Subject : Maintenance and Rehabilitation of Structure(3360605)

“UNIT-4 : Materials and Techniques For Repair”

Introduction:

- Though the concrete is relatively durable construction material, it may suffer damage or distress during its ife period due to number of reasons. Deterioration of concrete structure is the natural process of gradual degradation of constituent materials through physical, chemical and mechanical process. Occasionally natural or manmade calamities accentuate this process. As a result ,the ability of a structure to perform its intended function is impaired and there arise a need of repair or upgrade a structure to restore the desired level of serviceability.
- A basic understanding on causes of concrete defects or deficiencies is essential for performing meaningful evaluation and successful repairs. Which help in selection of repair material and appropriate repair techniques.

- Selection of suitable repair material is one of the most important tasks for ensuring durability and trustworthy repair. Though the detailed investigation of cause of distress is the prerequisite for a sound repair technique.
- The process of selection of repair material and its effectiveness under service condition is very important.
- Availability of repair techniques, equipment/tools, and skilled labour have to be explored before deciding upon the repair materials.

Classification of Repair materials:

(I) Patch repair material

- Cementitious mortar/concrete
- Polymer mortar/concrete
- Quick setting compound

(II) Injection grouts

- Cementitious grout (with or without fibres)
- Polymer grouts
- Sulpho-aluminate grouts

(III) Bonding Materials:

- Polymer emulsion and Polymer resin type

(IV) Resurfacing Materials:

- Protective coating and membranes
- Overlays
- Topping/screeds,
- Gunite/shotcrete

(V) Sealing Materials

(VI) Water proofing materials:

(vii) Other repair materials

- Corrosion inhibitors
- Rebar protective coating
- Cathodic protection
- Alkalization

Factors Affecting the Selection of Repair Materials

Bond and compressive strengths are important properties **in** almost all **repairs** and protective works. ...The factors are

1. Low shrinkage properties
2. Good hardening /setting properties
3. Good workability
4. Good bond strength with existing sub-state
5. Compatible coefficient of thermal expansion
6. Compatible mechanical properties and strength to that of the sub- strata
7. Low air and water permeability

Factors Affecting the Selection of Repair Materials

8. Alkaline character
9. Durability, non-degradable
10. Minimal or no curing
11. Should allow relative movement, if expected
12. Cost
13. Non-polluting/non-hazardous
14. Good aesthetics

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- **Special Concrete:**
- The following are the different types of special concrete available, they are
- Polymer concrete
- Sulphur-Infiltrated Concrete
- Ferro cement
- Fiber Reinforced Concrete
- Rust eliminators and polymers coating for reinforcement
- Vacuum Concrete
- Foamed Concrete
- Pre-Packed Concrete/ Dry pack
- Asphalt sheeting

Other special concrete …

- Vacuum Dewatered Concrete
- Light-weight Concrete
- Aerated Concrete
- No-fines Concrete
- Drying Shrinkage
- High Density Concrete Roller Compacted Concrete
- Self Compacting Concrete (SCC)

Special Mortar:

- The following are the different types of special mortars available, they are
- Cement-clay mortar
- Light-weight and heavy mortars
- Decorative mortar
- Air-entrained mortar
- Gypsum mortar
- Fire-resistance mortar
- Packing mortar
- Sound absorbing mortar
- X-ray shielding mortar

MATERIALS FOR REPAIR

TYPES	APPLICATIONS
▪Premixed Cement concrete/mortars ▪Polymers/latex modified cement additives for mortars/concrete/ceme nt slurry ▪Epoxy resins ▪Chemicals for corrosion inhibitor, removal of rust	▪Materials for Surface Preparation ▪Chemical Rust removers for corroded reinforcement ▪Passivators for reinforcement protection ▪Bonding Agents ▪Structural Repair Materials ▪Non-structural Repair Materials ▪Injection grouts ▪Joint sealants ▪Surface coatings for protection of RCC

Most suitable for repair, restoration and seismic strengthening of buildings:

- Non-Shrink Grouts.
- Shotcrete.
- Epoxy Resins.
- Epoxy **Mortar**.
- Quick-Setting **Cement Mortar**.
- Mechanical Anchors.
- Ferrocement – Fibre **Concrete**.
- Fibre Reinforced Plastics (FRP)

- **Light weight mortars:**
- These are prepared form light porous sands from pumice and other fine aggregates. They are also prepared by mixing wood powder, wood shavings or saw dust with cement mortar or lime mortar.
- In such mortars, fiber of jute coir and hair, cut into pieces of suitable size, or asbestos fiber can also be used.
- These mortars have bulk density less than 15KN/m3.

- **Heavy weight mortars:**
- These are prepared from heavy quartz or other sands.
- They have bulk density of 15 KN/m3 or more.
- They are used in load bearing capacity.

- **Techniques for Repairs:**
- Gunniting and Grouting
- Shotcrete
- Epoxy injection
- Jacketing
- Crack repairing techniques for concrete and masonry work
- Methods of corrosion protection

  - corrosion inhibitors

  - corrosion resistant steel

  - coating and cathodic protection

  - Under pinning, shoring

Repairing Materials :

- Bonding, water proofing, epoxy, etc.
- Concrete and Construction Chemicals
- Expansive concrete

- **Necessity of adding concrete chemicals**
- To improve the performance of concrete
- To have the early strength gain as early as possible
- To accelerate the setting time of concrete
- To make the structure waterproof

1. Polymer Concrete

- The porosity is due to air-voids, water voids or due to the inherent porosity of gel structure itself. On account of the porosity, the strength of concrete is naturally reduced. It is conceived by many research workers that reduction of porosity results in increase of strength of concrete.
- None of the methods could really help to reduce the water voids and the inherent porosity of gel, which is estimated to be about 28%. The impregnation of monomer and subsequent polymerization is the latest technique adopted to reduce the inherent porosity of the concrete, to improve the strength and other properties of concrete.

