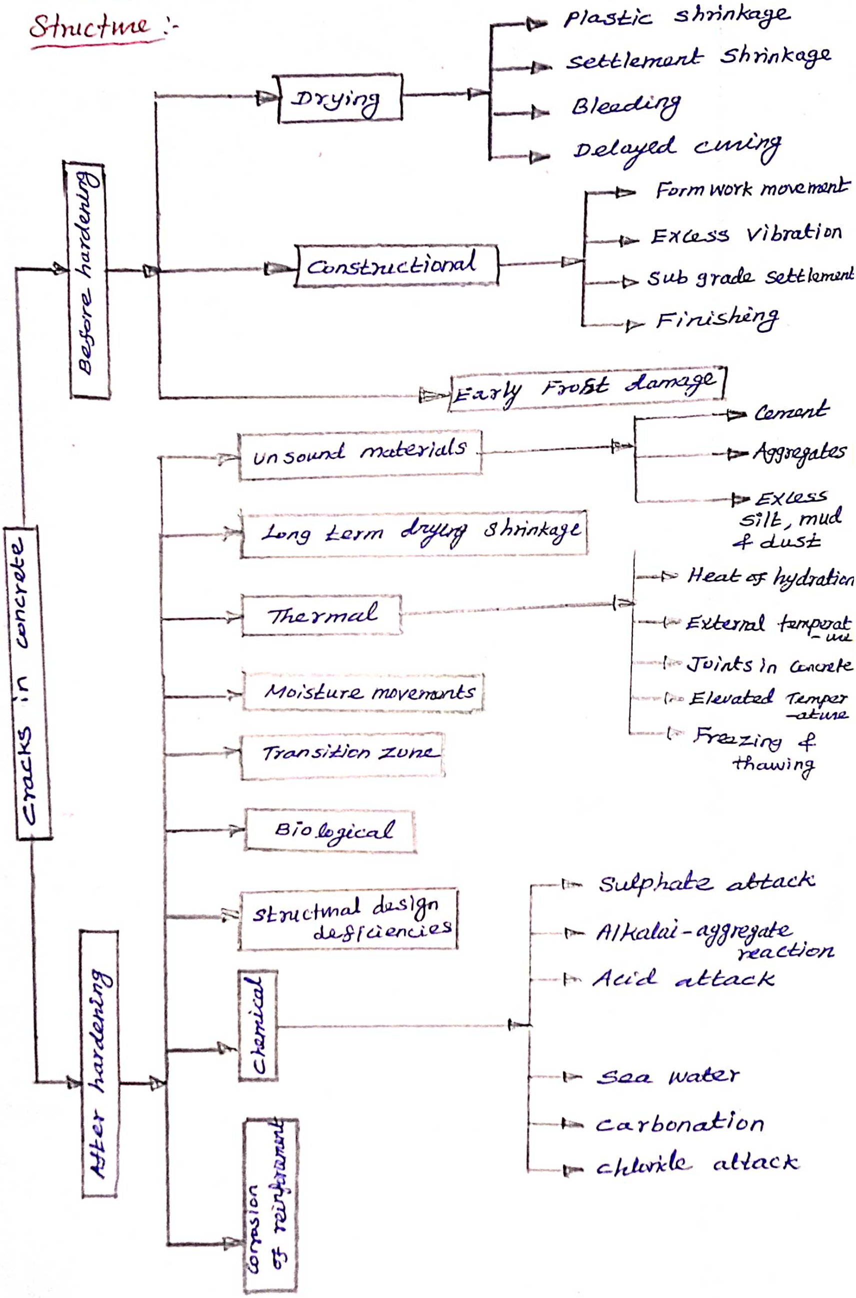
* Little difficulty arises in relation.
* Indicate that failure is near and that margin of saftey are seriously reduced, may have formed in concrete, which was expected by the designer, to carry load in its uncracked condition.
* cracks are necessarily wide, & may lead to the detachment of parts of the structure.

Class II - causing corrosion

* no unique relationship b/w crack width & on set of corrosion.
* difficulty arises from the nature of cracks.
* For flexural members, many cracks taper from a certain width at the surface of the concrete the near zero width at the steel-concrete interface.
* Flexural cracks that are controlled by the overall depth of the beam are not the tapered shape, and it is likely that cracks due to temperature & shrinkage are nearer to being parallel sided.

*

Various types and causes of cracks in concrete Structure :-



Unit - III

Special concretes

Polymer concrete - Sulphur infiltrated concrete, Fibre reinforced concrete - High strength concrete High performance concrete - Vacuum concrete, Self compacting concrete, Geopolymer concrete - Reactive powder concrete, concrete made with industrial waste

—x —x —x —x —x —x —x —

Polymer concrete

* Polymer concrete is part of group of concretes that use polymers to supplement or replace cement as a binder.

* The types include
  - (i) polymer-impregnated concrete (PIC)
  - (ii) Polymer cement concrete (PCC)
  - (iii) Polymer Concrete (PC)

(i) polymer concrete :-

* In polymer concrete, thermosetting resins are used as the principal polymer component due to their high thermal stability and resistance to a wide variety of chemicals.

* It is also composed of aggregates that include silica, quartz, granite, limestone, and other high quality material.

* Polymer Concrete may be used for new Construction or repairing of old concrete.

* Polymer concrete is a composite material which results from polymerization of a monomer and aggregate mixture.

* The Polymerized monomer acts as a binder for the aggregates and the resulting composite is called polymer concrete.

* Two techniques are used to mix monomer with aggregate.

* The first is the conventional method of adding monomer to dry aggregate and stirring until a uniform blend is achieved.

* The second technique consists of placing the monomer in the specimen mould and then gradually adding aggregate to the monomer.

* The mixture is consolidated by mechanical vibration.

Types of monomer

* Methyl methacrylate (MMA)
* styrene
* Acrylontrile
* T - butyl styrene
* thermoplastic monomer.

Properties

* They are highly resistant to chemical attack, freeze & thaw.
* Permeability and absorption is almost zero

* Cement concrete is an inherently porous material and as such, it has a low tensile strength.

* It exhibits a tendency to cracks and can deteriorate under the influence of severe chemicals in the atmosphere or in solution.

* Concrete polymer materials have been developed during th last 15 years in a number of laboratorie around the world.

* For applications as a constructional material offering the potential advantages of a higher strength, water tightness and improved durability & resistance to freeze - thaw cycles over normal portland cement Concrete.

* The production of polymer concrete composites involves the introduction of chemicals with in the pores of the concrete and their polymerization

* PC is formed by polymerizing a monomer, mixed with aggregate at ambient temperature, using curing agents or a chemical catalyst.

Advantages of polymer concrete

* It has high impact resistance and high compressive strength.
* highly resistant to freezing & thawing.
* highly resistant to chemical attack & abrasion.
* Permeability is lower than other conventional concrete.
* Rapid curing at ambient temperatures.
* Good long term durability with respect to freeze & thaw cycles.
* Low permeability to water & aggressive Solutions.
* Good resistance against corrosion.

Dis-advantages of PC

* It tends to be brittle in nature ie, fiber reinforcement is not provided in some polymer concrete cases, to develop cracks.

* cost high.

Application of Polymer Concrete

* Nuclear power Plants
* kerb stones
* Prefabricated Structural Element
* Precast slabs for bridge decks.
* Roads
* Marine works.
* Prestressed concrete structures
* Irrigation works
* Sewage works
* water proofing of buildings
* Food processing buildings etc.

(ii) Polymer modified concrete

* Polymer cement Concrete.
* popular, because of its ease of handling, economy & Satisfactory results.
* Low water absorption, effective material used for hydraulic structure.
* Setting Quickly.

Polymer portland cement concrete (PPCC)

* Conventional Portland cement concrete, replaced by a part of mixing water with a latex (Polymer emulsion)
* Earlier latex based on polyvinyl acetate or polyvinylidene chloride.
  - Risk of corrosion of steel.
  - Low wet strength
* Later case → high wet strength
* Latex → contains 50% wt of spherical & very small polymer particles.
* 10 to 25% polymer by wt of cement is used in typical latex modified concrete formulation

Advantages of PMC

* ability to bond strongly with old concrete
* Resist the entry of water
* epoxy resins produced

Dis-advantages of PMC

* Modest improvement of strength & durability

Polymer-Impregnated concrete (PIC)

* Precast & hydrated Portland cement concrete which has been cleaned, dried & impregnated with a low viscosity ~~mon~~ monomer. (eventually soaked under pressure) before being polymerized.
* Improvements in the structural & durability properties.

* large part of the voids volume in the capill. pores is filled with the polymer and forms a continuous internal reinforcing structure.

* Improvement in strength & durability

Properties of PIC

* Mechanical & chemical resistant properties of PIC composites are superior to the conventional cement mortar.

* Porosity of the conventional cement mortar is greatly reduced, when it is impregnated with polymers, increasing its durability.

* PIC seals the voids formed during the cement hydration.

* compressive strength & tensile strength increases & is different for different composition & types of polymers used.

* ~~q~~

Partially impregnated & surface coated polymer concrete

* It can be easily produced by initially soaking the dried specimens in the liquid monomer.

