UNIT 3-SPECIAL CONCRETES

2 MARKS

1. **Define polymer concrete. (April/May 2018)**

Polymer concrete is an aggregate bound polymer binder instead of Portlandcement as in conventional concrete polymer concrete is normally used to minimizevoids volume in aggregate mass. This can be achieved by property grading themixing to attain the max density and (mixing) the aggregates to attain minimumvoid volume. The entrapped aggregates are prepacked and vibrated in a mould.

2. What are the applications of Polymer concrete?(Nov/Dec 2017)

During curing Portland cement form mineral voids. Water can be entrappedin these voids which (or) freezing can readily attack the concrete, Also alkalinePortland cement is easily attacked by chemically aggressive materials which resultsin rapid deformation. Therefore using polymers can counter chemical attack.

3.What are the applications of sulphur infiltrated concrete? (April/MAY 2017)

Sulphur - (impregnated) infiltration can be employed in the precast industries.Sulphur infiltration concrete has found considerable used in industry situationwhere high corrosion resistant concrete is required. This method cannot beconveniently applied to cast-in place concrete. Sulphur impregnation has showngreat improvement in strength.

4. State the applications of polymer impregnated concrete? (Nov/Dec 2018)

PIC is a widely used polymer composition concrete, cured and dried in ovenor dielectric heating from which the air in the (pipes) open cell is removed byvacuum.

Then low density manpower is diffused through a open cell andpolymerized by using radiation, application of heat or by chemical initiation.

5. What are the Methods of Production of High Strength Concrete: (April/May 2019)

a. Some of them are as follows:
b. Use of Admixture:
c. Re-Vibration:
d. High Speed Slurry Mixing:
e. Inhibition or Prevention of Cracks:
f. Sulphur Filling or Impregnation:

6. Why FRC is preferred in water retaining structures and repair and rehabilitation work (April/MAY 2017)

Fiber-reinforced concrete is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibers that are uniformly distributed and randomly oriented.

7. In what situation self- concreting concrete is desirable (Nov/Dec 2018)

SCC can be used for casting heavily reinforced sections, places where there can be no access to vibrators for compaction and in complex shapes of formwork which may otherwise be impossible to cast, giving a far superior surface than conventional concrete.

8. What are the industrial waste for alternate ingredient in concrete (Nov/Dec 2017)

The industrial wastes (fly ash, red mud, copper slag and silica fumes) have already been tried in the application of cement production and partial replacement of construction materials in civil engineering field.

9. What is Geo-polymer concrete (April/May 2018)

Geo-polymer concrete is an innovative construction material which shall be produced by the chemical action of inorganic molecules. Fly Ash, a by-product of coal obtained from the thermal power plant

10. Differentiate filling and passing ability of ssc (April/May 2019)

Passing ability of self-consolidating concrete (SCC) is the ability to flow through tight openings, such as spaces between reinforcing bars, under its own weight.

Filling ability of SCC to flow into all spaces within the formwork under its own weight. Tests, such as slump flow, V-funnel etc, are used to determine the filling ability of fresh concrete.

11. State merits and application of sulphur infiltrated concrete (April/May 2017)

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

12. Enumerate the methods of producing high strength concrete(April/May 2019)

- Use of Admixture:
- Re-Vibration
- High Speed Slurry Mixing:
- Inhibition or Prevention of Cracks:
- Sulphur Filling or Impregnation:
- The process of impregnation is as follows:
- Use of Cementitious Aggregates:

13. List the various types of polymer concrete. (April/May 2018)

(i) Polymer impregnated concrete (PIC)

(ii) Polymer cement concrete (PCC)

(iii) Polymer Concrete (PC)

(iv) Partially impregnated and surface coat.

14 . What is expansive cement?

A slight change in volume on drying is known as expansion with time andwill prove to be advantageous for grouping purpose. This type of cement whichsuffers no overall change in volume on drying is known as "Expansive cement".

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

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

16. Give the various monomers used in polymer concrete.

- Mehylmethacrylate
- Styrene
- Acrylonitrile
- t-butylo styrene

17. What is sulphur infiltrated concrete?

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

18. What is drying shrinkage?

Concrete made with ordinary Portland cement shrinks while setting due toless of water concrete also shrinks contiguously for a long time. This is known as"drying shrinkage".

19. What is self stressing cement?

This cement when used in concrete with restrained expansion inducescompressive stresses which approximately offset the tensile stresses induced byshrinkage "self Stressing cement".

20. Define polymer partially impregnated concrete.

Polymer' partially impregnated and surface coated (SC) control partiallypolymer impregnated concrete is used to in the strength of concrete is the partiallyimpregnated concrete is sufficient insituations where the major requirement isthe surface persistent against chemical and mechanical attacks.

21. How can we manufacture sulphur infiltrated concrete'!

Sulphur is heated to bring it into molten condition to which coarse and fineaggregates are poured and mixed together. On cooling, this mixture gives fairlygood strength, exhibit acid resistance and also other chemical resistance, but itproved to be either than ordinary cement concrete.

22. What is the difference between ordinary cement and expansivecement?

Ordinary concrete shrinks while setting whereas expansive cement expandswhile setting.

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

Gas formation and expansive chemicals produce light weight concrete aswell as to cause expansion on application such as grouts for anchor bolts.They are non stinking type. Principal chemicals used are Hydrogenperoxide, metallic aluminum or activated carbon. Sometimes bentoniteclays and natural gum are also used.

24. What is the use of corrosion inhibiting chemicals?

They resist corrosion of reinforcement in adverse environment sodiumbenzoate, calcium lingosulphonate and sodium nitrate have good results.

25. Write the use of antifungus admixtures.

These are added to control and inhibit growth of bacteria or fungus in surfacesexposed moisture. Polyhalogenated phenol.Dieldrin emulsion and coppercompounds are some of the chemicals used for this.

26. What are the uses of curing compounds?

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

27. What are the uses of sealants?

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

28. What are the uses of flooring?

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

29. What are the applications of expansive cement?

Expansive cements are hydraulic cements which, unlike Portland cement,expand during the early hydration period after setting. When the magnitude ofexpansion is small but usually adequate to offset the tensile stress from restrained drying shrinkage, the cement is known as shrinkage compensating. When themagnitude of expansion is large, the cement is called self-stressing and can beused for the production of chemically pre stressed concrete elements.

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

The critical length of fibre pull-out define as the maximum embedded fibrelength for a fibre to be pull out from a matrix without rupture its closely associatedwith fracture behaviour of short fibre reinforced brittle matrix composites.

31. What are the disadvantages of FRP?

The uses of composites in bridges are high cost creep and shrinkage. Thedesign and construction require highly trained specialists. The composites have apotential for environmental degradation. There is a possibility of either debordingof FRP plate from the concrete or development of horizontal cracks andsubsequenced determination leading to anc1urage failure.

32. What are admixtures? Give examples.

There are two types of admixtures:

Chemical admixtures:

- Super plasticisers
- Accelerators
- Retarders

Mineral admixtures:

- Fly ash
- Ground granulated blast furnace slag (GGBS)
- Silica fume (CSF)
- Fibre reinforced concrete.

33. What you mean by aspect ratio?

Conventional concrete is modified by random dispersal of short discrete fibresof asbestos, steel, glass, polypropylene, nylon etc. Asbestos cement fibres so farhave proved to be commercially successful. The improvement in structuralperformance depends on the strength characteristics, volume, spacing, dispersionand orientation, shape and aspect ratio of the fibres. Aspect ratio is the ratio ofthe length to the diameter of the fibres. It has been reported that to aspect ratio75, increase in the aspect ratio increases the ultimate strength of the concretelinearly.

34. Mention any two important types of concrete widely used?

- Polymer-modified cement composites
  - Polymer concrete composites
  - Polymer impregnated concrete
  - Resin concrete
- Fibre reinforced concrete
  - Glass fibre reinforced concrete
  - Steel fibre reinforced concrete
  - Polypropylene fibre reinforced concrete.

35. Name the types of reinforcement used in ferrocement?

Wire mesh with closely s aced wires i the most commonly used reinforcementIn ferrocement, Expanded metal mesh, welded wire fabrics, square steel wire, mesh,hexagonal or chicken wire mesh are also used.

36.With a simple sketch explain ferrocement jacketing?

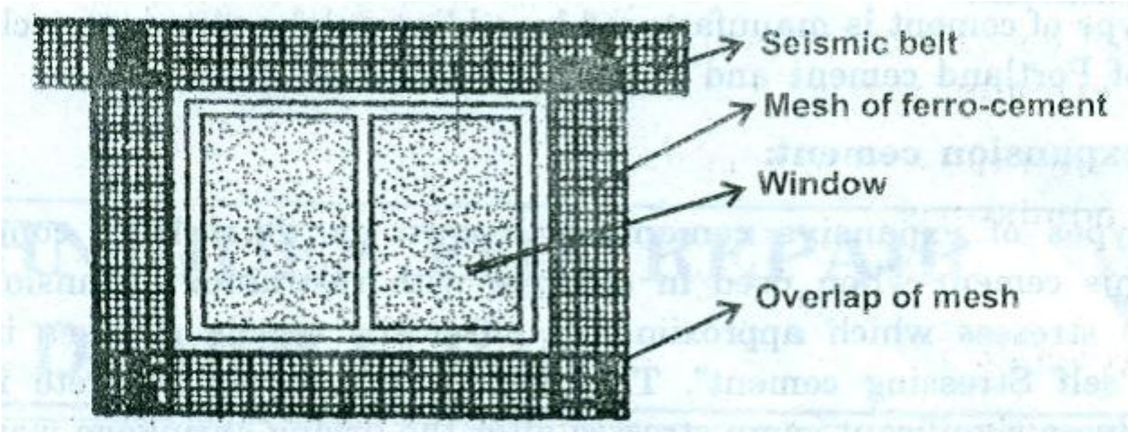


Fig. 3.3

37. What is the expected life time for a RC Structure?

Reinforced concrete is commonly used in structures designed for heavy useand long life such as governmental and institutional buildings and public workstructures.

38. From visual inspection of concrete structures what arc the causes ofdamage that can be identified?

Visual inspection is the most important non-destructive test. It forms the basisof all inspections. A detailed visual inspection makes it possible to narrow downthe critical areas in a structure that need further investigation using sophisticatedtechniques. The trained eye of an inspector can often reveal Information that IS sometimes difficult to pick up using hi-tech instruments. Visual inspection may be performed directly or indirectly (when photographs. radiograph or videos of thedamaged areas are analyzed at a later stage).

39. What is Shrinkage Compensating Concrete?

Shrinkage compensating concrete (SCC) is an expansive cement concretewhich, when properly restrained by reinforcement or other means with expand anamount equal or slightly greater than the anticipated drying shrinkage.

40. Classify admixtures based on their functions?

Based on their functions, admixtures can be classified into the following five major categories:

(i) Retarding admixtures
(ii) Accelerating admixtures
(iii) Super plasticizers
(iv) Water reducing admixtures
(v) Air-entraining admixtures

16 Marks

1. **Demonstrate the arrangement of vacuum treatment of concrete (April/May 2019)(April/May 2017)**

Vacuum concrete is the one from which water is removed by vacuum pressure after placement of concrete structural member. Vacuum concrete has high strength and durability than normal concrete.

Water-cement ratio is detrimental for concrete. We always try to restrict the water-cement ratio in order to achieve higher strength.