- The main technique in producing PC is to minimize void volume in the aggregate mass so as to reduce the quantity of polymer needed for binding the aggregates. This is achieved by properly grading and mixing the aggregates to attain the maximum density and minimum void volume. The graded aggregates are prepacked and vibrated in a mould. Monomer is then diffused up through the aggregates and polymerization is initiated by radiation or chemical means. A saline coupling agent is added to the monomer to improve the bond strength between the polymer and the aggregate.
- The strength obtained with PC can be as high as 140 MPa with a short curing period.
- However, such polymer concretes tend to be brittle, and it is reported that dispersion of fiber reinforcement would improve the toughness and tensile strength of the material.

Advantages

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

Disadvantages

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

In short …

- It is a mixture of aggregate with a polymer as the sole binder.
- There is no other bonding material present i.e. Portland cement is not used.
- Polymerization can be achieved by any of the following methods :-
- Thermal-catalytic reaction
- Catalyst-promoter reaction
- Radiation

POLYMER CONCRETE

- Polymer – Impregnated concrete (PIC)
- Polymer Portland Cement Concrete (PPCC)
- Polymer Concrete (PC)
-

Application of Polymer concrete:-

1. Repair for overlays
2. Air field pavements
3. Industrial structures
4. Sluiceways
5. Stilling basin of the dam
6. Rock bolting

2. Polymer Impregnated Concrete (PIC)

- Polymer impregnated concrete is one of the widely used polymer composite. It is nothing but a precast conventional concrete, cured and dried in oven, or by dielectric heating from which the air in the open cell is removed by vacuum. Then a low viscosity monomer is diffused through the open cell and polymerized by using radiation, application of heat or by chemical initiation.
- Mainly the following types of monomer are used:

  (a) Methylmethacrylate (MMA),

  (b) Styrene,

  (c) Acrylonitrile,

  (d) t-butyl styrene,

  (e) Other thermoplastic monomers.
- The amount of monomer that can be loaded into a concrete specimen is limited by the amount of water and air that has occupied the total void space. It is necessary to know the concentration of water and air void in the system to determine the rate of monomer penetration.

3. Polymer Cement Concrete (PCC)

- Polymer cement concrete is made by mixing cement, aggregates, water and monomer. Such plastic mixture is cast in moulds, cured, dried and polymerised.

  The monomers that are used in PCC are:

  (a) Polyster-styrene.

  (b) Epoxy-styrene.

  (c) Furans.

  (d) Vinylidene Chloride.

- Recently Russian authors have reported the production of a superior Polymer cement concrete by the incorporation of furfuryl alcohol and aniline hydrochloride in the wet mix. This material is claimed to be specially dense and non-shrinking and to have high corrosion resistance, low permeability and high resistance to vibrations and axial extension.

3. Sulphur-Infiltrated Concrete

- New types of composites have been produced a porous materials like concrete using sulphur with great improvement in strength, water impermeability.
- Sulphur is heated to bring it into molten condition to which coarse and fine aggregates are poured and mixed together.eability and resistance to corrosion. It is reported that compressive strength of about 100 MPa could be achieved in about 2 day's time.
- **Application of Sulphur-infiltrated Concrete**
- The sulphur-infiltration can be employed in the precast industry. This method of achieving high strength can be used in the manufacture of pre-cast roofing elements, fencing posts,sewer pipes, and railway sleepers.
- Sulphur-infiltrated concrete should find considerable usein industrial situations, where high corrosion resistant concrete is required.

4. Fiber Reinforced Concrete

- Plain concrete possesses a very low tensile strength, limited ductility and little resistance to cracking. Internal micro cracks are inherently present in the concrete and its poor tensile strength is due to the propagation of such micro cracks, eventually leading to brittle fracture of the concrete.
- It has been recognized that the addition of small, closely spaced and uniformly dispersed fibers to concrete would act as crack arrester and would substantially improve its static and dynamic properties. This type of concrete is known as Fiber Reinforced Concrete.
- Fiber reinforced concrete can be defined as a composite material consisting of mixtures of cement, mortar or concrete and discontinuous, discrete, uniformly dispersed suitable fibers. Continuous meshes, woven fabrics and long wires or rods are not considered to be discrete fibers.

- Polypropylene and nylon fibers are found to be suitable to increase the impact strength.
- They possess very high tensile strength, but their low modulus of elasticity and higher elongation do not contribute to the flexural strength.
- Asbestos is a mineral fiber and has proved to be most successful of all fibers as it can be mixed with Portland cement. Tensile strength of asbestos varies between 560 to 980 N/mm2.
- For unimportant fiber concrete, organic fibers like coir, jute, cane splits are also used.

- FRC can be defined as a composites material, consisting of mixtures of cement mortar or concrete and discontinuous, discrete uniformly dispersed suitable fibres.
- Fibre is a small piece of reinforcing material that can be circular or flat.
- **Properties of FRC:**
- It have more tensile strength.
- Fibres improve the impact and abrasion resistance of concrete.
- It posses high compressive strength.
- It posses low thermal and electrical conductivity.
- **Aspect ratio**
- The fibre is often described by a convenient parameter called "aspect ratio". The aspect ratio of the fibre is the ratio of its length to its diameter. Typical aspect ratio ranges from 30 to 150.

Types of Fibers:

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

Applications

- Pavement and floors
- Water retaining structures
- Blast resistant structures
- Precast products
- Wearing surface to existing bridges/ culvert
- Repairs and rehabilitation works

- **Steel Fibers**
- Steel fibre is one of the most commonly used fibre. Generally round fibres are used. The diameter may vary from 0.25 to 0.75mm. The steel fibre is likely to get rusted and lose some of its strength. But investigations have shown that the rusting of the fibres take place only at the surface. Use of steel fibre makes significant improvements in flexural, impact and fatigue strength of concrete. It has very high tensile strength of 1700N/mm2. Steel fibres are incorporated in the shotcrete to improve its crack resistance, ductility and energy absorption and impact resistance characteristics.