* Then sealing them by keeping under hot water at 70°C, to prevent or minimize loss due to evaporation.

* partial impregnation may be sufficient in situations, where the major requirement is surface resistance against chemical & mechanical attack in addition to increase in its strength.

* The depth of monomer penetration depends upon pore structure duration of soaking viscosity of the monomer.

Advantages

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

Applications

* structural floors
* Swimming pools
* pipes
* storage tanks for distilled water
* Anti_abrasive surface
* Marine structures
* Tunnel liners
* Telephone cable ducts.

Sulphur Infiltrated concrete

* New types of composition
* Recently developed techniques
* Impregnating porous material
* concrete with sulphur
* Sulphur having strength impregnation as Shown great improvement in strength.
* physical properties have been found to improve by several 100% and large improvement in water impermeability.
* Resistance to corrosion have also been achieved.
* Some attempts sulphur as a binding material instead of cement.

Manufacture Method :-

* The quantity of sulphur used is also comparatively less and the Process is made economical.
* sulphur is heated to bring it into molten condition to which coarse and fine aggregate are poured and mixed together.
* This mixture give fairly good strength, acid resistance and other chemical resistance.
* It proved to be costlier than ordinary Cement Concrete.
* Its compressive strength of about 100 MPa could be achieved in about 2 day time.

* commercial sulphur of Purity 99.9 % are used.
* A large number of trial mix are mode to determine the best mix proportion.
* The W/C of 0.7 or over as been adopted in all the trial.
* After 24 hrs of moist curing the specimen is dried in heating cabin at for 24 hours in 121°c
* Then the dried specimen are placed in a Container of molten sulphur at 121°c for 3hrs
* The sulphur infiltrations can be employed in the Precast industries.

Applications:-

* high strength can be used in the manufacture of Precast roofing element
* Fencing post
* sewer pipes
* Railway sleeper.

* In this concrete should find considerable use in industrial situation.
* High corrassion resistant concrete is required.
* This method cannot be conveniently applied to cast in place concrete
* It is cheaper than ~~come~~ commercial concrete.
* The techniques are simple effective and in expansive.

High performance concrete (HPC)

* It is a high strength, ductile material formulated by combining portland cement, silica fume, quartz flour, fine silica sand, high-range water reducer, water and steel or organic fibers.

* Possessing high workability, high durability and high ultimate strength.

* As per ACI, HPC is defined as a concrete meeting special combination of performance and uniformity requirements that cannot always be achieved routinely using conventional constitutents and normal mixing, placing and curing practices.

* The strategic Highway Research program (SHRP) in the united states defined as highway structures by three requirements, namely a maximum w/c, a minimum durability factor to cycles of freezing & thawing & a minimum early age or ultimate compressive strength.

Characteristics of HPC:-

* High early strength
* High strength
* High modulus of elasticity
* High abrasion resistance
* High durability and long life in severe environments.

* Low permeability and diffusion
* Resistance to chemical attack high resistance to adverse climatic conditions.
* Toughness and impact resistance
* Volume stability
* Ease of placement
* compaction without segregation
* Inhibition of bacterial and mold growth.

Types of HPC :-

* Very early strength (14 MPa in 6 hours)
* High early strength (34 MPa in 24 hours)
* Very high strength (69 MPa in 28 days).
* High early strength with fiber - reinforcement.

Admixture :-

(i) water reducing admixture

* Increase workability
* Reduces water and cement content requirement
* High early strength.

(ii) consists Lignosulfonic acid, carboxylic acids

Applications :-

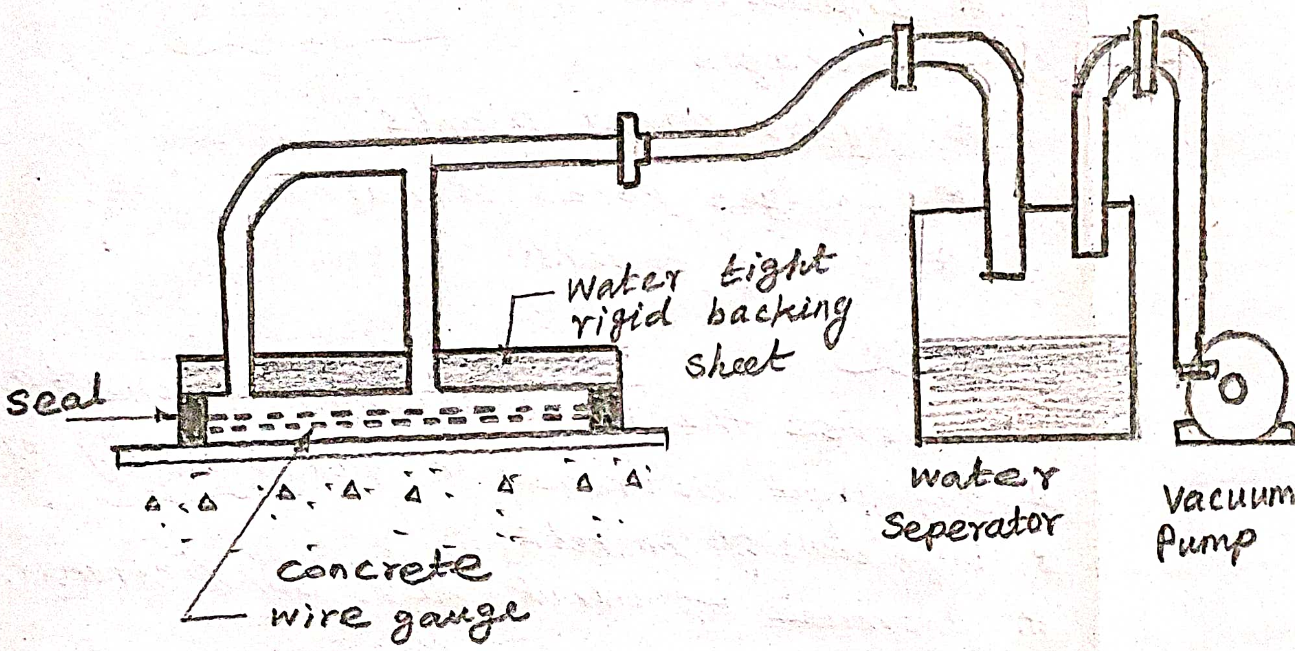
* High density radiations shielding
* Precast blocks
* Mass concrete projects
* High density concrete applications columns
* Gravity sea wall, coastal production & break water structures,

* Bridge counter weights.
* Ballast for ocean Vessels
* off shore platforms noise & vibration dampening

Vacuum concrete → Invented by Billner in US 1935

* The type of concrete –
  - excess water is removed
  - improving concrete strength
  - → by use of vacuum mats connected to a vacuum pump.

* Reducing the final W/c ratio of concrete before setting, to control strength and other properties of concrete.



Need for vacuum Concrete

* The chemical reaction of cement with water requires a water-cement ratio less than 0.38.
* But it is always taken more than 0.38.
* Workability is also Important for concrete.
* Workability & high strength don't go together as their requirements are contradictory to each other.
* It is the effective technique used to overcome this contradiction of opposite requirements of workability & high strength.

Equipments use in Vacuum Concrete

* Vacuum pump with hose pipe
* Filtering pad
* Water seperator
* Screed board vibrator
* Power floater
* Power trowel

Applications

* Industrials floors, sheds like cold storages
* Hydro power plants
* Bridges ports & harbor
* Cooling towers.

Advantages

* Increase the final strength of concrete about 25%.
* Sufficient decrease in permeability of concrete
* High density concrete
* Increase of about 20% bond strength of concrete.
* Appreciable reduction of time for final finishing.
* Early removal of wall forms.
* Increase in durability
* Good quality of floors & pavements can be obtained.
* Compressive strength increased by 25 to 45%.
* Durability of the floor can be increased.
* 15 to 25% of water can be extracted out.

Disadvantages of Vacuum concrete

- * High initial cost
- * Need trained labour
- * Need specific equipment
- * Need power consumption
- * Porosity of the concrete allows water, oil & grease to seep through, consequently weakening the concrete.

Self compacting concrete (scc)

- * self consolidating concrete
- * It is a concrete mix which has a low yield stress, high deformability, good segregation resistance (prevents separation of particles in the mix) and moderate viscosity. (necessary to ensure uniform suspension of solid particles during
- * scc is an innovative concrete that does not require vibration for placing & compaction.
- * It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement.
- * The hardened concrete is dense, homogeneous and has the same engineering properties and durability as traditional vibrated concrete.

*Type of self compacting concrete

(i) Powder type of scc

* This is the proportioned to give the required self compact ability by reducing the water powder ratio & provide adequate segregation resistance.

(ii) Viscosity agent type scc

* To provide self compaction by the use of viscosity modifying admixtures to provide segregation resistance.

(iii) combination type scc

* It is proportioned to obtain self compact ability mainly by reducing the water powder ratio.