The chemical reaction of cement with water requires a water-cement ratio of less than 0.38, whereas the adopted water-cement ratio is much more than that mainly because of the requirement of workability. Workability is also important for concrete, so it can be placed in the formwork easily without honeycombing.

After the requirement of workability is over, this excess water will eventually evaporate leaving capillary pores in the concrete. These pores result into high permeability and less strength in the concrete. Therefore, workability and high strength don’t go together as their requirements are contradictory to each other.

Vacuum concrete is the effective technique used to overcome this contradiction of opposite requirements of workability and high strength. With this technique both these are possible at the same time.

In this technique, the excess water after placement and compaction of concrete is sucked out with the help of vacuum pumps. This technique is effectively used in industrial floors, parking lots and deck slabs of bridges etc. The magnitude of applied vacuum is usually about 0.08 MPa and the water content is reduced by upto 20-25%. The reduction is effective upto a depth of about 100 to 150 mm only.

Technique and Equipments for Vacuum Concrete:

The main aim of the technique is to extract extra water from concrete surface using vacuum dewatering. As a result of dewatering, there is a marked reduction in effective water-cement ratio and the performance of concrete improves drastically. The improvement is more on the surface where it is required the most.

Mainly, **four components are required in vacuum dewatering of concrete**, which are given below:

Vacuum pump

Water separator

Filtering pad

Screed board vibrator

Vacuum pump is a small but strong pump of 5 to 10 HP. Water is extracted by vacuum and stored in the water separator. The mats are placed over fine filter pads, which prevent the removal of cement with water.

Proper control on the magnitude of the water removed is equal to the contraction in total volume of concrete. About 3% reduction in concrete layer depth takes place. Filtering pad consists of rigid backing sheet, expanded metal, wire gauze or muslin cloth sheet.

A rubber seal is also fitted around the filtering pad as shown in fig.1. Filtering pad should have minimum dimension of 90cm x 60cm.

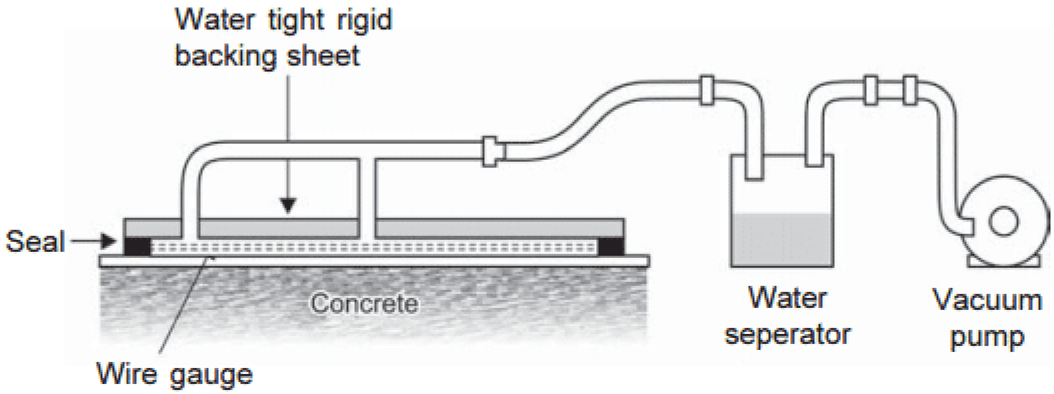


Fig. 1: Vacuum dewatering of concrete

Advantages of vacuum concreting:

Due to dewatering through vacuum, both workability and high strength are achieved simultaneously.

Reduction in water-cement ratio may increase the compressive strength by 10 to 50% and lowers the permeability.

It enhances the wear resistance of concrete surface.

The surface obtained after vacuum dewatering is plain and smooth due to reduced shrinkage.

The formwork can be removed early and surface can be put to use early.

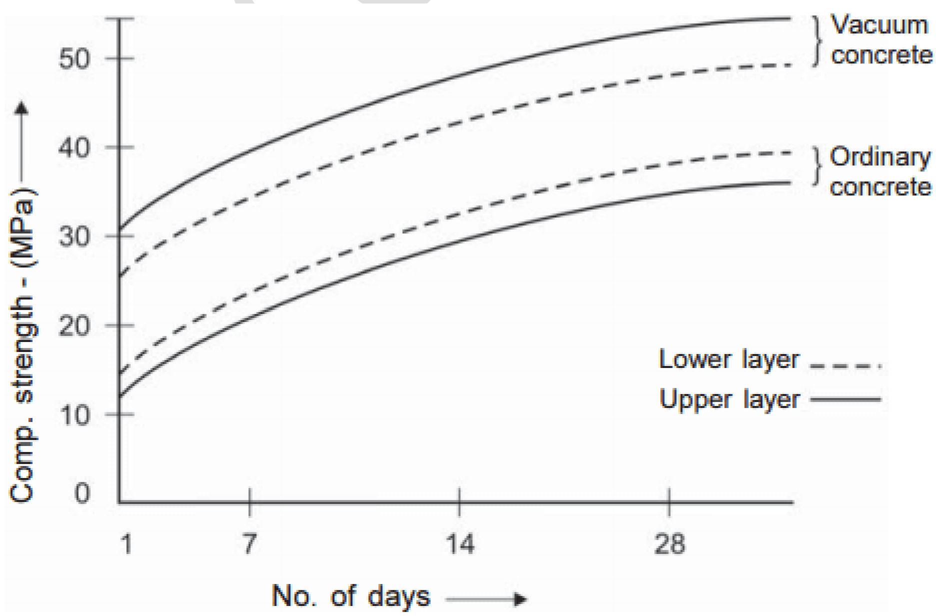


Fig. 2: Effect of vacuum dewatering of concrete

The advantages of dewatering are more prominent on the top layer as compared to bottom layer as shown in fig. 2 above. The effect beyond a depth of 150mm is negligible.

2. Explain Polymer Impregnated Concrete?(April/May 2017)

The ways in which the polymer is introduced into the hardened concrete widely depend upon the commercial objective, but include some or all of the following operations.

(a) The concrete is thoroughly dried, usually by heating.

(b) The dry concrete is evacuated.

(c) The concrete is immersed in the chosen monomer (or the monomer applied to the surface of the concrete).

(d) Pressure is applied.

(e) The impregnated concrete is sealed to avoid loss of monomer.

(f) The monomer is converted to polymer either by gamma radiation or by thermal, Catalytic method.

(g) The concrete is cooled.

The full sequence of operations can only be followed in a precast concrete factory. In the site work, it is normally possible to dry the concrete only partially and to apply the monomer to the surface and to use beat to control the polymer conversion.

A wide range of monomers have been used. These include:

(a) acrylonitrile

(b) ethyl acrylate.

(c) methyl methacrylate (MMA).

(d) Polyester styrene.

(e) styrene.

(f) vinyl chloride.

A mixture of 70% MMA plus 30% of trimethylopropanetrimethacrylateas also been used for high temperature applications in desalination plants. Improvements in compressive and tensile strength result from the introduction of polymer. However, the quality of polymer the can be introduced depends on the porosity of the concrete and hence the potential improvement of a particular' concrete is large if the original concrete is weak (i.e., has a high porosity) but in very small if the basic concrete is of high strength and of law porosity. In fact, in careful mix design, it is not different to make workable plain concretes from Portland cement and strong natural aggregates with a 28 day cube strength of 100 N/mm^2 whereas most Polymer impregnated concretes, irrespective ranging of the strength of the basic modified concrete, have cube strengths from 120 to 150 N/mm^2. These high strength are stable and do not increase higher with age but the strength of the plain concretes continue to rise and at one stage, the 'advantage shown by the polymer impregnated concretes would have largely disappeared. On the other hand, if very high early age strengths are required (at 8 days say), the polymer impregnation technique could prove worthwhile. However, if the polymer cement ratio is only 1:20, the material costs are above doubled and with the addition of extra handling, curing and polymerization costs, the resulting product if necessarily expensive.

Properties:

Polymer - impregnated concretes normally have cube crushing strengths in excess of 100 N/mm^2 irrespective of the strength of the original untreated concrete. The weaker Concretes will absorb a higher proportion of the monomer and hence will have higher material costs. The flexural strengths are usually about 15 N/mm^2, which is slightly higher than that for the higher strength plain concretes that can be made from normal constituents. The elastic moduli lie in the range from 30 to 60 kN/mm^2.which are similar to those for high-strength plain 'concrete (about 45 kN/mm^2).

As the strength and elastic moduli of high-strength plain and polymer impregnated concretes are not very different. the failure and cracking strains are unlikely to differ significantly. High - strength concretes of the types tend to be brittle and cracks, once imitated, propagate rapidly and frequently run through the aggregate. This can mean that the total energy expended in fracturing high-strength material is less than that demanded by more conventional (medium-strength) concretes in which the aggregate impends, the propagation of cracks and failure relatively CIrcle and not explosive and catastrophic.

During the manufacturing cycle, polymer-impregnated concretes have other been heated to 150°C and in consequence of this and of the reduced porosity and permeability, these concretes have low shrinkage and creeping characteristics. If the temperature is above ambient, it is possible that the creep will be greater.

All the polymer-impregnated concretes tented have improved resistance to sulphate, chloride and acid attack compared with the pain concrete from which they are made. Whilst significant improvement have also been observed in the resistance to cycles of freezing and thawing it is important to note that similar improvements are shown by ground (high-strength) air-entrained concretes devoid of any polymer.

Applications:

Polymer-cement concretes are several times more expensive that plain so that they will only be used for special applications. The principal shown by these concretes are:

(a) greater failure strain;

•(b) good bond with old concrete

(c) improved resistances to abrasion.

(d) improved durability and resistance to chemical attack.

Some typical applications in which these properties have been worthwhile are:

(a) for factory floors, particularly where chemical or oil are liable to be spilt.

(b) for repair of old or damaged concrete.

(c) for surfacing steel bridge or ship decks.

(d) for flooring in a frozen food factory

(e) for loading ramps where the abrasive wear of concrete is high.

(f) for concretes subjected to large doses of defeating salts.

3. Explain Polymer Concrete (PC)in detail (OR) how polymerization is achieved in polymer concrete (April/May 2019)(April/May 2018)

Polymer concrete (PC) is a composite material in which the binder consists entirely of a synthetic organic polymer. It is variously known as synthetic resin concrete, plastic resin concrete or simply resin concrete. Because the use of a polymer instead of Portland cement represents a substantial increase in cost. Polymers should be used only in applications in which the higher cost can be justified by superior properties, low labor cost or low energy requirements during processing and handling. It is therefore important that architects and engineers have some knowledge of the capabilities and limitations of Polymer Concrete materials in order to select the most appropriate and economic product for a specific application.

There are mainly 4 types of polymer concrete

1. Polymer impregnated concrete
2. Polymer cement concrete
3. Polymer concrete
4. Partially impregnated and surface coated polymer concrete.

<u>Nature and General Properties:</u>

Polymer concrete consists of a mineral filler (for example, an aggregate) and a polymer binder (which may be a thermoplastic, but more frequently, it is a thermosetting polymer. When sand is used as a filler, the composite is referred to as a polymer mortar.