- Glass fiber is a recent introduction in making fibre concrete. It has very high tensile strength 1020 to 4080 N/mm2. Glass fibre which is originally used in conjunction with cement was found to be effected by alkaline condition of cement.
- Therefore, alkali-resistant glass fiber by trade name "CEM-FIL" has been developed and used. The alkali resistant fibre reinforced

  concrete shows considerable improvement in durability when compared to the conventional E-glass fibre.
- Carbon fibres perhaps posses very high tensile strength 2110 to 2815 N/mm2 and Young's modulus. The use of carbon fibres for structures like cladding, panels and shells will have promising future.

Glass-fiber Reinforced Concrete (GRC) panel

Dramix glued steel fibres. The above fibres were used for casting tunnel segments in the construction of channel tunnel rail link (UK).

Fibers Used

- The fibers that could be used are steel fibers, polypropylene, nylons, asbestos, coir, glass and carbon.
- Fiber is a small piece of reinforcing material possessing certain characteristic properties. They can be circular or flat.
- Steel fiber is one of the most commonly used fiber. Generally, round fibers are used. The diameter may vary from 0.25 to 0.75 mm. The steel fiber is likely to get rusted and lose some of its strengths.
- Use of steel fiber makes significant improvements in flexural, impact and fatigue strength of concrete, It has been extensively used in various types of structures, particularly for overlays of roads, airfield pavements and bridge decks. Thin shells and plates have also been constructed using steel fibers.

Hollow Gypsum

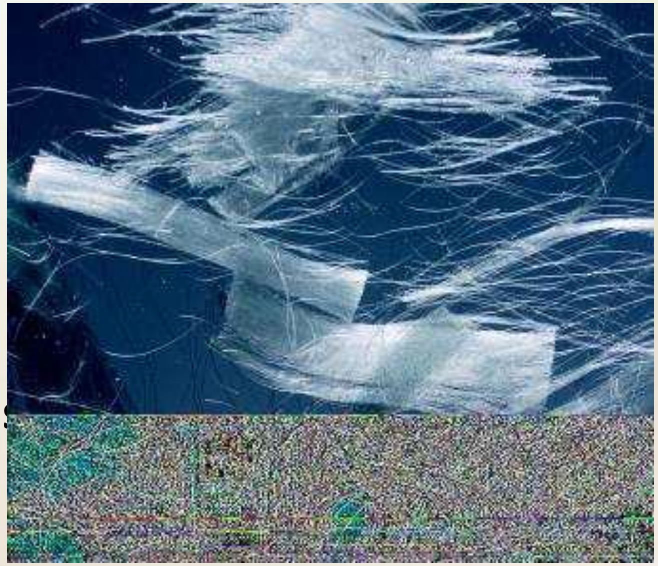
Board & Blocks

Factors Effecting Properties of Fibre Reinforced Concrete

Fiber reinforced concrete is the composite material containing fibers in the cement matrix in an orderly manner or randomly distributed manner. Its properties would obviously, depend upon the efficient transfer of stress between matrix and the fibers, which is largely dependent on

1. The type of fiber, fiber geometry, fiber content, orientation and distribution of the fibers,
2. Mixing and compaction techniques of concrete, and size and shape of the aggregate. OR

- **Relative Fiber Matrix Stiffness**
- **Volume of Fibers**
- **Aspect Ratio of the Fiber**
- **Orientation of Fiber**
- **Workability and Compaction of Concrete**
- **Size of Coarse Aggregate**
- **Mixing**

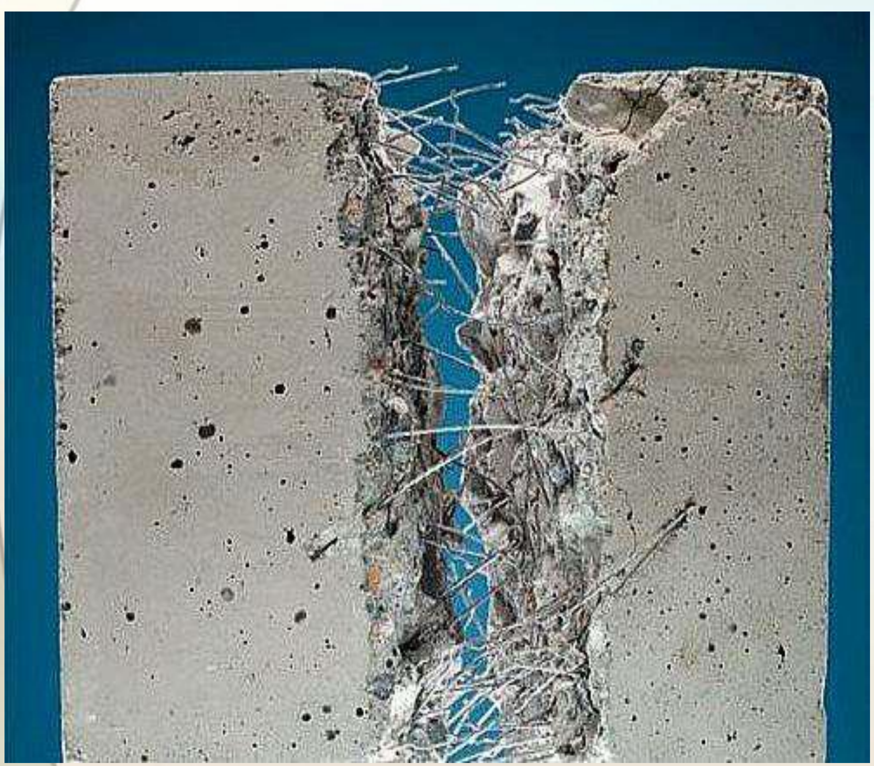


Polypropylene fibre Reinforced (PFR)

Applications

- Fibre reinforced concrete is increasingly used on account of the advantages of increased static and dynamic tensile strength, energy absorbing characteristics and better fatigue strength.
- Fibre reinforced concrete has been tried on overlays of air-field, road pavements, industrial floorings, bridge decks, canal lining, explosive resistant structures, refractory linings etc.
- The fibre reinforced concrete can also be used for the fabrication of precast products like pipes, boats, beams, stair case steps, wall panels, roof panels, manhole covers etc.
- Fibre reinforced concrete in also being tried for the manufacture of prefabricated formwork moulds of “U” shape for casting lintels and small beams.