Fresh scc properties

* Filling ability (excellent deformability)
* Passing ability (ability to pass reinforcement without blocking).
* High resistance to segregation.
* It has been observed that the compressive strength of scc produced with the combination of admixtures goes on increasing up to 2% addition of red mud.
* After 2% addition of red mud, the compressive strength starts decreasing. ie, the compressive strength of scc produced is max. when 2% red mud is added.
* The percentage increase in the compressive strength at 2% addition of red mud is +9.11

Advantages of SCC

* Improved constructability
* Labour reduction
* Bond to reinforcing steel
* Improved structural integrity.
* Accelerators project schedules.
* Reduced skilled labour
* Flows into complex forms
* Reduces equipment wear
* Minimizes void on highly reinforced areas.
* produces superior Surface finishes.
* Superior strength & durability
* Produces a uniform surface
* Allows for easier pumping procedure
* allow for innovative architectural features.
* It is recommended for deep sections (or) longer span applications.
* Lowering noise levels produced by mechanical Vibrators.

Factors affecting SCC

* Hot weather
* Long haul distances — reduce flow ability.
* Delays on job site → ~~affect~~ increase in flow ability.

Geopolymer Concrete

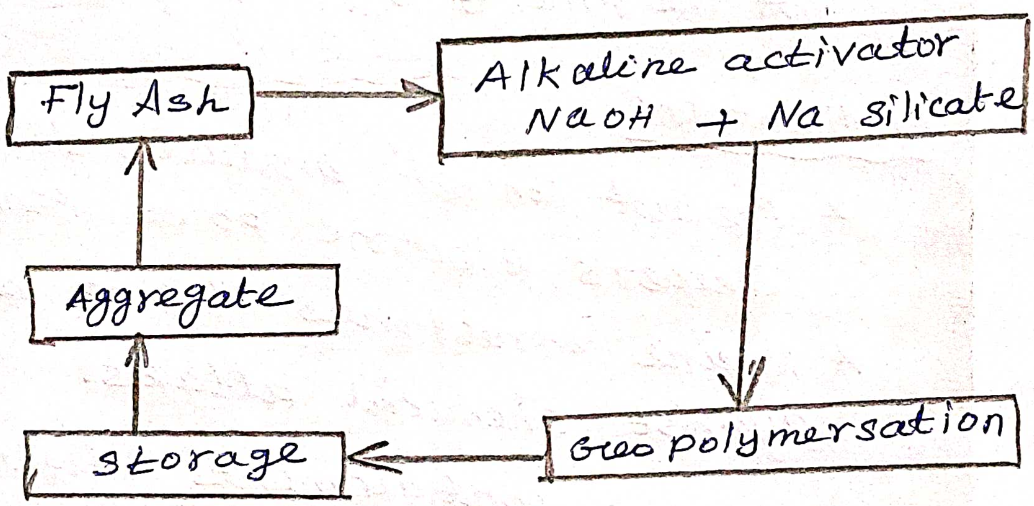
* Geopolymer is an inorganic alumino-silicate polymer, synthesized from predominantly silicon & aluminium material such as fly Ash.
* Alkaline solutions are used, to induce the silicon & aluminium atoms, in the source materials (fly Ash) to dissolve to form gel. The polymerisation process may be assisted by applied heat followed by during.
* The Geopolymer gel binds the loose coarse & fine aggregates to form geopolymer concrete.
* Geopolymer gel replace the C-S-H gel in cement concrete.
* chemical reaction period is substantially fast and the required curing period may be with in 24 to 48 hours.
* high compressive & tensile strength.
* Rapid Strength gain & lower shrinkage
* Green house gas reduction potential as much as 90% when compared with OPC.
* Hardened cementations paste made from fly ash & alkaline solutions.
* combines waste products into useful Product.
* setting mechanism depends on polymerization
* curing temp is b/w 60 – 90°C.

Constituents

Source material

* Alumina Silicate
* Alkaline liquids
* Combination of sodium hydroxide ($NaOH$) or potassium hydroxide (KOH) & Sodium silicate (or) potássium Silicate or potassium silicate.

Preparation of geopolymer concrete



Process:-

* Alkaline solutions induced the Si & Al atoms in the source materials.
* Gel formation is assisted by applying heat.
* Gel binds the aggregates & the unreacted source material from the Geopolymer concrete.

Alumina & silica Sources

* Fly ash
* silica fume
* sodium silicate
* metakaolin
* oiibbate

* Compressive strength → 1.5 times more than that of the comp. strength with OPC for the same mix.

Advantages

* Fire proof
* Eco-friendly
* Low permeability
* Excellent properties with in both acid & salt environment.
* Better compressive strength.
* The price of fly Ash is low.

Applications

* Precast concret products like railway sleepers, electric poles, parking tiles etc
* Marine structures due to resistance against chemical attaks.
* Waste containments (fly Ash)

OPC

Reactive powder Concrete (RPC)

* It is characterized by extremely good physical properties, particularly strength and ductility.

* A Composite material of ultra high strength with mechanical properties.

* Mixture of fibre reinforced, super plasticized silica fume, cement & quartz sand with very low w/c ratio.

* Quartz sand used instead of ordinary aggregate, ie, increase comp. strength.

Composition

* To obtain its improved properties by using a very dense mix, consisting of fine particles and fibers.

* Low w/c ratio → 0.16 to 0.24 (as low as 0.13)

* Type 20M (like type II), Portland cement (no C3A less HOH).

* silica fume (25% by weight

* water, High dosages of ~~sup~~ super plasticizer

* Fine Quartz sand (S.G = 2.75)

* steel fibers → (2.5 to 10% by volume)

* No rebar needed.

* cured in steam bath for 48 hrs @ 190°F (88°C) ~~the~~ after initial set,

placed under pressure at the molding stage

RPC mix & placing

* can be mixed & produced in a ready-mix truck and still have similar strengths to those made in a central mixer.

* self placing requires no internal vibration.

* Despite its composition, the large amount of super plasticizer still makes it workable

Function parameters of RPC

* Give strength to aggregate
* Binding material
* Maximum reactivity during heat treating
* Filling the Voids
* Improve ductility.
* Reduce water binding.

Concrete made with industrial waste

* Fly Ash
* Red mud
* metakaolin
* GGBS
* Micro silica
* RHA

Fly Ash :-

* Non combusted by product of coal fired power plants.
* During combustion, the coal's mineral impurities such as clay, feldspar, quartz and shale fuse in suspension and are carried away from the combustion chamber by the exhaust gases.
* Such fuesed material cools & solidfies into spherical glassy particles called Fly Ash
* It is a finely divided Powder resembling Portland cement mostly SiO_2.

Red mud :-

* Major industrial waste by Bayer Process for the extraction of alumina.
* characterized by strong alkality due to Presence of excessive amount of dissolved NaOH.
* The red color is by the oxidized Fe Present, which ~~as~~ can make up to 60% of mass of the red mud.

* In addition to Fe, the other dominant Particles include silica, unleached residual Al & TiO_2

* Disposal becomes a huge problem due to the Presence of high PH, heavy metals & radio activity.

* new technologies utilising red mud are gently needed, besides the use of GPC.

Unit - IV

Special concrete

Introduction:

* concrete may be used for some special purpose for which special properties are more important than normal concrete.
* In order to achieve a special concrete, suitable proportions of chemical and mineral admixtures are used. This concrete is called as special concrete.

Uses of special concrete

* special concrete is used in extreme weather.
* It has been used in large structures.
* Good cohesiveness or sticky in mixes with very high binder content.
* comparable flexural strength and elastic modulus.
* Better drying shrinkage and significantly lower creep.
* Good protection to steel reinforcement in high chloride environment.
* Excellent durability in aggressive sulphate environments.
* Lower heat characteristics.
* Low resistance to de-icing salt scaling.
* PC pipes with good resistance to chemical attack.

Types of special concrete

* Light weight concrete
* High strength concrete
* Fibre reinforced concrete
* Ferro cement
* Ready mix concrete
* SIFCON
* Shortcrete
* polymer concrete
* High performance concrete
* Geo polymer concrete.

Light weight concrete (LWC)

* Density Varies from 300 Kg/m^3 to 1850 Kg/m^3.

* It is mainly used to reduce the dead weight of Concrete. With same load carrying capacity like normal concrete.

* It is achieved by using light weight aggregate or by introducing air bubbles in mortar or by omitting fines. (fine aggregate)

* Density of normal concrete varies from 2200 to 2600 kg/m^3

Types of Light weight concrete

* Light weight aggregate concrete
* Aerator or cellular or Foamed concrete
* No. fine light weight concrete

1) Light weight aggregate concrete

* It is used to reduce the density of concrete.
* Natural light weight aggregate
  - (i) Pumice
  - (ii) Diatomite
  - (iii) Scoria
  - (iv) Volcanic cinder
  - (v) Saw dust
  - (vi) Rice husk

Artificial light Wt aggregate
  - (i) Artificial cinder
  - (ii) Coke breeze
  - (iii) Foamed slag
  - (iv) Bloated clay
  - (v) Expanded shales & slate
  - (vi) Sintered fly ash
  - (vii) Expanded Perlite

2) Aerator/cellular/foamed concrete

* This concrete is achieved by introducing of air or gas into mortar so that when the mix sets and hardens, a uniform cellular structure is foamed.