Generally, any dry, non-absorbent, solid material can be used as a filler. To produce PC, a monomer or a pre-polymer (i.e., a product resulting from the partial polymerization of a monomer), a hardener (cross-linking agent) and a catalyst are mixed with the filler. Other ingredients added to the mix include plasticizers and fire retardants.

Sometimes, silane coupling agents (bonds Organic to inorganic materials) are used to increase the bond strength between the polymer matrix and the filler.

To achieve the full potential of polymer concrete products for certain applications, various fiber reinforcements are used. These include glass fiber, glass fiber-based mats, fabrics and metal fiber.

Setting times and times for development of maximum strength can be readily varied from a few minutes to several hours by adjusting the temperature and the catalyst system. Normally the polymer content will range from 5 to 15 percent of the total weight, but if the filler is fine, up to 30 percent may be required.

Polymer concrete composites have generally good resistance to attack by chemicals and other corrosive agents, havevery low water sorption properties, good resistance to abrasion and marked freeze-thawstability.

Also, the greater strength of polymer concrete in comparison to that of Portland cement concrete permits the use of up to 50 percent less material. This puts polymer concrete on a competitive basis with cement concrete in certain special applications.

The chemical resistance and physical properties are generally determined by the nature of the polymer binder to a greater extent than by the type and the amount of filler. In turn, the properties of the matrix polymer are highly dependent on time and the temperature to which it is exposed.

The viscoelastic properties of the polymerbinder give rise tohigh creep values.This is a factor in the restricted use of PCin structural applications. Its deformation response is highly variable depending on formulation; the elastic moduli may range from 20 to about 50 GPa, the tensile failure strainbeing usually 1%.

Shrinkage strains vary with the polymer used (high for polyester and low for epoxy-based binder) and must be taken into account in an application. A wide variety of monomers and pre-polymers are used to produce PC.

The polymers most frequently used are based on four types of monomers or pre-polymer systems: methyl methacrylate (MMA), polyester pre-polymer-styrene, epoxide pre-polymer hardener (cross-linking monomer) and furfuryl alcohol.

Applications:

Poly (methylmethacrylate) --Used in the manufacture of stair units, façade plates, sanitary products for curbstones

Polyester --Because of lower cost, widely used in panels for public and commercial buildings, floor tiles, pipes, stairs, various precast and cast-in applications in construction works.

Epoxy --Epoxy polymer products are relatively costly; they are mainly used in special applications, including use in mortar for industrial flooring, skid-resistant overlays in highways, epoxy plaster for exterior walls and resurfacing of deteriorated structures.

Furan-based polymer --Furan polymer mortars and grouts are used for brick (e.g. carbon brick, red shale brick, etc.) floors and linings that are resistant to chemicals, elevated temperatures and thermal shocks.

4. **Discuss the procedure of properties, manufacture, and uses of fibre reinforced concrete(April/May 2019)(Nov/Dec 2018)(Nov/Dec 2017)**

Properties:

(i) Compressive Strength

The presence of fibers may alter the failure mode of cylinders, but the fiber effect will be minor on the improvement of compressive strength values (0 to 15 percent).

(ii) Modulus of Elasticity:

Modulus of elasticity of FRC increases slightly with an increase in the fibers content. It was found that for each 1 percent increase in fiber content by volume there is an increase of 3percent in the modulus of elasticity.

(iii) Flexure:

The flexural strength was reported be increased by 2.5 times using 4 percent fibers.

(iv) <u>Toughness:</u>

For FRC, toughness is about 10 to 40 times that of plain concrete. Splitting Tensile Strength The presence of 3 percent fiber by volume was reported to increase the splitting tensile strength of mortar about 2.5 times that of the unreinforced one.

(v) <u>Fatigue Strength:</u>

The addition of fibers increases fatigue strength of about 90 percent and 70 percent of the static strength at 2×10^{6} cycles for non-reverse and full reversal of loading, respectively.

(vi) <u>Impact Resistance:</u>

The impact strength for fibrous concrete is generally 5 to 10 times that of plain concrete depending on the volume of fiber used.

<u>The following are some of the structural behavior</u>

(a) <u>Flexure:</u>

The use of fibers in reinforced concrete flexure members increases ductility, tensile strength, moment capacity, and stiffness. The fibers improve crack control and preserve post cracking structural integrity of members.

(b) <u>Torsion:</u>

The use of fibers eliminates the sudden failure characteristic of plain concrete beams. It increases stiffness, torsional strength, ductility, rotational capacity, and the number of cracks with less crack width. Shear Addition of fibers increases shear capacity of reinforced concrete beams up to 100 percent. Addition of randomly distributed fibers increases shear-friction strength, the first crack strength, and ultimate strength.

(c) <u>Column:</u>

The increase of fiber content slightly increases the ductility of axially loaded specimen. The use of fibers helps in reducing the explosive type failure for columns.

(d) <u>High Strength Concrete</u> :

Fibers increases the ductility of high strength concrete. The use of high strength concrete and steel produces slender members. Fiber addition will help in controlling cracks and deflections.

(e) Cracking and Deflection:

The fiber reinforcement effectively controls cracking and deflection, in addition to strength improvement. In conventionally reinforced concrete beams, fiber addition increases stiffness, and reduces deflection.

Applications/Uses:

The uniform dispersion of fibers throughout the concrete mix provides isotropic properties not common to conventionally reinforced concrete. The applications of fibers in concrete industries depend on the designer and builder in taking advantage of the static and dynamic characteristics of this new material. The main area of FRC applications are 1101 : Runway, Aircraft Parking, and Pavements For the same wheel load FRC slabs could be about one half the thickness of plain concrete slab. Compared to a 375mm thickness' of conventionally reinforced con- crete slab, a 150mm thick crimped-end FRC slab was used to overlay an existing asphaltic-paved aircraft parking area. FRC pavements are now in service in severe and mild environments.

(i) Tunnel Lining and Slope Stabilization:

Steel fiber reinforcedshortcrete (SFRS) are being used to line underground open- ings and rock slope stabilization. It eliminates the need for mesh reinforcement and scaffolding.

(ii) Blast Resistant Structures:

When plain concrete slabs are reinforced conventionally, tests showed(llj that there is no reduction of fragment velocities or number of fragments under blast and shock waves. Similarly, reinforced slabs of fibrous concrete, however, showed 20 percent reduction in velocities, and over 80 percent in fragmentations.

(iii) Thin Shell, Walls, Pipes, and Manholes

Fibrous concrete permits the use of thinner flat and curved structural elements. Steel fibrousshortcrete is used in the construction of hemispherical domes using the inflatedmembrane process. Glass fiber reinforced cement or concrete (GFRC), made by the spray-up process, have been used to construct wall panels. Steel and glass fibers addition in concrete pipes and manholes improves strength, reduces thickness, and diminishes handling damages.

(iv) Dams and Hydraulic Structure:

FRC is being used for the construction and repair of dams and other hydraulic structures to provide resistance to cavitation and severe erosion caused by the im- pact of large Waterboro debris.

Other Applications:

These include machine tool frames, lighting poles, water and oil tanks and con- crete repairs.

(a) Residential:

Including driveways, sidewalks, pool construction with shotcrete, basements, colored concrete, foundations, drainage, etc.

(b) Commercial:

Exterior and interior floors, slabs and parking areas, roadways and

(c) Warehouse / Industrial:

Light to heavy duty loaded floors and roadways

(d) Highways / Roadways / Bridges:

Conventional concrete paving, SCC, white-toppings, barrier rails, curb and gutter work, pervious concrete, sound attenuation barriers, etc.

(e) Ports and Airports:

Runways, taxiways, aprons, seawalls, dock areas, parking and loading ramps.

(f) Waterways:

Dams, lock structures, channel linings, ditches, storm-water structures, etc.

(g) Elevated Decks:

Including commercial and industrial composite metal deck construction and elevated formwork at airports, commercial buildings, shopping centers, etc.

(h) Agriculture:

Farm and animal storage structures, walls, silos, paving, etc.

(i) Precast Concrete and Products:

Architectural panels, tilt-up construction, walls, fencing, septic tanks, burial vaults, grease trap structures, bank vaults and sculptures

5. Enumerate the procedure of manufacture, properties and uses of sulphur infiltrated concrete(Nov/Dec 2018) (Nov/Dec 2017)

Sulphur-infiltrated concrete was developed as an economical alternative to polymer-impregnated concrete (PIC) to be used for higher strength and durable precast concrete elements. Sulphur is a material which is considerably cheaper than the monomers used in the production of PIC.Sulphur-infiltrated concrete is obtained by infiltrating the lean concrete with molten sulphur.

Production of SIC:

The concrete to be infiltrated should be produced usingnormal aggregates with aggregate cement ratios between 3:1 to 5:1 and havingwater cement ratio preferably in the range 0.60 to 0.80. The infiltration procedurenormally used consist of moist-curing of concrete element for 24 hour, at about23°C followed by drying (at. 121°C) for a period of 24 hours, immersing driedelement in molten sulphur at 121°C under vacuum for two hours, releasing thevacuum and soaking for an additional half an hour, and then removing theelements from molten sulphur to cool. In case of low water cement ratio concretewhich are relatively dense external pressure may be applied following the releaseof vacuum to force sulphur into concrete. The foregoing procedure may be modified tosuit individual Job conditions. However, the following points should be kept in mind.

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

(ii) The drying temperature should be kept as high as possible but notexceeding 150°C since a higher temperature may damage the gel-structureof the young hydrated cement paste. The period of drying will depend onthe type and size of element.

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

Mechanical Properties of SIC:

Filling of capillary voids in the hydrated cementpaste and larger voids present at the interface between aggregate and cement pastewith infiltrated sulphur modifies the physical and mechanical properties of concreteconsiderably. The final porosity determines the mechanical properties of SICregardless of mix proportion . This is in agreement with the behaviour of PIC.

The improvements in the properties of concrete due to infiltration of sulphur are given in Table below

Properties	**Improvements over reference infiltrated concrete, per cent**
Compressive strength (i) non air-entrained concrete	150
(ii) air-entrained concrete	200
Splitting tensile strength	100
Elastic modulus	100

The stress- strain relationship of SIC is linear and the strain at failure isnotsubstantially increased because of brittleness of sulphur component.

<u>Durability:</u>

Generally the performance of sulphur-infiltrated concrete issatisfactory against freezing and thawing, sea-water attack and wetting anddrying. The sulphur-infiltrated concrete is more durable than conventional concretein higher concentrations of H_2 S04 and *HO.* 'When left submerged in stagnantwater over extended .periods of time. slight leaching of sulphur may take placeand concrete may eventually show undesirable expansion followed by somecracking. The instability of SIC in aqueous media is apparently related to thepresence of' polysulphide anions formed during infiltration and found to be highlysoluble in alkaline pore solutions of wet concrete. The polysulphide and calciumions (dissolved from concrete) form concentrated calcium polysulphade, a yelloworange leachate. Under moist aerated conditions it reacts with oxygen to formsulphur efflorescence,The strength properties of sulphur infiltrated concrete are not significantlyaffected when it is exposed to short term temperatures up to 100°C. At thesetemperatures SIC exhibits certain amount of ductile behaviour before failure,The magnitude of increase in abrasion resistance of SIC depends on thesulphur loading of the test specimens. However, the sulphur filling of the poresin concrete provides an uninterrupted path for heat flow resulting in increasedvalues of thermal conductivity over that of normal dry concrete.