Fibre Reinforced Concrete



5. Ferrocement

- Ferro cement techniques though of recent origin, have been extensively used in many countries, notably in U.K., New Zealand and China.
- Ferro cement is a relatively new material consisting of wire meshes and cement mortar. This material was developed by P.L. Nervi, an Italian architect and engineer, in 1940.
- Ferro cement is a relatively new material consisting of wire meshes and cement mortar.
- It consists of closely spaced wire meshed which are impregnated with rich cement mortar mix.
- While the mortar provides the mass, the wire mesh imparts tensile strength and ductility to the material.
- The Ferro cement possesses high resistance against cracking, high fatigue resistance higher toughness and higher impermeability.

- It consists of closely spaced wire meshes which are impregnated with rich cement mortar mix. The wire mesh is usually of 0.5 to 1.0 mm dia. wire at 5 mm to 10 mm spacing and cement mortar is of cement sand ratio of 1 : 2 or 1 : 3 with water/cement ratio of 0.4 to 0.45. The ferrocement elements are usually of the order of 2 to 3 cm. in thickness with 2 to 3 mm external cover to the reinforcement.

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

TYPICAL CROSS SECTION OF FERROCEMENT

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

Small diameter wires and chickenwire mesh reinforcement used in casting ferrocement water tank

Ferrocement water tank- 1000 litre capacity - thickness 15 mm.

Ferrocement boat floating on water- thickness 25 mm.

APPLICATIONS OF FERROCEMENT:-

- Mobile homes
- Watertight structures
- Silos and bins
- Boat hulls
- Biogas holders
- Pipes
- Folded plates
- Shell roofs
- Wind tunnel
- Swimming pool
- Curved benches for parks

- **Types of Wire mesh reinforcement used in Ferro cement:**

1) Hexagonal wire mesh

2) Square mesh

3) Three dimensional mesh

Types of mortar for ferro cement:

- 1. Ordinary Cement Mortar
- 2. High Performance Mortar
- 3. Lightweight Aggregate Mortar
- 4. Fiber Reinforced Mortar
- 5. Polymer Mortar
- **Ordinary Cement Mortar:**
- Portland cement is used to make ordinarily cement mortar. The filter material is usually a well-graded sand capable of passing 2.36mm sieve. However, depending upon the characteristics of the reinforcing material mortar may contain some small-size gravel.
- The mix proportion ranges of the mortar for ferrocement are sand-cement ratio by weight, 1.4 to 2.5, water-cement ratio by weight, 0.3 to 0.5.

- **High Performance Mortar:**
- This mortar is similar to conventional cement mortar but it contains mineral admixture to produce impermeable matrix. This enhances the durability of ferro cement by providing greater protection to the steel reinforcement. By proper selection of chemical and mineral activities and W/C ratio, FC mortar can reduce pore size considerably and thereby achieving very high strength levels, which are not possible conventionally.
- It having comprehensive strengths in the range of 50 to 100Mpa.

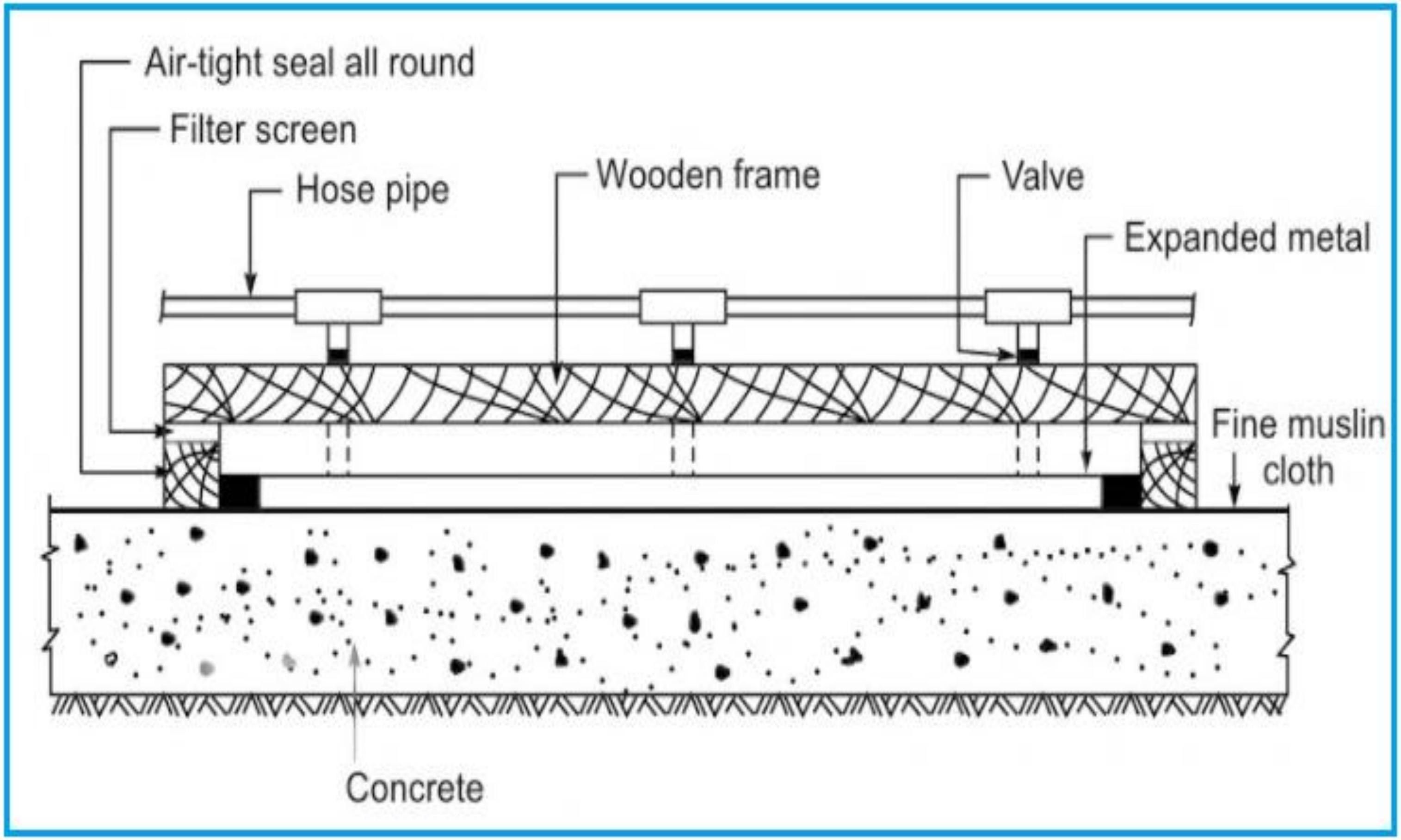
The main advantages are simplicity of its construction, lesser dead weight of the elements due to their small thickness, its high tensile strength, less crack widths compared to conventional concrete,easy repairability, noncorrosive nature and easier mouldability to any required shape.