* Due to this cellular structure, the overall weight of the concrete is much reduced.

* Aluminium powders, zinc are used to produced hydrogen gas.

3) No-fines light weight aggregate

* Omit the fines from the conventional concrete.
* Its means in this concrete the fine aggregate is completely omitted and made only by coarse aggregate.
* The main aim is to produce large voids inside the concrete, and suitable for pavement construction.

Advantages of Light weight concrete :-

* Reduced dead load of the concrete allows longer span. This saves both labour & time.
* screeds & walls where timber has to be attached by nailing.
* casting structural steel to protect it against fire and corrosion or as a covering for architectural purposes.
* Gives heat insulation on roofs.
* Used in insulation of water pipes.
* construction of partition walls and panel walls in frame structures.
* Fixing bricks to receive nails from joinery, mainly in domestic or domestic type construction.
* General insulation of walls.
* It is also being used for reinforced concrete.

2) High strength concrete (HSC)

* High strength concrete can be defined by compressive strength of concrete at 28 days of water curing
* When the grade of concrete exceeds M35, then the concrete may be called as High strength Concrete.
* In general, producing of HSC is difficult with the use of conventional materials like cement, aggregate and water alone and it can be achieved by using of chemical & mineral admixtures or any one of the following methods.

(i) seeding → small percentage of finely ground, fully hydrated portland cement is added to fresh concrete mix.

(ii) Re-vibration → * Mixing water to concrete mix creates continuous capillary channels, bleeding & accumulates of water at some selected places. All these reduce the strength of concrete

* Hence controlled re-vibration is given after suitable time and it is increasing the strength of concrete.

(iii) High speed slurry mixing

* This process involves advanced preparation of cement water ~~mixing~~ mixture which is then blended with aggregate to produce HSC.

(iv) Use of admixtures :-

* High strength can be achieved by adding chemical admixtures such as super plasticizer and mineral admixtures such as fly ash, silica fume, etc.

(V) Inhibition of cracks :-

* Inhibition (or) arresting of crack is needed to improve the strength of concrete.

* Normally, it is achieved by replacing 2 to 3% of the fine aggregate (Polythene of 0.025 mm thick & 3 to 4 mm in diameter)

* Polythene is act as a crack arrester.

* By this method the strength is much improved upto 105 N/mm^2 (or) MPa

(vi) sulphur Impregnation :-

* satisfactory HSC has been produced by impregnating low strength porous concrete by sulphur.

* The process consist of the harden concrete (drying them at 120° C for 24 hours), immersing in molten sulphur under vacuum for 2 hours.

* By this method the strength is improved up to 58 N/mm^5 (or) MPa.

(vii) Use of cementitious aggregate :-

* Some kind of Clinkers are used as aggregate in concrete & is called cementitious aggregate.
* Example : ALAG
* It gives high strength to the concrete upto $125\ N/mm^2$ with very low water cement ratio of 0.32.

3) Fibre Reinforced Concrete (FRC)

* It is defined as a composite material consisting of mixtures of cement, aggregate and uniformly dispersed fibres.
* Fibre is a small piece of reinforcing material processing certain characteristics properties.
* The fiber 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 fibre :-

* Steel fiber
* Polypropylene fiber
* Glass fiber (GFRC)
* Asbestos fibre
* carbon fibre
* organic fibre
* Natural fibre
  - coir fibre
  - cotton fibre
  - sisal fibre
  - Jute fibre
  - Wool fibre.

Necessity of FRC :-

* It increases the tensile strength of concrete.
* It reduces the air voids and water voids the inherent porosity of gel.
* Increases the durability of concrete
* Fibers such as graphite and glass have excellent resistance to creep.

* Differential deformation is minimized.
* It has been recognized that the addition of small, closely spaced and uniformly dispersed fibers to concrete would act as crack arrester.
* It substantially improves its static and dynamic properties.

Factors affecting properties of FRC :-

* Relative fiber matrix stiffness
* Volume of fibers
* Aspect ratio of the fiber
* orientation of fibers
* Workability and compaction of concrete
* size of coarse aggregate
* Mixing.

4) Ferrocement :-

* Ferro cement is a type of thin wall reinforced concrete, commonly constructed of hydraulic cement mortar, reinforced with closely spaced layers of continuous and relatively small size wire mesh.
* The mesh may be made of metallic or other suitable materials.

Materials for ferro cement :-

* cement mortar mix
* skeleton steel
* steel mesh reinforcement

Advantages of Ferrocement :-

* It is highly versatile and can be formed into almost any shape for a wide ranges of uses.
* 20% savings on materials & cost.
* suitability for pre-casting.
* flexibility in cutting, drilling & jointing.
* Good fire resistance.

* Very appropriate for developing countries: labour intensive
* Good impermeability
* Low maintenance costs.
* Reduction in self weight & its simple techniques requires a minimum of skilled labour.
* Reduction in expensive form work. so economy & speed can be achieved.
* Only a few simple hand tools are needed to build any structures
* structures are highly water proof and higher strength to weight ratio than R.C.C.

5) Ready mix concrete (RMC)

* It is away from the construction site and then it is delivered to the construction site by the truck in a ready to ~~the construction~~ site use condition is called ready mix concrete.

Advantages of RMC

* Concrete is produced under controlled conditions using consistent quality of raw material.
* Speed of construction can be very fast in case RMC is used.
* Reduction in cement consumption by 10 to 12% due to better handling and proper mixing.
* The mix design of the concrete can be tailor made to suit the placing methods of the contractor.
* RMC uses bulk cement instead of bagged cement, dust, pollution will be reduced.
* Conservation of energy and resources because of saving of cement.
* Environment pollution is reduced due to less production of cement.
* Better durability of structure.

* minimising human error & reduction in dependency on labour.
* Timely deliveries in large as well as small pours.
* No need for space for storing the materials.
* Reduced noise & air pollution;
* Less consumption of petrol & diesel & less time loss to business.

6) SIFCON → slurry infiltrated fibrous concrete.

* SIFCON is a high strength, high performance material containing a relatively high volume percentage of steel fibres and gives ductility.
* The cement slurry is introduced over the steel fibre and coarse aggregate is omitted.

Advantages of SIFCON :-

* Tensile strength is higher than ordinary FRC
* In FRC there is a risk of clustering
* Fibre content is limited to 2 to 5% in FRC
* High flow ability and passing ability.
* Excellent durability, energy absorption capacity, impact and abrasion resistance & toughness.
* Modulus of elasticity (E) values is more compared with plain concrete.
* High ductility.
* Deflection very less compared to conventional & will act as rigid body.

Usage/ Application of SIFCON :-

* Pavement rehabilitation & Pre cast concrete products.
* over lays, bridge decks & protective revetments
* Seismic & explosive resistant structures.
* security concrete applications.
* Refractory applications.
* Sea protecting works
* Military applications → anti-missile hangers, under ground shelters.
* Aerospace launching platforms
* Repair, rehabilitation & strengthening of structures.
* Concrete mega Structures → offshore & long span Structure solar tower.
*

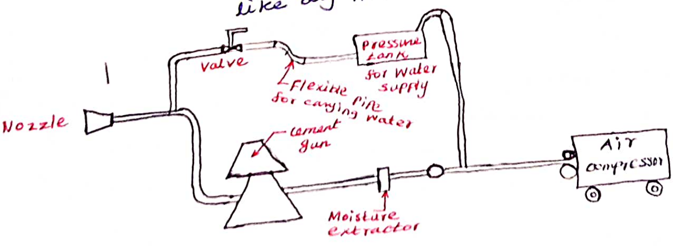
7) shotcrete (or) Gunite :-

* process of conveying dry (or damp) sand & cement by means of compressed air through material hose to a nozzle where water is added before the material is sprayed on the construction surface is called shotcrete or Gunite.

Methods — Dry mix / Wet mix

1) Dry mix :- → The cement & sand is mixed thoughly in dry state.

2) Wet mix → Concrete is mixed with water before conveying through delivery pipe & not suitable like dry mix.



Procedure of shotcrete on surface :-

* Throughly clean all surfaces to receive shotcrete by removing loose materials & dust, Pressure washing & dampen the surface to saturated surface dry condition.
* Fix wire mesh to the concrete surface.
* The steel wire mesh has to be placed in position keeping the mesh with in 10 to 15 mm from the surface.
* Suitable fixing pins are to be inserted to keep the mesh in proper position and to ensure that the weld mesh is not disturbed during shotcreting.
* Prepare cement-sand / water mix & Pour this mix into pump hose for lubrication before starting to pump the production mixture.
* When the pumped mixture reaches the nozzle, turn on compressed air.
* Apply shotcrete evenly to targeted surface. Built-up the desired thickness of shotcrete in layers of about 30mm thick each.
* The presence of voids can be found by hollow hammering sound after the shotcrete has attained strength after around 3 days.

Application of shotcrete :-

* It can be used to repair the damaged surface of concrete.
* Shotcrete repair can be used for bridge deck rehabilitation
* repair of fire & earthquake damage and detoriation strengthening walls.
* To merine structures can result from detoriation of the concrete and of the reinforcement.
* Underground excavations in rock.
* Used for temporary protection of exposed rock surfaces that will deteriorate when exposed to air.
* to construct concrete swimming pools.