The ductility of sand cement mortar infiltrated with sulphurincreasessignificantly by inclusion of fibres. The addition of fibres increases both ultimate .

flexural strength and peak deflection. The addition of fibers may increase the peakdeflection by as many as six times.The sulphur infiltrated concrete provides a corrosive protection to embeddedsteel. The sulphur loading required for a given corrosive protection depends uponwater cement ratio used ill concrete. Higher the water cement ratio, higher thesulphur loading required. The minimum sulphur loading vario from 10 per centfor 0.70 water cement ratio to 5 per cent for 0.40 water cement ratio.

<u>Applications:</u>

- The sulphur infiltrated concrete is ideally suited for precast units such as patio slabs, sidewalks, kerbs, sewer pipes, and precast units for tunnel linings.
- High impermeability makes SIC suitable for industrial applications requiring high corrosion resistance.
- SIC can also be used for the repair of deteriorated structures and bridge decks.
- The sulphur infiltration can enhance the life span of the sewer pipe due to extremely low permeability of infiltrated product and good chemical resistance.
- It is estimated that the life span of SIC pipes could be doubled at a cost of approximately 25 per cent higher than for infiltrated concrete pipes.
- New types of composition have been produced by the recently developed techniques of impregnating porous material like concrete with sulphur.

- Sulphur impregnation has shown great improvement in strength.
- Sulphur-(impregnated) infiltration can be employed in the precast industries. Sulphur infiltration concrete should found considerable use in industry situation where high corrosion resistant concrete is required.

6. Explain the various test methods of Self compacting concrete (Nov/Dec 2018) (April/May 2018)

A self compacting concrete has the properties such as filling ability, passing ability and segregation resistance. Various workability tests methods are available for self compacting concrete such as slump flow tests, V-funnel test, L-box test, U-Box test, Fill box test etc.

Test Methods for Self Compacting Concrete

The tests methods presented here are devised specifically for self compacting concrete. Existing rheological test procedure have not considered here, though the relationship between the results of these tests and the rheological characteristics of the concrete is likely to figure highly in future work, including standardization work.

In considering these tests there are number of points which should be taken into account:

- There is no clear relation between test results & performance on site.
- There is little precise data, therefore no clear guidance on compliance limits.

A concrete mix can only be classified as self compacting concrete if the requirements for all the following three workability properties are fulfilled.

1. Filling ability
2. Passing ability and
3. Segregation resistance.

Filling Ability of Self Compacting Concrete

It is the ability of SCC to flow into all spaces within the formwork under its own weight. Tests, such as slump flow, V-funnel etc, are used to determine the filling ability of fresh concrete.

Passing Ability of Self Compacting Concrete

It is the ability of SCC to flow through tight openings, such as spaces between steel reinforcing bars, under its own weight. Passing ability can be determined by using U-box, L-box, Fill-box, and J-ring test methods.

Segregation Resistance

The self compacting concrete must meet the filling ability and passing ability with uniform composition throughout the process of transport and placing.

Workability of Self Compacting Concrete

Test methods to determine workability of Self Compacting Concrete are:

1. Slump flow test

The slump flow test is used assess the horizontal free flow of self compacting concrete in the absence of obstructions. The test method is based on the test method for determining the slump

2. V Funnel Test

V funnel test on self compacting concrete is used to measure the flowability. But the flowability of concrete is affected by its other properties as well which may affect the flowability of the concrete during testing.

3. L Box Test

This test assesses the flow of the concrete and also the extent to which it is subjected to blocking by reinforcement.

4. U Box Test

U Box test is used to measure the filing ability of self compacting concrete. U box test was developed by the Technology Research Centre of the Taisei Corporation in Japan. Some time the apparatus is called a “box shaped” test.

5. Fill Box Test

Fill box test is also known as ‘Kajima test’ is used to measure the filling ability of self compacting concrete with a maximum aggregate size of 20 mm.

7. Enumerate the procedure of manufacture, properties and uses of high performance concrete (April/May 2018)

The composition of high performance concrete (HPC) are almost same as those of Conventional Cement Concretes(CCC). But, because of lower Water Cement Ratio, presence of Pozzolans and chemical admixtures etc., the HPCs usually have many features which distinguish them from CCCs.

The proportioning (or mix design) of normal strength concretes is based primarily on the w/c ratio ‘law’ first proposed by Abrams in 1918. For high strength concretes, however, all the components of the concrete mixture are pushed to their limits. Therefore, it is necessary to pay careful attention to all aspects of concrete production, i.e., selection of materials, mix design, handling and placing.

The proportioning (mix design) of High Performance concrete consists of three interrelated steps :

1) **Selection of suitable ingredients** – cement, supplementary cementing materials (SCM),aggregates, water and chemical admixtures.

2) **Determination of relative quantities of these materials** in order to produce, as economically as possible, a concrete that has the rheological properties, strength and durability.

3) **Careful quality control** of every phase of the concrete making process.

COMPOSITION OF HPC

The most common **composition of high performance concrete** as supplementing cementitious materials or **mineral admixtures**are:

1. Silica Fume

2. Fly Ash

3. GGBFS(Ground granulated blast furnace slag)

1. Silica Fume in HPC

Silica fume is a waste by-product of the production of silicon and silicon alloys. Silica fume is available in different forms, of which the most commonly used now is in a densified form. In developed countries it is already available readily blended with cement.

It is possible to make high strength concrete without silica fume, at compressive strength of upto 98 Mpa. Beyond that strength level however, silica fume becomes essential. With silica fume it is easier to make HPC for strengths between 63-98 Mpa.

2. Fly Ash in HPC

Fly Ash of course, been used extensively in concrete for many years. Fly ash is , unfortunately, much more variable than silica fumes in both their physical and chemical characteristics. Most fly ashes will result in strengths of not more than 70 Mpa. Therefore for higher strengths, silica fume must be used in conjunction with fly ash.

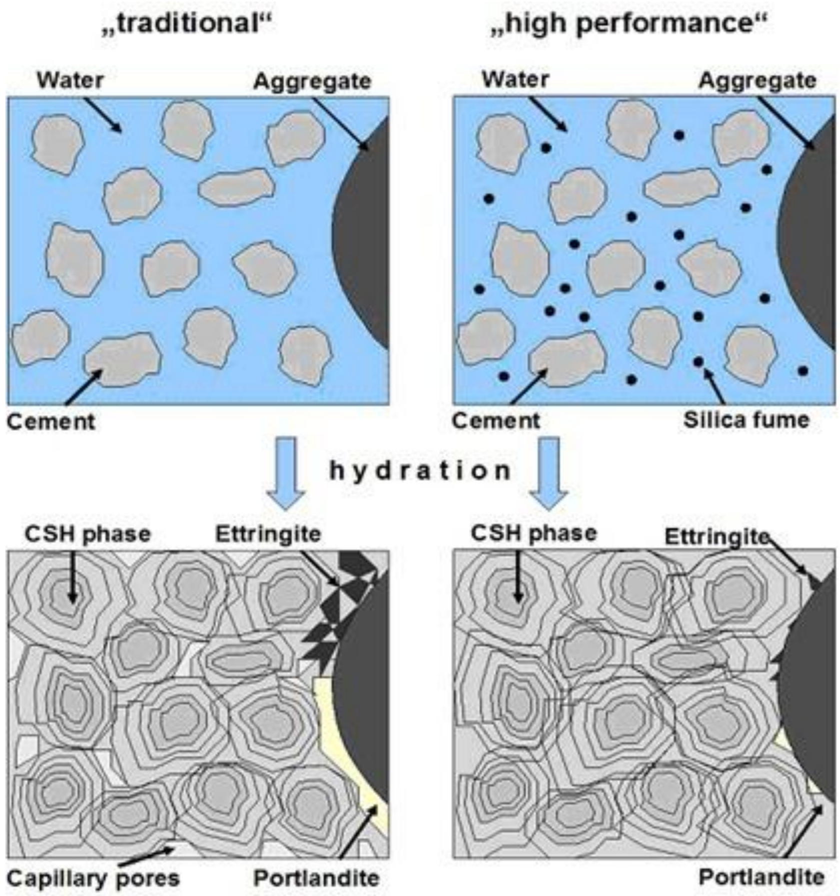
For high strength concrete, fly ash is used at dosage rates of about 15 % of cement content.

3. Ground granulated blast furnace slag (GGBFS) in HPC:

Slags are suitable for use in high strength concrete at dosage rates between 15-30 %. However, for very high strengths, in excess of 98Mpa, it is necessary to use the slag in conjunction with silica fumes.

Key Features of High Performance Concrete (HPC)

- Compressive strength > 80 MPa ,even upto 800 MPa
- Water-binder ratio =0.25-0.35 ,therefore very little free water
- Reduced flocculation of cement grains
- Wide range of grain sizes
- Densified cement paste
- No bleeding – homogeneous mix
- Less capillary porosity
- Discontinuous pores
- Stronger transition zone at the interface between cement paste and aggregate
- Low free lime content
- Endogenous shrinkage
- Powerful confinement of aggregates
- Little micro-cracking until about 65-70% of fck
- Smooth fracture surface



8. Tabulate the different types of fibers used in concrete. What are its advantages?

Fiber-reinforced concrete is concrete that uses other materials mixed in with the still liquid cement to reinforce the concrete structure. These fibers help make the concrete stronger and more resistant to temperature extremes. They also improve the concrete's water resistance.

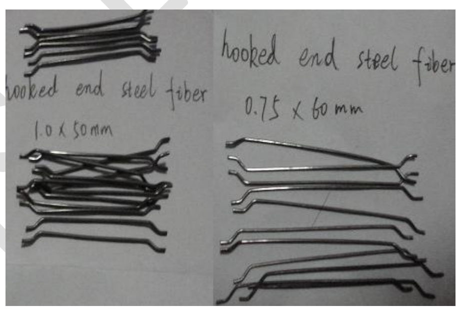
There are different types of fiber-reinforced concrete

1. Steel fiber
2. Glass fiber
3. Polypropylene Fiber Reinforced (PFR) concrete
4. Asbestos Fibers
5. Carbon Fibers
6. Synthetic fiber and
7. Natural fiber reinforced concrete

1) Steel Fiber-Reinforced Concrete

Rebar reinforced concrete uses steel bars that are laid within the liquid cement, which requires a great deal of preparation work but make for a much stronger concrete. Steel fiber-reinforced concrete uses thin steel wires mixed in with the cement. This imparts the concrete with greater structural strength, reduces cracking and helps protect against extreme cold. Steel fiber is often used in conjunction with rebar or one of the other fiber types.

- Commonly used fiber
- Round fibers are used diameter 0.25 to 0.75mm



Advantages:

- ✓ Improved structural strength
- ✓ Reduced steel reinforcement requirements
- ✓ Improved ductility
- ✓ Reduced crack widths and control of crack widths thus improving durability
- ✓ Improved impact & abrasion resistance
- ✓ Improved freeze-thaw resistance
- ✓ Crack, Impact and Fatigue Resistance
- ✓ Shrinkage Reduction

- ✓ Toughness-by preventing/delaying crack propagation from micro-cracks to macro-cracks.