Ferrocement plank 3000 x 300 x 25 mm, bends like a bow when supported as shown above

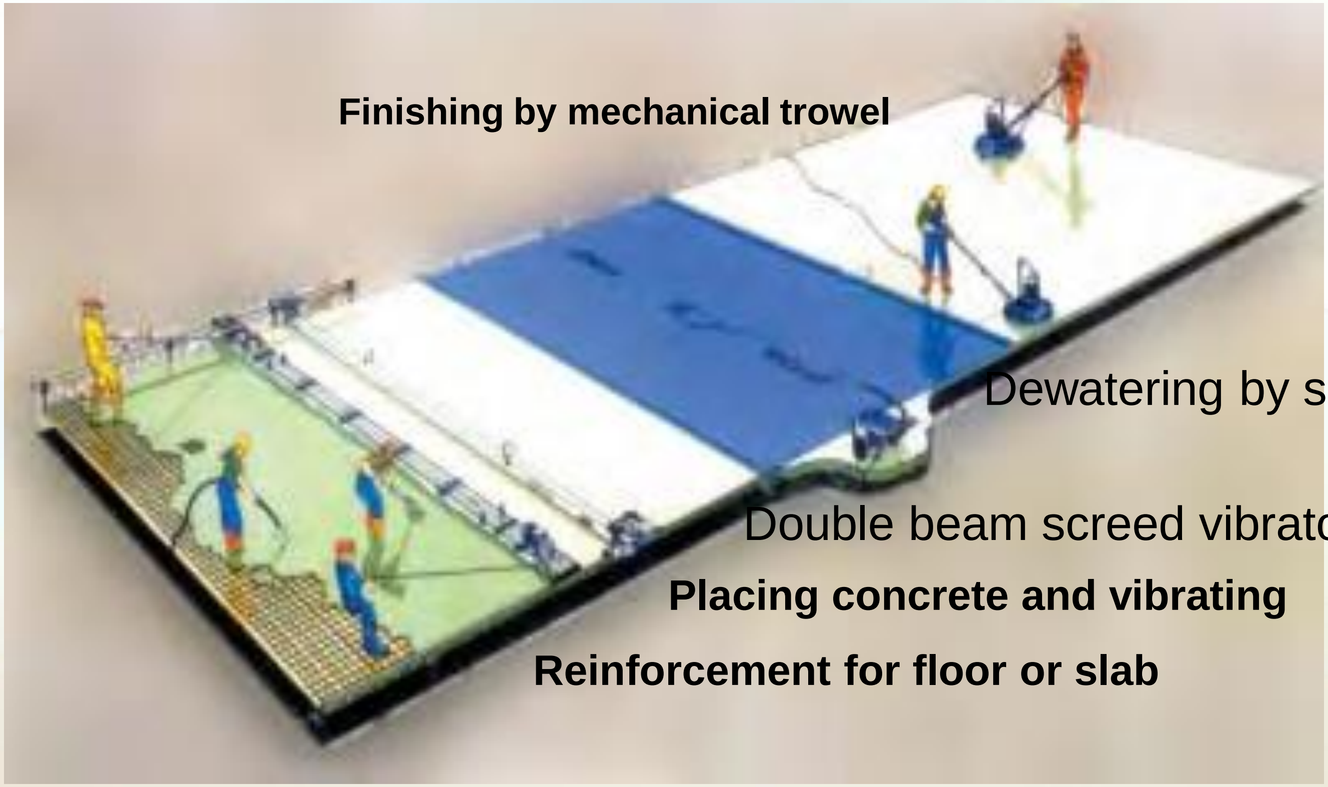
Sample of ferrocement manhole covers

6. Vacuum Concrete

- High water/cement ratio is harmful to the overall quality of concrete, whereas low water/cement ratio does not give enough workability for concrete to be compacted hundred per cent. Generally, higher workability and higher strength or very low workability and higher strength do not go hand in hand.
- Vacuum process of concreting enables to meet this conflicting demand. This process helps a high workable concrete to get high strength.
- In this process, excess water used for higher workability, not required for hydration, and harmful in many ways to the hardened concrete is withdrawn by means of vacuum pump, subsequent to the placing of the concrete. The process when properly applied, produces concrete of quality. It also permits removal of formwork at an early age to be used in other repetitive work.



Air-tight seal all round
Filter screen
Hose pipe
Wooden frame
Valve
Expanded metal
Fine muslin cloth
Concrete



Schematic sketch showing method of vacuum dewatering system.