* Shotcrete floors in tanks & pools on well compacte sub base.

8) Polymer concrete

Unit - IV

Techniques for Repair & Protection Methods

Non-destructive Testing techniques — Load Test for stability - Epoxy Injection, Shoring under pining, — corrosion protection techniques — corrosion, Inhibitors, Corrosion resistant steels — coatings to reinforcement, — cathodic protection.

—— x —— x —— x —— x —— x —— x —— x ——

Corrosion protection Techniques :-

- The following methods are protecting steel from corrosion.

* Corrosion inhibitors
* Protective coatings for reinforcement
* Cathodic protection.
* Corrosion Resistance steel

(1) Corrosion Inhibitors :-

* It is a substance when added in a small concentration to an environment reduces the corrosion rate of metal exposed to that environment.
* Oil extraction and Processing industries.

* Types of corrosion inhibitors

(i) Anodic Inhibitors :-

* Forming a protective oxide film on the surface of the metal causing large anodic shift of the corrosion potential.
* This shift forces the metallic surface into passivation region.
* chromates, nitrates, tungstate, molybdates are some example.

(ii) Cathodic Inhibitors :-

* act by slowing the cathodic reaction itself or selectively participating on cathodic areas to limit the diffusion of reducing species to the surface.
* The rates of the cathodic reactions can be reduced by the use of cathodic poisons.
* It can also increase the susceptibility of a metal to hydrogen induced cracking since hydrogen can also absorbed by the metal during aqueous corrosion or cathodic charging.
* The corrosion rates can be reduced by the use of oxygen scavengers that react with dissolved oxygen.
* Example : sulphite and bisulphite ions.

(iii) Mixed Inhibitors :-

* mixed inhibitors work by reducing both the cathodic and anodic reactions.
* They are typically film forming compounds that cause the formation of precipitates on the surface blocking both anodic & cathodic sites indirectly.
* Hard water is high in calcium and magnesium is less corrosive than soft water (because of salt in hard water)
* Most common inhibitors — silicates & phosphates.
* Sodium silicates, for example is used in many domestic water softeners to prevent the occurrence of rust water.
* In aerated hot water system, sodium silicates protects steel, copper and brass.
* protection is not always reliable & depends heavily on Ph
* Phosphates require oxygen for effective inhibition.
* silicates & phosphates do not afford the degree of protection provided by chromates & nitrites.

* They are very useful in situations where non-toxic additivies are required.

2. Coatings to Reinforcement :-

* It is to provide a durable barrier to aggressive materials (chlorides).
* to withstand fabrication of reinforcement cage & Pouring of concrete and compaction by vibrating needle.
* Simple cement slurry coating is cheap method for temporary protection against rusting of reinforcement in storage.
* Central Electro chemical Research Institute (CECRI) Karaikudi have suggested a method for ~~protection~~ Prevention of corrosion in steel reinforcement in concrete.

* The steps involved in the process are

(i) Derusting :-

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

(ii) phosphating :-

* phosphate jelly is applied to the bars with fine brush.
* The jelly is left for 45-60 minutes and then removed by wet cloth.
* An inhibitor solution is then brushed over the Phosphated surface.

(iii) Cement coating :-

* A slurry is made by mixing the inhibitor solution with Portland cement applied on the bar.
* A sealing solution is brushed after the rods are air cured.

* The sealing solution has an insite curing effect.
* The second coat of slurry is then applied and the bars are air dried.

(iv) Sealing:-

* Two coats of sealing solutions are applied to the bars in order to the micro-pores of the cement coat and to make it impermeable to corrosive salts.

(v) Fusion Bonded Epoxy Coating:-

* It is one of the effective methods of coating rebars.
* It carried out in a factory and at not at site of work.
* Plants are designed to coat the straight bars in a continuous process.
* Initially the bar is shot blasted to remove all mill scale & to give the kind of surface finish required.
* To ensures an adequate bond b/w epoxy & steel.
* The bar is heated to carefully controlled temperature, before passing through a spray booth.
* Electrostatically charged epoxy powder particles are deposited evenly on the surface of the bar.
* It looks, greenish in colour.
* coating thickness vary from 130 to 300 microns.
* epoxy coated bars have an excellent protection to corrosion in aggressive environment.

Limitations:-

* After the treatment cutting & bending injure the steel.
* site treatment is inefficient.
* induced localised severe corrosion

* bars can not be welded.
* epoxy is not resistant to UV rays of sun.
* coating get damaged during vibration of concrete.
* This treatment is very costly. (nearly costly as that of steel)

(vi) Galvanised Reinforcement :-

* It consists of dipping the steel bars in molten zinc.
* this results - coating of zinc bonded to the surface of steel.
* Zinc surface reacts with calcium hydroxide in a concrete to form a passive layer and prevents corrosion.

3) cathodic protection :- (CP)

* It is one of the well known, and extensively used methods for prevention of corrosion in concrete structures in ~~more~~ more advanced countries.
* Due to high cost and long term monitoring required for this method, it is not very much used in India.
* Two basic methods of supplying electrical currents required to interface with electrochemical cell action.
* They are
  1. Cathodic protection with galvanic anodes
  2. Impressed current cathodic protection.

1. Cathodic protection with galvanic anodes

* It is a technique to control the corrosion of a metal surface by making it work as a cathode of an electrochemical cell.
* 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.

* It is also called sacrificial anode cathodic protection system.

* It is high energy electrons required for Cathodic protection are supplied by the corrosion of an active metal.

* depend on the differences in corrosion potential that are established by the corrosion reactions that occur on different metals or alloys.

* Example:- The natural corrosion potential of iron is about -0.550 Volts in sea water.

* The natural corrosion potential of zinc in seawater is -1.2 volts.

* 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 ensure that the anode will produce the despired output.

* Sacrificial anodes are normally supplied with either lead wires or cast-in straps to facilitate their connection to the structure being protected.

* The lead wires may attached to the structures by welding or mechanical connections.

* Low resistance & should be insulated to prevent increased resistance or damage due to corrosion.

* When anodes with cast-in straps are used, the straps weeded directly to the structure or the straps can be used as locations for attachment

* 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.

(2) Impressed current Cathodic protection

* The cathodic protection comprises of application of impressed current to an electrode laid on the concrete above steel reinforcement.

* This electrode serves as anode and the steel reinforcement which is connected to the negative terminal of a DC source acts as a cathode.

* In this process the external anode is subjected to corrode the cathodic reinforcement and hence is protected against corrosion and hence the name "cathodic protection".

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

* The environment around the steel reinforcement reverts back to alkaline condition which protects the steel.

* The other recent development in corrosion control methods are Realkalisation and Desalination.

* Realkalisation process allows to make the concrete alkaline again and passivate of reinforcing steel by electro-chemical method.

* the lost alkalinity of concrete to sufficiently high level to reform 4 maintain the passive layer on the steel.

* In the desalination process the chloride ions are removed from the concrete, particularly from the vicinity of the steel reinforcement by certain electrical method to restablish the passive layer on the steel.

(4) Corrosion Resisting steel :-

* In mild steel, the corrosion is not sufficiently or significantly affected by composing, grade or level or stresses.

* Substitute steels for corrusion resistance will have a significantly different compaction.

* Based on some atmosphere, corrosion weathering, steel of correct type were tested in concrete.

* They did not perform well in most content containing chloride it is observed that the weathering steel corrode in similar concrete to those can corrosion at high yield strength of steel.

* Total amount of corrosion less than would occur on high yield steel under similar conditions, deep localized pitting developed, which could be more structurally weakened.

* Stainless steel pipe has been used special applications especially as flames in precast members, but generally not expect use as a substitute for wild ~~street~~ steel any case stainless steel should not concrete involving under corrosion resistant.

* stainless steel contains relatively lower content of chloride levels, delayed time to cracking for high strength steels.

* very high corrosion resistance was shown by austenitic stainless steel, in all the environment.

Factors Influencing Corrosion of Reinforcement for RC Structures

1). General Influencing factors

* pH value
* Moisture
* oxygen
* chloride
* corbonation
* Ambient Temperature
* severity of exposure
* Quality of concrete
* Cover to the reinforcement
* Initial curing condition
* Formation of cracks.

2). General Accelerating factors

* chlorides
* sulphates
* chlorine
* Electrical charges
* Methane Acids.

Epoxy - Injection Grouting

* Cracks as narrow as 0.002 in. (0.05mm) can be bonded by the injection of epoxy.
* The technique generally consists of establishing entry & venting ports at close intervals along the cracks, sealing the crack on exposed surfaces, and injecting the epoxy under pressure.
* Epoxy injection has been successfully used in the repair of cracks in buildings, bridges, dams, and other types of concrete structures.
* The causes of the cracking has ~~been~~ been corrected, it will probably recur near the original crack.
* The general procedure are given below.
  - clean the cracks
  - seal the surfaces
  - fittings inserted into drilled holes
  - Bonded flush fittings.