2) Glass Fiber Reinforced Concrete

Glass fiber-reinforced concrete uses fiberglass, much like found in fiberglass insulation, to reinforce the concrete. The glass fiber helps insulate the concrete in addition to making it stronger. Glass fiber also helps prevent the concrete from cracking over time due to mechanical or thermal stress. In addition, the glass fiber does not interfere with radio signals like the steel fiber reinforcement does. It has a very high tensile strength 1020 to 4080N / mm^2

Advantages:

- ✓ Highly durable and safe
- ✓ Design freedom since GFRC is able to be molded into almost any shape and color
- ✓ Requires very low maintenance
- ✓ Installation is quick and cost effective
- ✓ Weather and fire resistant
- ✓ Economical
- ✓ Energy efficient

3) Polypropylene Fiber Reinforced (PFR) concrete:

Polypropylene is a cheap and abundant polymer widely used due to its resistance to forming chemical reactions.

- Increase the impact strength Very high tensile strength
- Low modulus of elasticity and higher elongation do not contribute to the flexural strength

Advantages:

- ✓ Improved mix cohesion and enhanced pumpability over long distances
- ✓ Improved freeze-thaw resistance
- ✓ Improved resistance to explosive spalling in case of a severe fire
- ✓ Improved impact resistance
- ✓ Increased resistance to plastic shrinkage during curing

4) Asbestos Fibers:

These fibers are cheap and provide the cement with mechanical, chemical and thermal resistance, although the asbestos fiber reinforced concrete appears to have low impact strength.

- Mineral fiber.
- Tensile strength of asbestos varies between 560 to 980 N\mm2
- Higher flexural strength.

5) Carbon Fibers:

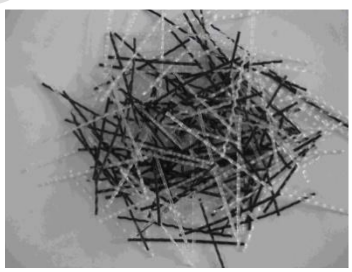
These fibers have been recently used due to their very high modulus of elasticity and flexural strength. Characteristics such as strength and stiffness are better than those of steel fibers, although they are more susceptible to damage.

Advantages:

- ✓ Very high tensile strength 2110 to2815 N/mm2 and Young'sModulus.
- ✓ Very high modulus of elasticity and flexural strength
- ✓ Good durability

6) Synthetic Fibers

Synthetic fiber-reinforced concrete uses plastic and nylon fibers to improve the concrete's strength. In addition, the synthetic fibers have a number of benefits over the other fibers. While they are not as strong as steel, they do help improve the cement pumpability by keeping it from sticking in the pipes. The synthetic fibers do not expand in heat or contract in the cold which helps prevent cracking. Finally, synthetic fibers help keep the concrete from spalling during impacts or fires.



Advantages:

1. **Strong:** Synthetic fibres are strong so they can take up heavy things easily.
2. **Retain their original shape:** Synthetic fibres retain their original shape so it's easy to wash and wear.
3. **Elastic:** Can easily be stretched out.

4. **Soft:** Synthetic fibres are generally soft so they are used in clothing materials.
5. **Colour:** Varieties of colours are available as they are manufactured.
6. **Cost:** Clothes made by synthetic fibres are generally cheaper than those made by natural fibres

7) Natural Fiber Reinforced Concrete

Historically, fiber-reinforced concrete has used natural fibers, such as hay or hair. While these fibers enhance the strength of concrete they can also make it weaker if too much is used. In addition, if the natural fibers are rotting while being mixed, then the rot can continue even while in the concrete. This eventually leads to the concrete crumbling from the inside which is why natural fibers are no longer used in construction.


Advantages:

2. **Comfortable:** Clothes made by natural fibres are more comfortable than those made by synthetic fibres.
3. **Environment:** Producing materials from natural fibres are less harmful to our environment.
4. **Fire resistant:** Natural fibres are resistant to fire but polymer based fibres will melt.

9. Briefly explain about the manufacturing process and application of expansive cement

This cement has a property of expanding while hardening whereas other cement shrink. Shrinkage cracks of ordinary cements may be eliminated by adding suitable proportions of expansive cement to it . In repair works also this cement is quite useful. Opened up joints can be repaired with this cement to make them water tight.

- ✓ Expansive cements are hydraulic cements which, unlike Portland cement, expand during the early hydration period after setting.
- ✓ When the magnitude of expansion is small but usually adequate to offset the tensile stress from restrained drying shrinkage, the cement is known as shrinkage compensating.
- ✓ When the magnitude of expansion is large, the cement is called self-stressing and can be used for the production of chemically prestressed concrete elements.

Expansive cement is a cement which, when mixed with water, forms a paste that, during and after setting and hardening, increases significantly in volume. Shrinkage-compensating concrete, mortar or grout is an expansive cement concrete, mortar or grout, in which expansion, if restrained, induces compressive stresses which approximately offset tensile stresses in the concrete induced by drying shrinkage. Self stressing concrete, mortar or grout is an expansive cement concrete, mortar or grout, in which expansion is restrained inducing compressive stresses of a high enough magnitude to result in a significant compression in the concrete after drying shrinkage has occurred.

<u>Types of Expansive Cements.</u>

Three kinds of expansive cements are defined in ASTM C 845.

1. **Type K**: Contains anhydrous calcium aluminate
2. **Type M**: Contains calcium aluminate and calcium sulfate
3. **Type S**: Contains tricalcium aluminate and calcium sulfate

<u>PROPERTIES:</u>

(i) Workability

Because of the water-imbibing characteristic of ettringite, which forms in relatively large quantities during very early stages of hydration, the concrete mixtures tend to be stiff but highly cohesive. The use of a somewhat higher water-cement ratio than recommended by the standard w/c-strength relationships for normal portland cement concrete is permitted with expansive cements for achieving a reasonable consistency. Compared to portland cements, the ettringite-forming expansive cements are quick setting and prone to suffer rapid slump loss. However, they show excellent workability.

These properties can be anticipated from the large amounts of ettringite formed and the water-imbibing characteristic of the ettringite.

(ii) Slump

Slumps in the range of 100 to 150 mm are recommended for most structural members, such as slabs, beams, reinforced walls, and columns. Because it is more cohesive or "fat" than Portland cement concrete and has less tendency to segregate, the Type K shrinkage- compensating concrete is reported to be especially suitable for placement by pumping.

(iii) Slump loss

Slump loss under hot (concrete temperatures 32C or higher) and dry conditions is more serious a problem in shrinkage-compensating concrete than in normal portland cement concrete.As a result of slump loss, excessive retempering of concrete on the job site will not only reduce the strength but also the expansion, which defeats the purpose for which the concrete is used. At higher than 17 to 29 deg. C ambient temperatures, unless the concrete is cooled, both the amount of ettringite formed and the rate of its formation may be large enough to cause severe slump loss and quick setting.

(iv) Plastic shrinkage

Because of lack of bleeding and quicker stiffening and setting of concrete under hot, dry, and windy conditions, plastic shrinkage cracking is another problem for which extra precautions must be taken when using the shrinkage-compensating concrete. When fresh concrete is likely to be in contact with an absorptive surface, the base should be thoroughly saturated by soaking it the evening before placement. Special precautions should be taken to avoid placement delays at the job site when using ready-mixed concrete. For slabs, fog spraying or covering the surface with wet blankets soon after placement is desirable in order to prevent rapid moisture loss.

(v) <u>Strength</u>

The development of compressive, tensile, and flexural strength in shrinkage-compensating concrete is generally influenced by the same factors as portland cement concrete.

(vi) <u>Frost resistance</u>

Air-entraining admixtures are as effective with shrinkage-compensating concrete as with Portland cement concrete in providing freeze-thaw and deicer salt durability.

(vii) <u>Durability</u>

The restrained expansion of concrete, lack of bleeding, and little or no micro-cracking by drying shrinkage, the shrinkage-compensating concrete provides a more dense and essentially impermeable mass than does portland cement concrete of an equivalent water-cement ratio in the range 0.4 to 0.6. Laboratory and field experience has shown that Type K cement concretes possess a significantly higher resistance to abrasion, erosion, and
chemical attack by aggressive solutions.

(viii) <u>Sulfate Resistance</u>

Type K shrinkage-compensating cements made with blending ASTM Type II or Type V Portland cement show excellent durability to sulfate attack because they contain little reactive alumina or monosulfate after hydration.

10. Explain in detail Shrinkage Compensating Concrete?

Shrinkage compensating concrete (SCC) is an expansive cement concretewhich, when properly restrained by reinforcement or other means with expand anamount equal or slightly greater than the anticipated drying shrinkage. Because of the restraintcompressive stresses will be induced in the concrete duringexpansion. Subsequently drying shrinkage will reduce these stresses. Ideally, aresidual compression will remain in the concrete, eliminating the risk of shrinkagecracking.

As the expansive cement used in the concrete hydrates, large amount of outranged are formed. When the concrete sets and develops strength, it will offerbond to the reinforcement and at the same time start expanding if sufficientquantity of curing water is present. Since the concrete is bonded to steel, itsexpansion under the restraining influence of steel induces tension in the latterwhile the concrete itself goes into compression.

At the end of moist curing, whenthe element is exposed to drying conditions, it will shrink like a PCC. However, the shrinkage will first relieve the recompression before inducing tensile stress inconcrete. By preventing the building of high tensile stress, the risk of cracking of concrete due to drying shrinkage is reduced.

Current design and construction practices assume that concrete will crackand try to get around the problem in many ways such as selection andproportioning of concrete mixes that will shrink loss, provision of adequate jointsin floor slabs or pavements and reinforcement of concrete elements with steel. Theadvent of expansive cement has offered an alternative and cost effective approach.

The same basic materials and methods necessary to produce high quality PCCarerequired to produce satisfactory results in the use of SCC. Additional care, however,is necessary to provide continuous moist curing for at least 7 days after placement,in order that the expansion does take place, and the structural design must besuch as to ensure adequate expansion to offset subsequent drying shrinkage.

Characteristics/ Properties:

(i) Workability:

Because of the water-imbibing characteristics of outranged, whichforms in relatively large quantities during very early stages of hydration. Theconcrete mix tends to stiff but is highly cohesive. Compared to OPC, the use of asomewhat higher w/c ratio (without the possibility of strength impairment) thanrecommended by the standard water-cement strength a relationship of PCC istherefore, permitted with expansive cements for achieving a reasonable consistency.

The slumps in the range of 100 to 150 mm are recommended for most structuralmemberssuch as slabs, beams, reinforced walls and columns.

(ii) <u>Slump Loss:</u>

Slump loss under hot (concrete temperature 32°C or higher and dryconditions) is more serious a problem in shrinkage compensating concrete than inPCC. As a result for slump loss, excessive retempering of concrete on the job sitewill not only reduce the strength but also the expansion, which defeats the purposefor which the concrete is used.

(iii) <u>Plastic Shrinkage:</u>

Because of lack of bleeding and quicker stiffening and settingof concrete under hot, dry, and windy conditions, plastic shrinkage cracking isanother problems for which extra precaution must be taken when using theshrinkage compensating concrete. When fresh concrete is likely to be in contactwith an absorptive surface such as a dry soil or as old concrete, the base shouldbe thoroughly strutted by soaking it the evening before placement.

(iv) <u>Strength:</u>

The development of compressive, tensile, and flexural strength in shrinkage compensating concrete is generally influenced by the same factors asPCC. In the case of SCC, a denser cement paste matrix and a stronger transitionzone between the cement paste and coarse aggregate are the factors responsiblefor strengths higher than those of PCC made with an equivalent w/c ratio.