- It essentially consists of a vacuum pump, water separator and filtering mat. The filtering consists of a backing piece with a rubber seal all round the periphery. A sheet of expanded metal and then a sheet of wire gauge also forms part of the filtering mat. The top of the suction mat is connected to the vacuum pump.
- When the vacuum pump operates, suction is created within the boundary of the suction mat and the excess of water is sucked from the concrete through the fine wire gauge or muslin cloth. The contraction of concrete caused by loss of water must be vibrated.
- The vacuum processing can be carried out either from the top surface or from the side surface.

- Whenever thin sections like slab and walls have to be concreted, it is necessary to adopt fluid mix with the w/c ratio between 0.50 to 0.65 to facilitate the placing and compaction.
- Such a mix will lead to a concrete of relatively low strength and poor abrasion resistance. In such situations, vacuum treatment of concrete is used.

Advantages of vacuum concrete:-

- It permits removal of formwork at a early age to be used in other repetitive work.
- The vacuum concrete bounds very well with old concrete.
- There is a considerable increase in strength and quality of concrete.
- The resistance to wear and abrasion is increased.

7. FORM ED CONCRETE

- If a sufficiently portion of concrete is removed, it can best be replaced with concrete placed in forms. This concrete can be placed without a bonding agent and without grout on the prepared surface of the old concrete.

This method should be used

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

(ii) For holes extending right though the concrete section

(iii) For holes in unreinforced concrete with area greater than 0.1m2 and over 100 mm deep, and

(iv)For holes in reinforced concrete which have an area greater than 0.05m2 and which extend deeper than the reinforcement.

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

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

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

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

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

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

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

8.Light-weight Concrete:

- The light-weight concrete as we call is a concrete whose density varies from 300 to 1850 kg/m3.
- There are many advantages of having low density.
- It helps in reduction of dead load, increases the progress of building, and lowers haulage and handling costs.
- The use of light-weight concrete with low thermal conductivity will be of considerable advantage from the point of view of thermal comforts and lower power consumption.
- The adoption of light-weight concrete gives an outlet for industrial wastes such as clinker, fly Ash, slag etc. which otherwise create problem for disposal.
- A particular type of light-weight concrete called structural light-weight concrete is the one which is comparatively lighter than conventional concrete but at the same time strong enough to be used for structural purposes.

- Basically, there is only one method for making concrete light i.e., by the inclusion of air in concrete. This is achieved in actual practice by three different ways.
- (a) By replacing the usual mineral aggregate by cellular porous or light-weight aggregate.
- (b) By introducing gas or air bubbles in mortar. This is known as aerated concrete.
- (c) By omitting sand fraction from the aggregate. This is called ‘no-fines’ concrete.

Groups of Light-weight Concrete:

No-fines Concrete

Light-weight aggregate concrete

Aerated Concrete- Chemical aerating ,Foaming mixture

9. Structural Light Weight Concrete

- The structural light weight concrete is going to be one of the important materials of construction. A concrete which is light in weight and sufficiently strong to be used in conjunction with steel reinforcement will be a material which is more economical than the conventional concrete. Therefore, a concrete which combines strength and lightness will have the unquestionable economic advantage.
- Structural light-weight aggregate concrete is a concrete having 28 day compressive strength more than 17 MPa and 28 day air dried unit weight not exceeding 1850 kg/m3.
- For practical reasons, it is common practice to use normal sand as fine aggregate and light-weight coarse aggregate of maximum size 19 mm. Such light-weight concrete is termed as “sanded light-weight concrete”, in contrast to “all light-weight concrete”.

10. Aerated Concrete

- Aerated concrete is made by introducing air or gas into a slurry composed of Portland cement or lime and finely crushed siliceous filler so that when the mix sets and hardens, a uniformly cellular structure is formed.
- Aerated concrete is also referred to as gas concrete, foam concrete, cellular concrete.
- Use of foam concrete has gained popularity not only because of the low density but also because of other properties mainly the thermal insulation property.
- Aerated concrete is made in the density range from 300 kg/m3 to about 800 kg/m3. Lower density grades are used for insulation purposes, while medium density grades are used for the manufacture of building blocks or load bearing walls and comparatively higher density grades are used in the manufacture of prefabricated structural members in conjunction with steel reinforcement.

11. No-fines Concrete

- The third method of producing light concrete is to omit the fines from conventional concrete.
- No-fines concrete as the term implies, is a kind of concrete from which the fine aggregate fraction has been omitted. This concrete is made up of only coarse aggregate, cement and water. Very often only single sized coarse aggregate, of size passing through 20 mm retained on 10 mm is used. No-fines concrete is becoming popular because of some of the advantages it possesses over the conventional concrete.
- The single sized aggregates make a good no-fines concrete, which in addition to having large voids and hence light in weight, also offers architecturally attractive look.
- no-fines concrete is made by using light weight aggregate, the density may come to about 360 kg/m3.
- No-fines concrete does not pose any serious problem for compaction.
- The compressive strength of no-fines concrete varies between 1.4 MPa to about 14 MPa.

12. High Density Concrete

- Density of normal concrete is in the order of about 2400 kg. per cubic meter. The density of light-weight concrete will be less than about density 1900 kg per cubic meter.
- To call the concrete, as high-density concrete, it must have unit weight ranging from about 3360 kg per cubic meter to 3840 kg per cubic meter, which is about 50% higher than the unit weight of conventional concrete.
- The high-density concrete is used in the construction of radiation shields.
- The use of nuclear reactors, particle accelerator, industrial radiography, and X-ray, gamma-ray therapy, require the need of shielding material for the protection of operating personnel against the biological hazards of such radiation.
- High modulus of elasticity, low thermal expansion and low elastic and creep deformations are ideal properties for both conventional and high-density concrete.