* Clean the cracks :-

- 1st step to clean the cracks have been contaminated
- contaminants such as oil, grease, dirt or fine particles of concrete prevent epoxy penetration & bonding & reduce the effectiveness of repairs
- contamination should be removed by vacuuming or flushing with water or the specially effective cleaning solutions.

* Seal the surfaces :-

* Surface cracks should be sealed to keep the epoxy from leaking out before it has gelled.
* A surface can be sealed by applying an epoxy, polyester or other sealing material to the surface of the crack & allowing it to harden.

* If a permanent glossy appearance along the crack is objectionable & if high injection Pressure is not required, a strippable plastic surface sealer may be applied along the face of the crack.

* Then the surface sealer can be stripped away to expose the gloss-free surface.

* Cementitious seals can also be used where appearance of the completed work is important

* If extremely high injection pressures are needed the crack can be cut out to a depth of 13 mm and width of about 20mm in V-shape filled with an epoxy and struck off flush with the surface.

* Install the entry and venting ports. Two methods are in general use

- Fittings inserted into drilled holes:-

  * This method was 1st to be used, and is often used in conjunction with V-grooving of the cracks.

  * The method entails drilling a hole into the cracks, approx. 20mm in diameter & 13 to 25mm below the apex of the V-grooved sectio

- Bonded flush fitting:-

  * When the cracks are not V-grooved a method frequently used to provide an entry port is to bond a fitting flush with the concrete face over the crack.

  * The flush fitting has an opening at the top for the adhesive to enter a flange at the bottom that is bonded to the concrete.

* Mix the epoxy:-

* This is done either by batch or continuous methods
* In batch mixing, the adhesive components are premixed according to the manufacturers instructions, usually with the use of a mechanical stirrer, like a paint mixing paddle.
* care must be taken to mix only the amount of adhesive that can be used prior to commenement of gelling of the material.

Inject the epoxy:-

* hydraulic pumps, Paint pressure pots, or air actuated caulking guns may be used.
* The pressure used for injection must be selected carefully.
* Increased pressure often does little to accelerate the rate of injection.
* If the cracks is vertical or inclined, the injection process should begin by pumping epoxy into the entry port at the lowest elevation until the epoxy level reaches the entry port above.
* For horizontal cracks, the injection should proceed from one end of the crack to the other in the same manner.
* The crack is full if the pressure can be maintains
* If the pressure can not be maintained, the epoxy is still flowing into unfilled portions or leaking out the crack.

Remove the surface seal:-

* After the injected epoxy has cured, the surface seal should be removed by grinding or other means as appropriate.

Routing & sealing

* It involves enlarging the cracks along its exposed surface, filling & finally seailing it with a suitable material.
* It is the simplest and most common technique for sealing cracks & is applicable for sealing both fine pattern cracks & larger isolated.

Non-Destructive Testing Techniques

* To evaluate the strength, durability & other properties of concrete without causing damage.
* NDT methods are relatively easy to perform & analysis of test result not so easy.
* The specimens are not loaded to failure.
* NDT → to measure some other properties of concrete (estimate its strength, durability & elastic parameters)
* Various properties — hardness, resistance to penetration of projectiles, rebound number, resonant frequency & ability to allow ultrasonic pulse velocity to directly indicate.
* The electrical properties of concrete its ability to absorb, scatter and transmit X-rays and Gamma rays, its response to nuclear activation and acoustic emission allow us to estimate its moisture content, density, thickness & its Cement Content.

Methods of Non-Destructive Testing of concrete:

Surface hardness Test:-

* These are of identation type, include the Williams testing pistol and impact hammers and are used only for estimation of concrete strength.

Rebound test:-

* The rebound hammer test measures the elastic rebound of Concrete and is primarily used for estimation of concrete strength and for comparitive investigations.

Penetration and Pull out techniques:-

* These include the use of the simbi hammer, spit pins, the windsor probe and the pullout test
* These measure the penetration and pullout resistance of concrete and are used for strength

estimations, but they can also be used for comparative studies.

Dynamic or vibration Tests:-

* These include resonant frequency and mechanical sonic & ultrasonic pulse velocity methods.
* These are used to evaluate durability and uniformity of concrete and to estimate its strength and elastic properties.

Combined methods:-

* The combined methods involving ultrasonic pulse velocity and rebound hammer have been used to estimate strength of concrete.

Radioactive and nuclear methods:-

* These include the X-ray & Gamma-ray penetration tests for measurement of density and thickness of concrete.
* The neutron scattering and neutron activation methods are used for moisture and cement content determination.

Magnetic and electrical methods:-

* The magnetic methods are primarily concerned with determining cover of reinforcement in concrete, whereas the electrical methods, including microwave absorption techniques, have been used to measure moisture content and thickness of concrete.

Acoustic emission techniques:-

* These have been used to study the initiation and growth of cracks in concrete.

Shoring

* It is used in construction to describe the Process of supporting a structure inorder to prevent collapse.

* It is used to support the beams and floors in a building while a column or wall is removed.

* In this situation vertical supports are used ~~to~~ as a temporary replacement for the building columns or walls.

* shoring is the construction of a temporary structure to support temporarily an unsafe structure.

* These support walls laterally.

* They can be used under the following circumstances
    * When walls bulge out
    * when walls crack due to unequal settlement of foundation and repairs are to be carried out to the cracked wall.
    * When an adjacent structure needs pulling down.
    * when openings are to be newly made or enlarged in a wall.

Trenches:-

* During excavation, shoring systems provide saftey for workers in a trench & speed excavation.
* shoring should not be confused with shielding.
* shoring is designed to Prevent collapse where shielding is only designed to protect workers when collapse occur.

~~Shoring~~

* concrete structures shoring, provides temporary support until the concrete becomes hard & achieves the desired strength to support loads.

Ships

* It is used on board when damage has been caused to a vessel's integrity, and to hold leak-stopping devices in place to reduce or stop becoming water.
* consists of timber 100 x 100mm and used in conjunction with wedges, to further jam shoring in place, pad pieces to spread the load. ~~and~~ ~~(illegible)~~
* The arrangement employed to prevent a damage structure, due to either foundation settlement or other reasons from collapse is called shoring
* It is used for providing temporary support to a structure which is being remodelled.

Types of shoring :-

1. Racking shores:-

* Notches are cut in the walls of the building and inclined posts are property, while demolishing the building are called ~~horizontal~~ ~~or flying shores~~. Racking shores.

2. Horizontal of flying shores:-

* Which are employed to support the walls of adjoining property while demolishing the building are called horizontal or flying shores.

3. Vertical Dead shores

* It is used to support walls temporary are called vertical ~~or~~ dead shores.

Underpining

* In construction or ~~as~~ renovation, underpining is the process of strengthning the foundation of an existing building or other structure.

* A mix of structural resins and hardener is injected into foundation ground beneath footings.

* On entering the ground the resin and hardener mix and expansion occurs due to a chemical reaction.

* The expanding structural resin mix fills any voids and crevices, compacts any weak soil and then, if the injection is continued the structure above may be raised and re-levelled.

* This relatively new method of underpining, has been in existence for approximately 30 yrs

* It does not involve any construction or excavation set-up is known to be a clean fast and non-disruptive underpining method.

Unit - V

Repair, Rehabilitation & Retrofitting of structures

Strengthening of structural elements — Repair of structures distressed due to corrosion — fire — leakage, earthquake — Transportation of structures from one place to other — Structural Health monitoring — demolition techniques — Engineered demolition methods case studies

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Strengthening of Structural elements:-

* Basic structural element in most building deteriorated and require attention to improve the load carrying capacity
* Modification or Strengthening give required relief to structure and enhance the Performance of columns, beam & slabs.

Need for Strengthening:

* load increases due to higher live load, increased wheel loads, installations of heavy machinery or vibrations.
* Damage to structural parts due to aging of construction materials or fire damage, corrosion of the steel reinforcement & impact of vehicles
* Improvements in suitability for use due to limitation of deflections, reductions of stress in steel reinforcement & reductions of crack width
* Special modification of structural system due to elimination of walls/columns & opening cut from slabs.

* Errors in planning or construction, due to insufficient design dimensions & insufficient reinforcing steel.

Deflection due to strengthen in flexural members:

* bridge girders → less attention paid to the bond between old concrete & new anchor blocks
* existing concrete cut back to the depth of the cover & roughened.
* new block injection → injected with low viscosity epoxyresin under pressure. Monitored ultrasonically.
* injection
* new tendons were deflected, reinforcement required.
* anchor blocks → success of repair → dowel bars provided.
* success → roughness imparted to the old concrete.
* Epoxy joining → deform over period & relax stressed tendons.

Strengthening of Beams:

* load acting on it should be reduced by removing the tiles etc.
* props erected at mid span of each slab & tightened → not damaged.
* after chipping off each plaster → additional reinforcement at bottom with new stirrups provided.
* bars are inserted in supporting columns through holes of appropriate diameter.
* spaced b/w bars & surrounding holes filled with epoxy grout. Expanded wire mesh is fixed → on 3 sides of beam.