(v) <u>Volume changes:</u>

The drying shrinkage characteristics of sec are comparable tothose of a corresponding PCC, the rate and the magnitude of shrinkage in boththe cases, are affected by the same factors, such as aggregate content and type,and water content. However, in the case of SCC, the influence of the w/cratio onexpansion during the early moist curing period is quite important. Since the degreeof needed pre-compression in SCC may reduce considerably with w/c ratio above 0.6, it is recommended that low wlcratios be used even when this is not neededfrom the standpoint of strength.

<u>(vi) Durability:</u>

For several reasons, such as the restrained expansion of concrete, lackof bleeding, and little or no micro-cracking by drying shrinkage, the see providesa more dense and essentially impermeable mass than does PCC of an equivalentw/c ratio in the range of 0.4 to 0.6.

Applications:

The higher cost of the expansive cement used can be balanced byreduced amount of drying shrinkage reinforcement required, large placementsections, and fewer construction joints and water stops compared with PCCconstruction. Since 1990s, expansive cements have been used in several countriesfor the purpose of producing both shrinkage compensating concrete andself-stressing concretes. Most of the applications have been in structural elements,such as slabs, pavements, prestressed beams and roofs.

11. With respect to fibre reinforced concrete explain aspects ratio and volume fraction. Also explain their effects on fresh and hardened concrete properties. Explain with its stress-strain curve.

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.

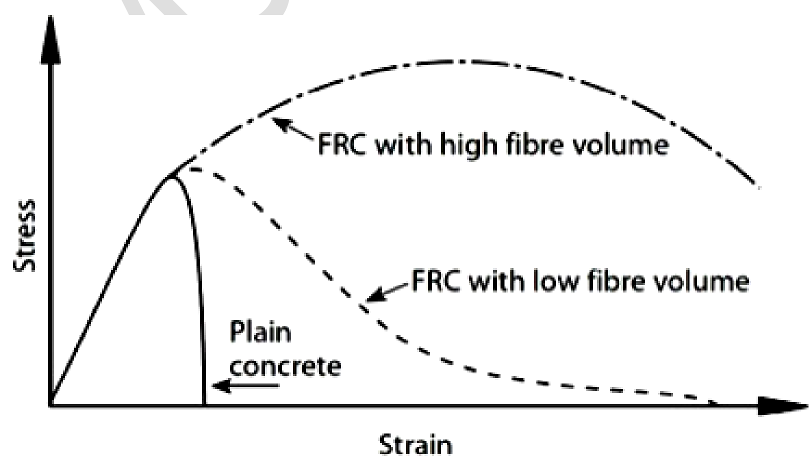


Fig. stress-strain curve

Aspect Ratio of the Fiber

Another important factor which influences the properties and behavior of the composite is the aspect ratio of the fiber. It has been reported that up to aspect ratio of 75, increase on the aspect ratio increases the ultimate concrete linearly. Beyond 75, relative strength and toughness is reduced. Table 1.1 shows the effect of aspect ratio on strength and toughness.

Table Aspect ratio of the fiber

Type of concrete	Aspect ratio	Relative strength	Relative toughness
Plain concrete	0	1	1
With	25	1.5	2.0
Randomly	50	1.6	8.0
Dispersed fibers	75	1.7	10.5
	100	1.5	8.5

Classification according to volume fraction

1. Low volume fraction (<1%)
2. Moderate volume fraction (between 1 and 2%)
3. High volume fraction (greater than 2)

Low volume fraction

- ✓ The fibers are used to reduce shrinkage cracking. These fibers are used in slabs and pavements that have large exposed surface leading to high shrinkage crack.
- ✓ Disperse fibers offer various advantages of steel bars and wiremesh to reduce shrinkage cracks:
    a) The fibers are uniformly distributed in three-dimensions making an efficient load distribution;
    b) The fibers are less sensitive to corrosion than the reinforcing steel bars,
    c) The fibers can reduce the labor cost of placing the bars and wiremesh.

Moderate volume fraction

- ✓ The presence of fibers at this volume fraction increases the modulus of rupture, fracture toughness, and impact resistance. These composite are used in construction methods such as shotcrete and in structures that require energy absorption capability, improved capacity against delamination, spalling, and fatigue.

High volume fraction

- ✓ The fibers used at this level lead to strain hardening of the composites. Because of this improved behavior, these composites are often referred as high-performance fiber-reinforced composites (HPFRC). In the last decade, even better composites were developed and are referred as ultra-high-performance fiber reinforced concretes (UHPFRC).

Fresh Properties of PPFRC

Fibrillated fibers in concrete tend to separate into individual fibers during the mixingprocess. The dispersion of such individual fibers has a crucial effect on theworkability of concrete. Consistency is reduced with increasing fiber contents, andthis reduction is even greater with longer fibers. Effect of the content and length offibrillated polypropylene fibers on the consistency of the concrete can be seen inFigure 10. Reduction in consistency may not be an indication of reduction inworkability. Under dynamic conditions, PPFRC can still show sufficient workabilityand can be compacted without excessive vibration.

Although modulus of elasticity of polypropylene fibers is lower than that of concretein the hardened state, it is higher in the plastic state of concrete. Thus polypropylenefibers can be effective in improving the cracking characteristics of the fresh concrete.Free shrinkage and restrained shrinkage tests conducted in laboratory conditionsshow that addition of polypropylene fibers reduce cracking and crack widths and thiseffect is more pronounced with increasing fiber contents.

12. Explain the 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, depends upon the efficient transfer of stress between matrix and the fibers. The factors are briefly discussed below:

1. Relative Fiber Matrix Stiffness

The modulus of elasticity of matrix must be much lower than that of fiber for efficient stress transfer. Low modulus of fiber such as nylons and polypropylene are, therefore, unlikely to give strength improvement, but the help in the absorbsion of large energy and therefore, impart greater degree of toughness and resistance to impart. High modulus fibers such as steel, glass and carbon impart strength and stiffness to the composite.

Interfacial bond between the matrix and the fiber also determine the effectiveness of stress transfer, from the matrix to the fiber. A good bond is essential for improving tensile strength of the composite.

2. Volume of Fibers

The strength of the composite largely depends on the quantity of fibers used in it. Fig 1.1 and 1.2 show the effect of volume on the toughness and strength. It can see from Fig 1.1 that the increase in the volume of fibers, increase approximately linearly, the tensile strength and toughness of the composite. Use of higher percentage of fiber is likely to cause segregation and harshness of concrete and mortar.

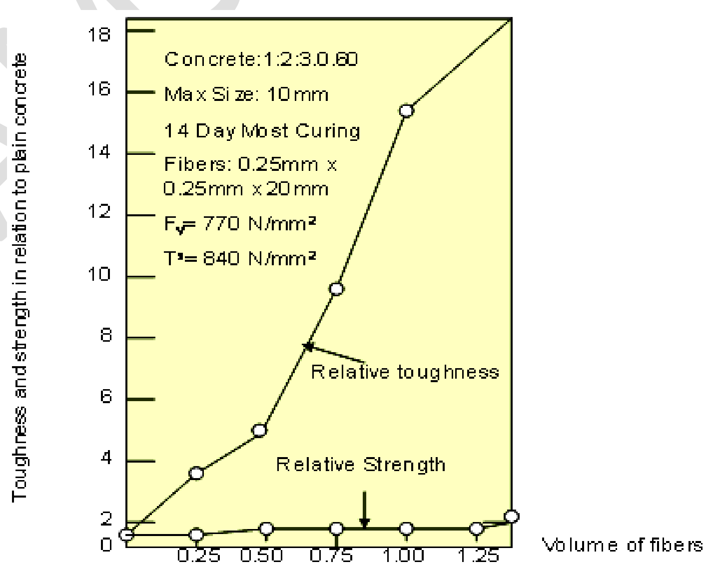


Fig. 1 Effect of volume of fibers in flexture.

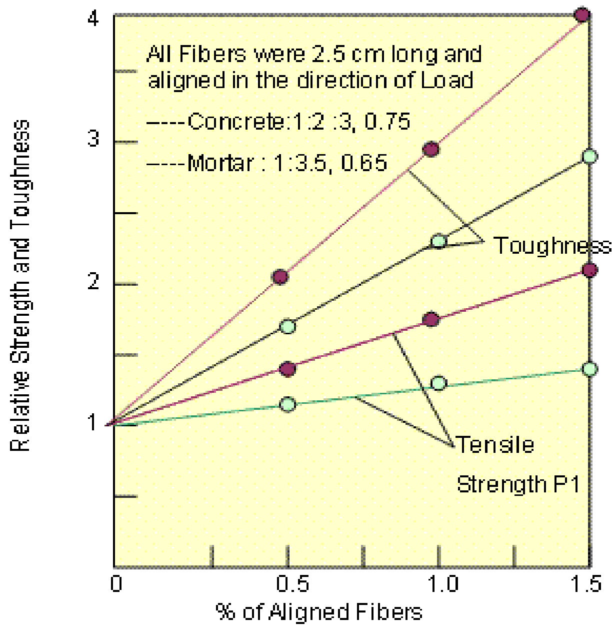


Fig. 2 Effect of volume of fibers in tension.

3. Aspect Ratio of the Fiber

Another important factor which influences the properties and behavior of the composite is the aspect ratio of the fiber. It has been reported that up to aspect ratio of 75, increase on the aspect ratio increases the ultimate concrete linearly. Beyond 75, relative strength and toughness is reduced. Table shows the effect of aspect ratio on strength and toughness.

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4. Orientation of Fibers

One of the differences between conventional reinforcement and fiber reinforcement is that in conventional reinforcement, bars are oriented in the direction desired while fibers are randomly oriented. To see the effect of randomness, mortar specimens reinforced with 0.5% volume of fibers were tested. In one set specimens, fibers were aligned in the direction of the load, in another in the direction perpendicular to that of the load, and in the third randomly distributed.

It was observed that the fibers aligned parallel to the applied load offered more tensile strength and toughness than randomly distributed or perpendicular fibers.

5. Workability and Compaction of Concrete

Incorporation of steel fiber decreases the workability considerably. This situation adversely affects the consolidation of fresh mix. Even prolonged external vibration fails to compact the concrete. The fiber volume at which this situation is reached depends on the length and diameter of the fiber.

Another consequence of poor workability is non-uniform distribution of the fibers. Generally, the workability and compaction standard of the mix is improved through increased water/ cement ratio or by the use of some kind of water reducing admixtures.

6. Size of Coarse Aggregate

Maximum size of the coarse aggregate should be restricted to 10mm, to avoid appreciable reduction in strength of the composite. Fibers also in effect, act as aggregate. Although they have a simple geometry, their influence on the properties of fresh concrete is complex. The inter-particle friction between fibers and between fibers and aggregates controls the orientation and distribution of the fibers and consequently the properties of the composite. Friction reducing admixtures and admixtures that improve the cohesiveness of the mix can significantly improve the mix.

7. Mixing

Mixing of fiber reinforced concrete needs careful conditions to avoid balling of fibers, segregation and in general the difficulty of mixing the materials uniformly. Increase in the aspect ratio, volume percentage and size and quantity of coarse aggregate intensify the difficulties and balling tendency. Steel fiber content in excess of 2% by volume and aspect ratio of more than 100 are difficult to mix.