Concrete Chemicals/Admixtures :

- Admixtures are used to modify the properties of fresh and hardened concrete. They are classified as chemical and mineral admixtures. Chemical admixtures are used in construction industry for building strong, durable and waterproof structures.
- Admixture are added to concrete batch immediately before or during mixing concrete. Concrete admixtures can improve concrete quality, manageability, acceleration, or retardation of setting time, among other properties that could be altered to get specific results. Many, not to say all, concrete mixes today contain one or more concrete admixtures that will help your pouring process driving down cost while increasing productivity, The cost of these admixtures will vary depending on the quantity and type of admixture being used. All of this will be added to the cubic yard/meter cost of concrete

- Depending on their use, chemical admixtures are used for the following four main purposes.
- 1. Some chemicals are mixed with concrete ingredients and spread throughout the body of concrete to favorably modify the molding and setting properties of the concrete mix. Such chemicals are generally known as *chemical admixtures Admixture are added to concrete to give it certain desirable properties in either the fresh or the hardened state. Most admixtures result in modifying more than one intended property.*

2. Some chemicals are applied on the surfaces of mould used to form concrete to effect easy mould-releasing operation.

3.Some chemicals are applied on the surfaces of concrete to protect it during or after its setting.

4. Some chemicals are applied to bond or repair broken or chipped concrete.

1. Accelerators:

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

- The properties and types of accelerating admixtures are
- **Properties:**
- Aids Cold Weather concreting
- Shortens Setting time
- Increases Early Strength
- **Types**
- Chloride-free calcium format used for reinforced and prestressed concrete members
- Chloride containing calcium chloride restricted to 1.5% for plain concrete construction

2. Retarders :

- Retarders increase the setting time of the concrete mix and reduce the water-cement ratio. Usually up to 10% water reduction can be achieved. A wide range of water-reducing and set retarding admixture are used in ready mixed concrete. Usually, these chemicals are derived from lignosulphonic acids and their salts, hydroxylated carboxylic acid and their salts and sulphonated melamine or naphthalene formaldehyde.
- These types of concrete admixtures are commonly used to reduce the effect of high temperatures that could produce a faster initial setting of concrete. Set retarding admixtures are used in concrete pavement construction, allowing more time for finishing concrete pavements reducing additional costs to place a new concrete batch plant on the job site and helps eliminate cold joints in concrete

- They have a detergent like property. They work on the principle that water-reducing agent migrate to the surface of water this increases the surfaces activity and hence imparts a soapy property to the mix and delays setting.
- **Properties**
- Surface Activity agent
- Hot weather concreting
- Retarding chemical activity

3. Plasticizers

- A plasticizer is defined as an admixture added to wet concrete mix to impart adequate workability properties.

Plasticizers can be of the following three types.

- 1. Finely divided minerals
- 2. Air-entraining agents
- 3. Synthetic derivatives

1. Finely divided minerals :

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

2.Air-entraining agents :

- These help in protecting concrete subjected to repeated freeze thaw cycles. Concrete with entrained air has higher workability and cohesiveness. Segregation and bleeding are reduced by using air-entraining agents. These agents are generally used to ensure durability against frost.
- Air-entraining agents are derived from synthetic detergents, salts of sulphonated lignin, fatty acids, organic salts of sulphonated hydrocarbons or salts of wood resins.
- These agents create millions of tiny air bubbles which relieve the expansion pressure. They result inn 9% increase in the volume of water, and osmotic pressure develops as water diffuses from gel pores into the capillaries.

- Ai Air entrained concrete can increase the freeze – thaw durability of concrete. This type of admixture produces a more workable concrete than non-entrained concrete while reducing bleeding and segregation of fresh concrete. Improved resistance of concrete to severe frost action or freeze/thaw cycles. Other benefits from this admixture are:
- High resistance to cycles of wetting and drying
- High degree of workability
- High degree of durability
- Air-entrainers admixtures are compatible with almost all the concrete admixtures. Typically for every one percent of entrained air, compressive strength will be reduced by about five percent.

3. Synthetic Derivatives:

- Synthetic derivatives introduce soapy into the mix. These are surface-active agents and are primarily added to increase workability. The best example of a synthetic derivative is benzene sulphonate. Chemically they comprise the same chemicals as found in retarders and hence they also generally retard the setting time.
- These derivates may react differently with different types of cement. Hence, a careful study of the type of cement is required before choosing a particular synthetic derivative.

Advantages of Plasticizer:

1. Increase Workability
2. Produces Soapy action
3. Produces discontinuous air bubbles

4.Superplasticizers

- Superplasticizers produce extreme workability and thus flowing concrete. They achieve reduction in the water content without loss of workability. Their use generally leads to an overall reduction in the cost.
- Superplasticizer molecules and cement grains are oppositely charged and hence repel each other. This increases the mobility and hence makes the concrete flow. Superplasticizers enables savings in cement for a given strength and are ideal for pumping concrete, casting heavily reinforced concrete members, and the precast elements of concrete.
- The main purpose of using superplasticizers is to produce flowing concrete with a high slump in the range of seven to nine inches to be used in heavily reinforced structures and in placements where adequate consolidation by vibration cannot be readily achieved. The other major application is the production of high strength concrete at w/c's ranging from 0.3 to 0.4. It has been found that for most types of cement, superplasticizer improves the workability of concrete.

Use of Superplasticizers in concrete

Expansion cement :

Concrete made with ordinary Portland cement shrinks while setting due to loss of free water. Concrete also shrinks continuously for long time. This is known as drying shrinkage. Cement used for grouting anchor bolts or grouting machine foundations or the cement used in grouting the prestress concrete ducts, if shrinks, the purpose for which the grout is used will be some extent defeated.

There has been a search for such type of cement which will not shrink while hardening and thereafter. As a matter of fact, a slight expansion with time will prove to be advantageous for grouting purpose.

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

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

One type of expansive cement is known as shrinkage compensating cement. This cement when used in concrete, with restrained expansion, induces compressive stresses which approximately offset the tensile stress induced by shrinkage.