* required thickness on three sides is acheived by application of 2 to 3 layers of Mortar.
↳ while applying to bottom of beam → thickness of Motor layer should be adjusted.
* cured by appropriate period water → after allowed to cure in air.
* Epoxy injected in the cracks
* new stirrups required then followed.

Deflection due to strengthening of slabs :-

Deflection due to strengthening of beam :
* Taken after strengthening of beam completed.
* reinforced structural concrete topping used → a composite construction of old & new slabs.
* good bond b/w old & new concrete → steel bolts inserted in holes drilled into slabs at intervals. → spaces around holes filled with epoxy, grout.
* shear connector is embeded for half of its length in old concrete and remaining embeded in new concrete.
* old floor slab thoroughly scabbled and cleaded before applying topping.
* Additional reinforcement may be required over the supports.
* epoxy coat is applied on it
* coat is touch dry 25 to 50mm thick M20 grade topping is laid.
* thickness of topping is governed by strength & thickness of old floor slab.
* application of topping increased dead weight
* after curing the beam & slab for 14 to 21 days props can be removed.

Deflection Due to strengthening of columns:-

* jacketing → process of fastening a durable material over concrete & filled the gap with a grout
* column jacket → increase the punching shear strength of column slab using its column capital
* its termed a collar → provide around the periphery of column.
* collar → transfer vertical load to the column.
* circular reinforcement → load transfer.
* transfering loads through dowel bars has embeded in to colums or shear keys

disadvantage → Require drilling of holes for dowels or cutting shear → costly, time consuming damage existing column.

* expansion of collar as its slides along roughened surface → cause tension of circular reinforcement result in radical compression. → lead to load transfer.
* the shear transfer strength is provided by both frictional resistance to sliding & dowel action of reinforcement crossing the crack
* collar is subjected to shear & bending as well as bearing stress under concentrated load.
* Column collars provided below slabs to improve punching shear strength.

Various technique to repair spalling & Disintegration of concrete:-

* Jacketing
* pneumatically applied morater or concrete
* prepacked concrete
* Replacement of concrete
* Dry pack
* over lays
* Epoxy resins
* protective surface treatment.

Structural Health monitoring (SHM)

Need for structural health monitoring

(i) Analysis & Design phases

* Imperfections in analysis & design
* Assumptions of ideal construction conditions.

(ii) Construction phases:-

* Compromises in implementing the design
* poor quality of materials & workmanship

(iii) Degradation

* Deterioration of material properties with time
* Damages due to excessive loading and unforeseen impacts.
* Environmental effects on material properties.

(iv) Natural Calamities:-

* Earthquakes
* Storms & cyclones
* Floods & Tsunami effect on structures built over water bodies
* Chemical attacks.

Need for continuous Monitoring:-

* Periodic visual inspections
* Efforts are being invested by many capable researchers around the world in recent times, the development of an efficient structural health monitoring ie, real time online automated health monitoring.

* Real time ~~implies~~ → monitoring is continuous even during the Service period of the structure.
  - quick to remedial action or evacution.

* on-line → altering system
  use user friendly on screen imaging & audible alarms.

* Automated → diagnosis & altering system
  does not need human interference for its operation.

* Motivation for a SHM system:-

I. Structural view

* Predicts optimal use of the structure
* ~~minimizes~~ minimizes downtime of the structure
* avoids catastrophic failures.

II. Constructor view:.

* gives the constructor a scope for improvement in his Products.
* gives him a chance for repair before an embarrassing collapse of the structure.

III. Maintenance Services view.

* drastically changes the work organization of maintenance Services.
* replaces scheduled and periodic maintenance inspection with Performance based (Condition based) Maintenance.
* reduces the present maintenance labour,
* minimize the human involvement, reducing labour, reducing human errors & improving saffety and reliability.

IV. Improving saftey
V. Reducing Accidents & losses
Vi. Economic savings primarily for end users.

SHM - Definition

* Structural Health monitoring is a process of real time, online & automated evaluation of a structure's integrity and performance, prediction of the remaining serviceable life of structure & timely warning to the end user of it deterioration.

* A critical structure in service is monitored for
  - strength of the constituents materials
  - stresses due to loads with permissible limits.
  - deflections & strains for serviceability conditions
  - integrity of the structural assembly at its joint
  - occurrences of damages.

SHM - Classification

(i) Diagnosis → determine the presence of flaws, their location.

(ii) Prognosis → the information of the diagnosis part & determine the remaining life of the structure.

Levels of SHM

* Level I → confirming the presence of damage
* Level II → determination of location & orientation of the damage.
* Level III → Evaluation of the severity of the damage.
* Level IV → Possiblity of controlling or delaying the growth of damage.
* Level V → Determining the remaining life in the structure (Prognosis).

Components of a SHM system:-

* Sensing Technology
* Diagnostic signal Generation
* Signal processing
* Damage identification Analysis
* System Integration

Sensing Technology:-

* It consists of an array of distributed sensors, either wired or wireless to interrogate the structure at periodic intervals or continuously.

Diagnostic signal Generation:-

* It involves generation of suitable signals from the sensors
* reflect the desired parameters in the health assessment of the structure with the properties of controllability, repeatability, reliability and sensitivity to damages.

signal Processing:-

* To efficiently transmit the diagnostic signal, while filtering out unwanted noise. so that the signal analysis gives ~~real~~ realistic picture of the state of the structure.

Damage identification Analysis:-

* Brain of the SHM system.
* it relates the sensor measurements to the physical changes in the structures.
* It involves expertize in identification & characterization of damages using the Knowledge of static & dynamic structural mechanics, material properties & physics of the specific sensing technology being used.

System Integration :-

* software development, with the support of suitable hardware components,

* to control the mentioned components with a user friendly interface

* Capable of giving needed indications & warnings to the maintenance department or the user.

Repair of Structures distressed due to Corrosion:

Sulphate Attack

* Sulphate are found in most of the Soils as calcium, potassium, Sodium and magnesium Sulphates.

* Sulphate attack occurs when pore system in Concrete is penetrated by solution of sulphates.

* Chemical Mechanism → The effect of sulphate on Concrete mainly chemical & physical.

* Sulphate attack or reaction is indicated by the characteristic whitish appearance on the surface.

* Results of chemical reaction b/w sulphate and hydration products, changed in the microstructure and pore size distribution of the cement paste.

* Sulphate Converts Calcium hydroxide into large of calcium sulphate.

$$Na_2So_4 \cdot 10H_2O + Ca(OH)_2 \; CaSO_4 \rightarrow 2H_2O + 2NaOH + 8H_2O$$

* The second hydration produce, tricalcium aluminates hydrate reacts with sulphate solution to form sulpho aluminates hydrate, which has a greater Volume than that original Compound.

Salt/weathering attack

* Solid salts donot attack concrete, but present in solution they can react with hardened concrete.
* It is more problems in masonry structures.
* Efflorescense is a whitish crystalline deposit on the surfate.
* Efflorescense → formation of calcium carbonate precipitate on the concrete surface.

Prevention measures:

* using sound materials free from salts
* Proper concrete proportioning
* Consolidation & curing
* Preventing the access of moisture to the structure

Water:-

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

Common materials

Metallic types

* pearlitic iron turnings
* crushed cast iron chilled grit.

Non-metalic types.

* silicon carbide grains
* Fused alumina grains
* Natural emergy grains

* Eccentrically loaded colums fail when reinforcement bars in tension heat up.

* The fire resistance of such elements can be increased by Increasing the thickness of Protective layer.

* Heat transmission and temperature of bottom reinforcement are keys to the behaviour of reinforced concrete slab exposed to fire.

* The reinforcing bars are assumed to retain one half of their original strength.

* Carrying Capacity of slab can be enhanced by increasing their thickness.

* For beams, — depth & width can be increased.

* In beams — weakening of bond b/w transverse reinforcement & concrete on accunt of heating reduces the residual shear load carrying capacity.

* Increase the c/s with suitable & increase the longitudinal steel.

Leakage

* The concrete structure causes to damage the reinforcement.

* construction joints, shrinkage & restraint cracks may from leak paths.

* The amount of water involved vary from damp-patches to evaporate as they are formed to running leaks which may eventually form undrained surfaces

* Water passes through the voids along reinforcing bars formed due to plastic settlement.

Fire :-

* A fire in a concrete structure causes damage.
* The principle types of damages are,
  - Reduction in strength of concrete
  - cracking & spalling of concrete
  - Deflection & deformation of members
  - Discolouration.
* Concrete structures are determined by three main factors
  - The capacity of concrete itself to withstand heat.
  - The conductivity of the concrete to heat
  - The co-efficient of thermal expansion of concrete.
* A large number of reinforced concrete structures salvaged from destruction in fires by timely fire fighting operations.
* Service after strengtheing & providing some cosmetic repairs.
* The cost of restoration of such structures less than that for dismantling and construction of new ones.
* The fire may cause different degrees of damage to the structure.
* The structure may be completely burnt or destroyed.
* Slightly damaged — slight deformation may occur.
* High temperature → fire reduces the strength of RCC structures, change in the strength & deformability of materials, reduction in c/s dimensions, weakening of bond strength b/w reinforcement & concrete.