It is important that the fibers are dispersed uniformly through out the mix; this can be done by the addition of the fibers before the water is added. When mixing in a laboratory mixer, introducing the fibers through a wire mesh basket will help even distribution of fibers. For field use, other suitable methods must be adopted.

13. Explain Concrete Chemicals (Admixtures) and their Applications

Concrete chemicals are now popularly used in construction industry for building strong, durable and water proof structures. Based on their use they can be grouped under the following four major groups:

1. Mixed with concrete ingredients and spread throughout the body of concrete in order to favorably modify the moulding and setting properties of a mix. These are generally known as admixtures.
2. Applied on surface to protect concrete during or after setting.
3. Applied on concrete forming or molding surfaces to effect mold releasing operations.
4. Applied to bond or repair broken or chipped concrete.

Admixtures are materials other than cement, aggregate and water that are added to concrete either before or during its mixing to alter its properties, such as workability, curing temperature range, set time or color. Some admixtures have been in use for a very long time in concrete construction, such as calcium chloride to provide a cold-weather setting concrete.

Based on their functions, admixtures can be classified into the following five major categories:

(i) Retarding admixtures
(ii) Accelerating admixtures
(iii) Super plasticizers
(iv) Water reducing admixtures
(v) Air-entraining admixtures

Among other important admixtures that do not fit into these categories are admixtures whose functions include bonding, shrinkage reduction, damp proofing and coloring. The following paragraphs provides details on the above-mentioned categories of concrete admixtures.

(i) <u>Retarding Admixtures</u>

Retarding admixtures**,** which slow the setting rate of concrete, are used to counteract the accelerating effect of hot weather on concrete setting. High temperatures often cause an increased rate of hardening which makes placing and finishing difficult. Retarders keep concrete workable during placement and delay the initial set of concrete. Most retarders also function as water reducers and may entrain some air in concrete.

(ii) <u>Accelerating admixtures</u>

Accelerators shorten the set time of concrete, allowing a cold-weather pour, early removal of forms, early surface finishing, and in some cases, early load application. Proper care must be taken while choosing the type and proportion of accelerators, as under most conditions, commonly used accelerators cause an increase in the drying shrinkage of concrete.

Calcium chloride is a common accelerator, used to accelerate the time of set and the rate of strength gain. Excessive amounts of calcium chloride in concrete mix may result in rapid stiffening, increase in drying shrinkage and corrosion of reinforcement. In colder climates, calcium chloride should not be used as an anti-freeze. Large amount of calcium chloride is required to lower the freezing point of the concrete, which may ruin the concrete.

(iii) <u>Super plasticizers</u>

Super plasticizers**,** also known as plasticizers or high-range water reducers (HRWR), reduce water content by 12 to 30 percent and can be added to concrete with a low-to-normal slump and water-cement ratio to make high-slump flowing concrete. Flowing concrete is a highly fluid but workable concrete that can be placed with little or no vibration or compaction. The effect of super plasticizers lasts only 30 to 60 minutes, depending on the brand and dosage rate, and is followed by a rapid loss in workability. As a result of the slump loss, super plasticizers are usually added to concrete at the jobsite.

(iv) <u>Water reducing admixtures</u>

Water reducing admixtures require less water to make a concrete of equal slump, or increase the slump of concrete at the same water content. They can have the side effect of changing initial set time. Water reducers are mostly used for hot weather concrete placing and to aid pumping. A water-reducer plasticizer, however, is a hygroscopic powder, which can entrain air into the concrete mix via its effect on water's surface tension, thereby also, obtaining some of the benefits of air-entrainment (see below).

(v) <u>Air-entraining admixtures</u>

Air-entraining agents entrain small air bubbles in the concrete. The major benefit of this is enhanced durability in freeze-thaw cycles, especially relevant in cold climates. While some strength loss typically accompanies increased air in concrete, it generally can be overcome by reducing the water-cement ratio via improved workability (due to the air-entraining agent itself) or through the use of other appropriate admixtures. As always, admixtures should only be combined in a concrete mix by a competent professional because some of them can interact in undesirable ways.

(vi) <u>Bonding admixtures</u>

Bonding admixtures including addition of compounds and materials such as polyvinyl chlorides and acetates, acrylics and butadiene-styrene co-polymers, can be used to assist in bonding new / fresh concrete with old / set concrete.

Coloring agents have become more commonly used, especially for patios and walkways. Most are surface applied and often have the additional effect of surface hardening. Such surface applied coloring admixtures generally should not be used on air-entrained concrete. Integrally colored concrete is also available.

(vii) <u>Waterproofing and damp proofing admixtures</u>

Water proofing and damp proofing admixtures including soaps, butyl stearate, mineral oil and asphalt emulsions, are used to decrease the amount of water penetration into the larger pores of concrete. "Antifreeze" admixtures typically are accelerators used in very high doses, with a corresponding high price, to achieve a very fast set-time, though they do not have properties to protect against freezing on their own. However, in general, these are not used for residential work

<u>Special admixture to concrete for repair work:</u>

Many special admixtures are in use in normal concrete. For repair work,following,types of admixtures are in use.

(i) Shrinkage-reducing agents:

The most frustrating problem in repair work is shrinkage, which leads to cracks in repair material. Current method of combating this problem includes the use of very low w/c ratio shrinkage reducing admixtures (8RA). The 8RA reduces shrinkage by reducing the surface tension of water in the pores between 2.5 and 50 mm in diameter.

Even after concrete hardens, the 8RA remains in the pores and continuesto reduce the surface tension, thus reducing shrinkage.

(ii) Viscosity-modifying agents:

Viscosity-modifying admixtures provide pseudoplastic. (viscosity decreasing) flow behaviour for concrete or slurries which are pumped or sprayed. 8uch self-levelling (8L) or self-compacting (8C) concretes are particularly needed for repair works. Highly flowable concrete can be effectively used in place without undergoing significant shrinkage or separation.

(iii) Retarders:

Retarders that control the hydration process for extended periods enable ready-mixed concrete to be transported over long distance. These also enable repair material to be plastic till the repair is over.

(iv) Corrosion-inhibiting admixture:

Corrosion inhibitors provide required protection against reinforcement corrosion of repaired materials. The current practice is to use multifunctional admixtures which provide more than one property modification. For example, corrosion inhibition and retardation or shrinkage reducing.

(v) High performance cementitious system:

High performance cementitious systems are chemically bonded ceramics (CBC) that have properties similar to fired ceramics. These have good potential as they are very strong, very dense, and are micro-defect free (MDF) and densified systems containing ultra-fine particles (DSUP). These are known as belite cement or sulfo-aluminate cements. These are technology-shaping parameters of repair materials.

(vi) Epoxy grouts, Mortars and coatings:

These are used:

1. To bond plastic concrete to hardened concrete
2. To bond rigid materials to each other
3. For patching work.
4. For casting over concrete to give colour, resistance to chemicals water penetration, abrasion etc., and epoxy coatings are available for marine underwater and moisture resistance condition.

Epoxy resins for Structural repairs anrehabilitations:

Amongst the synthetic resins such as epoxy, polyester, acrylic, polyurethane,etc. epoxy resins possess very high mechanical and adhesive strength propertiesmost desirable for Civil Engineering applications. Epoxy resins when cured withdifferent hardeners offer a wide range of properties.

1. High adhesive strength to almost all materials.
2. Low shrinkage during curing.
3. Exceptional dimensional stability.
4. Natural gap filling properties
5. Thermosetting (Does not melt)
6. Resistance to most chemicals and environments.

14. Explain the effects of chemical admixtures on fresh and hardened concrete?

<u>Fresh Concrete:</u>

(viii) Water reducers/ plasticizers.

- Improvement in workability when used as plasticizer
- Better appearance, and uniformity
- Better finishing characteristics
- Less bleeding; greater pumpability
- Some retardation of setting times.

(ii) High range water reducers/ super plasticizers

- Whatever is true of plasticizers more of that with super plasticizers, generally higher dosages; greater benefits in properties of fresh concrete

(iii) Air entraining agents

- Workability increases

- Mixes are more cohesive, Finish ability better.
- Freeze- Thaw resistance.

<u>Hardened Concrete</u>

(i) Water reducer / Plasticizer

- When used as plasticizer no significant effect on 28 day strength, modulus ofElasticity or permeability
- When used as water reducer- reduced creep and shrinkage. Other properties areUnaffected.
- When w/c is reduced enhanced strength, higher modulus of elasticity and allRound improvement in all properties including permeability.

(ii)High range water reducer/ super plasticizer

- Whatever is true for water reducer it is true for high range water reducer as well
- On a statistical basis the concrete is always more uniform, better compacted andVariability of strength is loss
- Long term gain in strength and other properties often noted.

(iii) Air entraining agents

- At the same W/C ratio, compressive strength, flexural and tensile strengths arereduced
- Approximately, for every 1% air entrained (by volume), 5% loss of strength
- Loss of strength overcome by a small reduction in W/C ratio made possible byreducing water content to a small extent
- Durability is better since capillary absorption of water is blocked by air bubbles
- Freeze-Thaw resistance, Resistance to aggressive solutions.

15. Explain polymer modified concrete?

Polymer concrete uses a polymer binder in place of Portland cement. Polymer-modified concrete is Portland cement concrete with polymer solutions added to the mix to achieve certain properties. Like Portland cement concrete, the primary curing mechanism for polymer-modified concrete is hydration of the cement binder.

<u>Physical and Mechanical Properties of Polymer Modified Mortars/Concrete:</u>

Admixing of polymer latex in cementitious mixtures modifies the following physical andmechanical properties:

i. <u>Workability:</u>

Generally polymer mortars/polymers modified concrete (PMM/PMC)
have better workability compared to conventional mortar/concrete.

<u>ii. Water retention:</u>

PMM/PMC have remarkably improved water retention propertyover ordinary mortar/concrete. The water-curing requirement is substantially reducedand needs to be specified accordingly to suit the polymer type, its proportion andmethod of curing.

ii. <u>Bleeding and Segregation:</u>

A better resistance to bleeding and segregation even though they have better flowability.

iii. <u>Increased Resistance to Crack Propagation:</u>

Micro cracks occur easily in theordinary stressed hardened cement paste. This leads to poor tensile strength and fracturetoughness. Whereas, in the latex-modified mortar and concrete, it appears that themicro cracks are bridged by the polymer films or membranes, which prevent crackpropagation and simultaneously, a strong cement hydrate-aggregate bond is developed.

iv. <u>Strength:</u>

PMM/PMC with styrene butadiene polymer (SBR) latexes have a noticeable increase in tensile and flexural strength but there is hardly any improvement in its compressive strength compared to ordinary mortar/concrete. An increase in the polymer content or polymer-cement ratio (defined as the weight ratio of the amount of total solids in polymer latex to the amount of cement in a latex-modified mortar or concrete) leads to increase in flexural tensile strength and fracture toughness. However, excess air entrainment and polymer inclusion cause discontinuities of the formed monolithic network structure, whose strength is reduced.

v. Chemical resistance of PMM/PMC:

This depends on the type of polymer, polymer cement ratio and type of chemicals. Most PMM & PMC with styrene butadiene polymers (includes other like modified acrylics etc.) are attacked by strong organic and inorganic acids and sulphate but these resist alkalis and salts other than sulphates. Their resistance to chlorides, fats and oils is also rated as good while they have a poor resistance to organic solvents.

vi. Temperature effect:

The strength of PMM/PMC depends on temperature. They
generally show a rapid reduction in strength with increase in temperature. Mostthermoplastic polymers have a glass transition temperature of 80 deg. to 100 deg.
Centigrade.

vii. Shrinkage:

The drying shrinkage of PMM/PMC may be larger or smaller than that of standard mortar or concrete depending on type of polymer and polymer: cement ratio used. More is the polymer ratio, lesser is drying shrinkage.

viii. Water proofing Quality or permeability:

PMM/ PMC have a structure in which the larger pores are filled by polymer or these are sealed by continuous polymer flow. The sealing effect and porosity due to the polymer films or membranes formed in the structure also provides a considerable increase in water proofness or water tightness as well as resistance to chloride ion penetration, moisture transmission, carbonation and oxygen diffusion chemical resistance, and freeze-thaw durability. Such an effect is promoted with increasing polymer- cement ratio upto a certain level of polymer loading.

ix. Adhesion or bond strength:

A very useful aspect of PMM/PMC is their improved adhesion or bond strength to various sub-strata compared to conventional mortar/ concrete.

x. Abrasion Resistance:

PMM/PMCs have abrasion resistance better than theconventional mortar/concrete.

xi. Durability and non-degradability:

Generally these materials are bio non-degradable after total polymerization takes place. However, certain polymers tend to disintegrate under any form of energy like ultra violet rays, heat etc. Particularly
"styrene" based materials are reported to undergo such rapiddisintegration and degradation and hence advised to be avoided. Whereas"acrylate" based materials are accepted due to their non-degradable and robustproperties.