Another similar type of cement is known as self stressing cement. This cement when used in concrete induces significant compressive stresses after the drying shrinkage has occurred. The induced compressive stresses not only compensate the shrinkage but also give some sort of prestressing effects in the tensile zone of the flexural member

Repair Chemicals

EPOXIES AND EPOXY SYSTEMS

- Epoxies also come in the category of polymers but in the case of epoxies, the polymerization process takes place when two materials called the epoxy resin and hardener come in contact by thoroughly mixing in specified proportion. The epoxy resin materials have good mechanical strength, chemical resistance and ease of working.
- These are being used in civil engineering for high performance coatings, adhesives, injection grouting, high performance systems, industrial flooring or grouting etc.

- **Epoxy resins:-** Epoxy resins are excellent binding agents with high tensile strength.
- There are chemical preparations the compositions of which can be changed as per requirements.
- The epoxy components are mixed just prior to application.
- The product is of low viscosity and can be injected in small cracks too.
- The higher viscosity epoxy resin can be used for surface coating or filling larger cracks or holes

- **Epoxies Resin:** It have very good mechanical strength, chemical resistance and ease of working. They are excellent binding agents with high tensile strength. The product is of low viscosity and can be injected into small cracks too. The higher viscosity epoxy resin can be use for surface coating or filling large cracks or holes.
- **Epoxy Hardener (Curing Agent):** it combines with the epoxy resin and changes it from liquid to a solid state. The most common used curing agents are aliphatic and aromatic amines and polyamides and their products. The aromatic polyamine curing agents react faster than the aliphatic polyamines

- **Epoxy Mortar and Concrete:** Epoxy resins are used with aggregate (silica sand) to produce epoxy mortar or epoxy concrete, which is used for structural repairs of concrete, RCC besides its use in new construction in industrial flooring, foundation grouting, roads etc. They are normally used where volume of materials is not large and where rapid curing can be obtained.
- **Epoxy mortar**:**-** For larger void spaces, it is possible to combine epoxy resins of either low viscosity or higher viscosity, with sand aggregate to form epoxy mortar.
- Epoxy mortar mixture has higher compressive strength, higher tensile strength and a lower modulus of elasticity than Portland cement concrete.
- The sand aggregate mixed to form the epoxy mortar provides a heat sink for heat generated and it provides increased modulus of elasticity too.

Advantages of Epoxies:

- Bonds strongly to most materials including metals, concrete, glass, ceramics, stone, wood, leather.
- Exceptions are plastics materials like polyethylene, polypropylene, Teflon, etc.
- Excellent resistance to chemicals and solvents.
- Very good electrical insulating properties.
- Outstanding mechanical strength including tensile, compressive, flexural and modulus.
- Very little shrinkage on curing, thus providing good dimensional stability.

Precautions While Using Epoxies

- Epoxies are generally toxic in nature and these require lot of care in their handling. The special care required to be taken during their mixing and applications.
- They should not come in contact with the skin. Workers should be provided with rubber gloves.
- The utensils/ equipment's used for the mixing resin and hardener should be cleaned immediately after their use.
- The epoxies are generally used as an adhesive to act as bond coat between the old concrete and repaired concrete.
- Epoxies have much higher bond strength than other polymers, but at the same time, these are costlier.

Field of Applications:

Anti Corrosive and Water Proofing Protective Coatings:

Bond Coats (Structural Adhesives) and Grouts:

Structural repairs to concrete


Surface Coatings

- Surface coating are also referred as resurfacing materials and toppings. Protective coatings can greatly reduce the effect of deteriorate conditions, and significantly improve the durability characteristics of the concrete.

Essential Parameters for coatings:

- Posses excellent bond to substrate
- Be durable with a long useful life normally 5 years.
- Little or no color change with time.
- Should have sufficient impermeability against the passage of
- oxygen and carbon dioxide from air to concrete.
- Should be available in a reasonable range of attractive colors.

Factors Considered on application of coatings:

- Climatic Conditions
- Temperature of concrete
- Moisture content of surface
- The thickness and number of coats
- **Types of Coating:**
- **1. Epoxy coatings**
- Excellent chemical resistance to most chemicals
- Excellent adhesion to concrete
- Good abrasion and impact resistance
- Excellent resistant to corrosion of steel reinforcement
- **2. Acrylic coatings:**
- Solvent Free acrylic coatings have excellent wetting characteristics , a fair degree of chemical resistance and good color retention characteristics

Sealing Materials

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

OR

- Definition for 'SEALANT' is "in building construction, a material that has the necessary adhesive and cohesive properties to form a seal."

- **Functions:**
- Sealants, despite not having great strength, convey a number of properties. They seal top structures to the substrate and are particularly effective in waterproofing processes by keeping moisture out (or in) the components in which they are used.
- They can provide thermal insulation and may serve as fire barriers.
- They may have electrical properties, as well. Sealants can also be used for simple smoothing or filling.
- To prevent ingress of water into the structure
- To accommodate joint movement


BEFORE
AFTER

Types of Construction Sealants

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

Advantages:

- Improves Product Durability and Reliability.
- Increases Product Performance.
- Increases Product Quality.
- Enhances Product Aesthetics.
- Increases weathering characteristics.

Epoxy sealant

Elastic sealant

Bituminous sealant

Bonding Materials

- Bonding materials are natural, synthetic or compounded materials used to join two structural members without mechanical fasteners.
- These materials are often used in various repair applications, such as bonding of new concrete to old concrete.
- The bonding between new concrete and old concrete depends upon:

i. The cleanliness of the old surface.

ii. The strength and integrity of the old surface

Two types of bonding agents are frequently used:

(a) Cement - based slurries

(b) Epoxies

Water Proofing Materials

- Waterproofing materials are applied on concrete surfaces to form impervious coatings that prevents the ingress of water into the concrete.
- Various waterproofing materials marketed are :

1. Cement based coatings:

A bedding layer of mortar 1 : 3 (cement : sand) of thickness not less than 5 mm may be applied.

2. Polymer resin-based coatings:

- Solvent based coatings are available as single or two component coatings. The coatings on drying produce a smooth dense continuous film that provides a barrier to moisture and mild chemical attack; these are preferred for location of high humidity.

Thank you…