Restoration of fire damaged elements :-

* Shear cracking can occur in columns & cracking resulting from inversion of moment, may detailing is not adequate.

Techniques

* Conventional leak - Sealing Methods
* Leak - sealing by injection techniques.

(i) Conventional Methods

* minor leakage may dry up by autogenously healing is an accumulation of calcium salts along the leak path.
* obstruct the passage of Water over period of time and reduce the leakage to negligible proportions.
* The remedial action involve the application of local or complete Surface seal in the form of a coating system.

Procedure

- Surface Preparations
- Filling of surface imperfections with resin based grouts.
- Application of primer.
- Application of two coats of high - build paint.

* The procedure may require quite extensive preparatory work including the injection of Suspect joints and random shrinkage cracks with allow viscosity resin.
* Honey combed concrete - filled out using resin based mortar.
* Laitance and surface contaminants may be removed by sand blasting and power wire brush

(ii) Injection sealing:-

* From liquid flow and pressure considerations the Simplest and most cost effective way is to seal the leakage from the water retaining side of the structure.

* The wet side is inaccessible, the leakage must be tackled from the dry side is considerably more difficult.

* Successful leak Sealing requires injection of sealant to fill water passes completely, & it is necessary to attain are latively high flow velocity. to achieve.

Procedure

* to resist or confine the water flow to tube through the Sealant any be introduced.

* Concrete being stressed during injection it is Preferable to maintain lower pressures.

* The direct methods are very slow due to Sealant being pumped Slowly through very narrow passage against pressure.

* The pressure Can not maintained for long enough to achieve Complete penetration.

* Indirect methods enable the work to be completed quickly because Surface Seals are not required & mechanical anchorages can be used.

Repair of Concrete structure distressed due to EQ Earthquake :-

* EQ damages depend on many parameters, including
  - Intensity
  - duration & frequency of ground motion
  - geologic & soil condition
  - quality of construction etc.

* Building design must be such as to ensure that the building has adequate strength, high ductility & will remain as an integral unit even when subjected to very large deformation.

* The study of the damage provides an important step in the evoluation of strengthening measures for different types of buildings.

* The following basic causes of building damages during EQ
  - Ground shaking
  - Ground failure
  - Tsunamis & tidal waves
  - Fire

* According to the extent of damage, the post disaster actions to be taken for various damage categories.

* Repairs for earthquake damaged Concrete & masonry wall buildings fall into three generic categories.
  - cosmetic repairs
  - Structural repairs
  - Structural Enhancements

Cosmetic repair

* improve the visual appearance of component damage
* To restore the non structural properties of component such as weather protection.

* Example : routing, sealing & Painting of cracks in concrete or masonry.

<u>Cosmetic Patch</u> :-

* It consists of applying a surface coating on the surface of the concrete or masonry wall to conceal the surface projection of cracks.

* Purpose → ~~the wall or~~
 * to improve the aesthetic appearance of the wall
 * to Provide an addition barrier against water infiltration into the wall.

<u>Repair Materials</u> → used for surface coatings
 → choice of repair material depends on functional & architectural requirements

(i) paint → to conceal fine cracks on the RCC & masonry walls

(ii) Dry wall taping ~~wall covering~~ Compound → fill cracks on interior surfaces before paint or wall coverings are applied.

~~(iii) Dry. wall taping compound →~~

(iii) Wall Covering → wall paper can be used on smooth interior concrete surface.

(iv) organic polymer Materials → fill cracks on interior & exterior concrete or reinforced masonry surfaces.

(v) coating or sealers → used for exterior surfaces
 * to reduce water penetration for concrete, reinforced masonry & un reinforced masonry walls.

(2) <u>structural repairs</u> → to restore structural properties.
 * The replacement of fractured reinforcing bars.
 * Example :- injection of cracks or replacement of reinforcing bars.

(i) crack injection → applying a structural binding agent into a crack for the purpose of filling the crack & adhering to the substrate material.

* For concrete & fully grouted, reinforced masonry walls, epoxy ~~is~~ is typically injected to cracks under pressure.

Repair Materials

* ASTM standard C881 - Type-I - Low viscosity grade Epoxy

* Fine cementitious grout & urethanes (used for structural bonding)

(ii) Bar Replacement

* It is necessary to cut out the damaged length of reinforcing bar & to replace it with new bar.

* In this instance two mechanical connections are required, (one connection is installed at each end of the replacement bar).

~~Repair materials~~

*

(3) Structural Enhancement :

* Supplemental addition or removal & replacement of existing damaged components.

* They are include the addition of new components in the structure not necessarily at the site of existing damaged components.

* to replace structural properties of damaged components.

Example :- include the application of concrete overlays to damaged wall or addition of shear walls or steel bracing to the building - before EQ

overlays concrete

* is applied shotcrete or cast in place layer on to one or both surface of the wall.

* Two different process for shotcrete used in practice.

(i) Dry mix process → dry cement & aggregate delivered to the nozzle.

(ii) Wet mix Process. → All ingredients are premixed delivered to the nozzle.

Repair Materials → Portland cement, aggregate & water

* mixing & proportions depend on number of factors, including the process (wet mix & dry mix process)

Demolition Techniques

Preliminary procedures in demolition of a structure:-

* Preliminary investigation
* preliminary considerations
* General site provisions
  - plant & equipment
  - Protective clothing
  - shoring & underpinning
  - working areas
  - Debris
  - Weather conditions
  - Flooding
  - over head cables
  - scaffolding & Hoarding
  - security
  - Dust
  - Noise
* Supervision of demolition work.

Demolition Process

* Demolition as part of the process of construction & is as follows.
  - Developing a demolition strategy.
  - Building information
  - Selecting appropriate techniques
    - saftey of personnel & public
    - working methods
    - Legislation applicable
    - Insurance cover.
  - Preliminary aopects prior to site Demolition work
    → site & building survey, with a structural bias
    → examination of drawing & detailing
    → Preparation of details & drawing
    → Programming sequency of demolition work
    → Preparation of a method Statement.

Demolition Methods

* Buildings & structures should be demolished in the reverse order to their erection.
* partial demolition → more careful – effects.
* demolition contractor is able to adopt a method
  - gradually reduces the height of the building
  - arrange the deliberate controlled collapse of the building or structure.

Demolition techniques

* Piecemeal demolition → using hand held tools.
* Mechanical method
  - Hydraulic crusher with Long Boom arm
  - wrecking Ball
  - Pusher arm
  - wire rope pulling
  - calm shell
  - other method
    - Non explosive demolition agent
    - Explosive demolition
    - Saw cutting
    - cutting & lifting
    - water jet.

Precautionary measures during demolition

* Training & communication → demolition workers/equipment operators
* Equipment maintenance
* Electrical saftey
* Fire → all furniture, timber, doors + windows removed
* occupational health → Dust, chemical exposure, Noise,
  * First aid Facilities must
* Emergency exit requirements in demolition sites
* Vibration.

Case study

Demolish a building using implosion technology

Details

* In western Railway, Mumbai division
* G+3 storied building, numbered 25/T railway. constructed in 1924 by BB + CI railway. 1st cement concrete residential structure in Mumbai.
* 80 nos (4×20) Type I quarters,
* Total land area 430 sqm.
* ht of building 13.2 m above rail level.
* Structure completed its designed life.

Necessity to use Implossion technology

* the structure very near to the running track.
* it requires continuous track protection/traffic block, resulting in long disruption to running traffic.
* The manual method was not suitable

* Mechanical method not suitable (no space for heavy machinery near the structure to work, ht 13.5 m)

* it was considered implosion.

* the building down on its foot print in very less time was considered suitable.

Drilling of holes for placement of explosive

* holes drilled about 25mm to 30mm dia & 20 to 30 cm deep (depending upon the quantity of explosive energy)

* provided totally 20 holes of 25mm dia & 30cm depth central column.

* It was reduced to 4 holes of 25mm dia & 20 cm deep (4 x 1) at colums away from centre.

Quantity of explosive :-

* to be placed depends on size of column & extent up to destroyed

* 250 gm of explosive in central 24 columns were placed. 125 gm in outer 16 columns

* No outer column was weakened (building collapsed towards its centre from both side)

Type of explosive & Detonators

* Two types of explosive commonly used
  (i) RDX
  (ii) Gelatin

* We use brand name Power Gel explosive (ammonium nitrate based)

* very high speed & very high pressure about 600 T/sq. inch.

* electronic detonatore used to ignite the explosive

Test Blast

* before actual blasting
* efficiency of explosive & detonators, to develop a confidense.

Wrapping of holes

* holes were covered with gunny bags & iron net after placement of explosive & detonators.

Ballasting

* time gap 1/100 second b/w two successive blasts.
* The trigger of charges in done in such a control manner — noise & air pollution should be minimum.
* Central column 1st triggered & then blast proceed towards out side to produce three way action.
* Result — fall of existing structure on its foot print.

Falling of Structures

* once central support/column will be destroyed & adjoining columns will be weakened,
* after blasting with in few second the entire structure (G+3) storied came down on its foot print without damaging.