Fields of Application:

A. Structural repairs to RCC:

PMM/PMC are used to make up the damaged/lost cover concrete due to their better bond with substrate, including the reinforcement.

B. Ultra Rapid Hardening Polymer Modified Shotcrete:

Ultra Rapid Hardening Polymer Modified Shotcrete system can be classified in to twocategories:

— One, which uses a polymerisable monomer that reacts with Ordinary Portland cement at ambient temperature. This system is used as repair and protective material
for concrete structures with leaking and flowing water. It uses magnesium acrylate monomer and its setting time can be controlled within few seconds or less. Fig 5.4 represents a schematic diagram of this shotcrete system.

— Second, which uses ultra rapid hardening cement concrete with SBR latex and is often used for urgent construction and repair works.

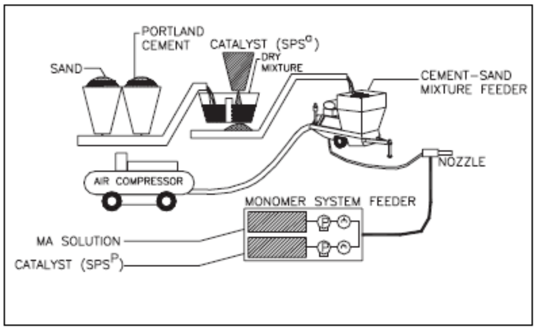

Fig 5.4: Schematic Diagram of Ultra-rapid hardening polymer modified shotcrete

C. Polymer Ferrocements:

For the purpose of improving the flexural behaviour and durability of conventional ferrocement, polymer-ferrocements have been developed using latex modified mortarsinstead of ordinary cement-sand mortars. Use of SBR and EVA modified mortars isfound to be very effective in improving their flexural behaviour, impact resistance, dryingshrinkage and durability. Incorporation of short fibres such as steel and carbon fibres inthe latex modified mortars is found to be further effective in improving such characteristics

applications	Location of work
Paving	office and shops, toilet floors, etc
Materials	Passengers, stairs, chemical plants, railway platforms, roads, garages, etc
Flooring	Concrete roof decks, mortar and concrete
Water	block walls, water tanks, swimming pools,
Proofing	septic tanks, silos, etc
Material	
Adhesive	Adhesives, when flooring materials, walling materials, heat insulating materials, etc are bonded to concrete floors and walls Joining new concrete to old concrete or new mortar to old mortar
	Repair Cracks
Anti corrosive lining	Effluent drains, chemical factory floors, grouting for acid proof tiles, septic tanks, foundation for machinery plants, floor for chemical laboratories, pharmaceutical warehouses, etc
Deck covering	Internal and external ship decks, bridge decks, train or car floors, foot bridge decks, etc

16. Explain ferro cement in detail?

Ferro cement mortar is a composite material, in which the fillermaterial, cement mortar is reinforced with fibers, usually seal mesh dispersedthroughout the composite. The fibres imparts tensile strength to the mass.

In rationally designed ferro cement structures, the reinforcement consists ofa small diameter wire meshes, where in uniform distribution of reinforcement ismade possible throughout the thickness of the element. Because of the distributionof such reinforcement over the entire matrix, high resistance to cracking isachieved. Toughness.fatigued resistance impermeability etc. are also improved.

<u>Construction:</u>

<u>Cement:</u>

The cement should comply with ASTMC 150 – 859, ASTMC 595 -85 or an equivalent standard. The cement should be fresh, of uniform consistency and free of lumps and foreign matter. It should be stored under dry conditions for as short duration as possible.A rich mix of portland cement andsand usually 1.2 to 1.15 mm to reinforcement. No form work is required since thewire mesh and chicken mesh receive the mortar wherein the mortar applied withpressure is held imposition by mechanical interlocking.Portland cement, rapid hardening cement, sulphate resisting portland cementor portland blast furnace cement may be used.

<u>Fine Aggregates:</u>

Normal weight fine aggregate used in ferro cement should comply with ASTMC 33-86 requirements or an equivalent standard. It should be clear, inert, free of organic matter and deleterious substances, and relatively free of silt and clay.

<u>Mixing Water:</u>

The mixing water should be fresh, clean and portable. The water should be relatively free from organic matter, silt, oil, sugar, chloride and acetic material. Salt water is not acceptable, but chlorinated drinking water can be used.

<u>Admixtures:</u>

Conventional and high range water reducing admixtures should be used.

<u>Reinforcement:</u>

Wire mesh with closely spaced wires is the most commonly used reinforcement in ferrocement. Expanded metal mesh, welded wire fabrics, square steel wire mesh, hexagonal or chicken wire mesh are used. The reinforcement may be hexagonal wire mesh (0.5 to 1.00 mm) diameterat 5.25 mm spacing welded wire mesh (18-19 gauge) woven mesh expanded metalsheet and steel mesh. The selected steel may be placed 300 mm apart to serveas a spacer rod to the mesh reinforcement.Steel bar are generally provided to make the form work of the structure and is known as skeletal steel. The size of the rod varies from 4 to 10 mm and spacing of 300 mm apart. In highly stressed structures like boats, barge and tubular sections, the spacing is reduced to 75 mm.

Advantages of Ferro cements:

The advantages of ferro cements are

1. Easy availability of raw materials.
2. Reduction in weight consequent of thick section.
3. Moulding can be done without any form work.
4. No. machinery or sophistication is required in construction.

Disadvantages of Ferro-Cement:

- Structures made of it can be punctured by collision with pointed objects.
- Corrosion of the reinforcing materials due to the incomplete coverage of metal by mortar.
- It is difficult to fasten to Ferro-cement with bolts, screws, welding and nail etc.
- Large no of labors required.
- Cost of semi-skilled and unskilled labors is high.
- Tying rods and mesh together is especially tedious and time consuming.

Ferro cement acts as a homogeneous material in elastic range. Stress straincurve for ferro cement is linear in elastic range and cracks do not develop withan increase in stress, beyond this limit cracks develop. On further increasing thestress member cracks increases rather than the crack width. Near yield thecracks widen and failure takes place.

Applications:

The excellent crack control are the characteristics of ferro cement,make it suitable for liquid retaining structures, boat building gas containers,caissons canallining etc.
Since it is cheaper than steel and RCC and can be castin thin sections, it is most suitable for low cost roofing, precast units, manholecovers, casings etc.
It is the most appropriate building material for theconstruction of domes, vaults, shells, ground surfaces, corrugated sheets and foldedplates.
Used extensively of homing application for the rehabilitation of distressed elements due to overloading, fire damaged beams and columns and general repair in the deteriorating structure.

<u>Ferro Cement as repair material:</u>

(a) Better cracking behavior
(b) Capability of improving some of the mechanical properties of the treated structure
(c) Further modification or repair of ferrocement treatment is not difficult
(d) Ability to withstand thermal changes very efficiently.
(e) Ability of achieving water proofing property without providing any surface treatment
(f) No need for special equipment
(g) Flexibility of further modification.

17. What are the Requirements for the repair materials?

(a) It must be thoroughly bonded to concrete.
(b) Shrinkage of material should be small enough not to jeopardize the bond.
(c) The material and old concrete should respond to changes in temperature, moisture and load similarly enough to avoid gross difference in movement.
(d) The permeability of the material should be sufficiently low.
(e) The material should be resistant to weather action.
(f) In addition to them requirements, it is sometimes necessary to match the color and texture of the old concrete.

18. What are the factors to be considered for selecting repair material?

(A) Function of repair material

(B) Physical and mechanical properties

  a. Dimensional stability
  b. Co-efficient of thermal expansion
  c. Strength in compression, tension and flexure
  d. Stiffness, elastic modulus and poisson's ratio

(C) Durability related properties

  a. Permeability to liquids, vapors and gases
  b. Diffusion resistance
  c. Water absorption, sorptivitiy and porosity
  d. Weathering resistance
  e. Resistance to chemical

(D) Chemical compatibility with other repair materials

(E) Identification of anticipated service conditions

Conditions prevailing at the time of repair

19. What are the classification of Repair materials?

The materials used for concrete repairs and the basis of the type of application into following categories:

(A) Patch repair materials

  a. Cementitious mortar / concrete
  b. Polymer modified cementitious mortar / concrete
  c. Polymer mortar / concrete
  d. Quick setting compounds
    (i) High alumina cement based
    (ii) Caciumsulphate based
    (iii) Magnesium Phosphates
    (iv) Sulphur Concrete

(B) Injection Grouts

  a. Cementitious grouts (with or without fibres)
  b. Gas forming grouts
  c. Sulpho aluminate grouts

d. Polymer grouts

(C) Bonding Aids

a. Polymer emulsion type
b. Polymer resin type

(D) Resurfacing materials

a. Protective coating and membranes
b. Impregnants and hydrophobic sealers
c. Toppings /screeds
d. Overlays
e. Gunite / short crete

(E) Other repair materials

a. Corrosion inhibitors
b. Rebar protective coatings
c. Cathodic protection
d. Realkalization

20. What is the methodology for selection of repair materials?

The following procedure to be adopted is as follows:

(A) Definition of service condition:

Identification of major and minor chemicals,tract spillages, cleaning chemicals, slurries and abrasives,their characteristics and the interaction with the environment under stagnant conditions, operating temperature range, dilute conditions,alternate wetting and drying effect.

(B) Determination of appropriate application condition:

Viscosity, flow characteristics, pot life, curing requirements, layer thickness and size of repair.

(C) Tools and equipments required:

Pump, sprayer, grouting machine, batching plant etc.,

(D) Repair and maintenance schedule:

Anticipated durability of repair, maintenance requirements, strength requirements.

(E) Product performance record:

Durability, functionality,environmental friendliness.

(F) Material testing and assessment for quality assurance and quality control

(G) Selection of applicator /contractor