1. Explain in detail about the SSC, Shottcrete, light weight concrete and high strength concrete (MAY 2019)(NOV 2017) (NOV 2016)

Self compacting concrete

- Self-compacting concrete (SCC) is an innovative concrete that does not require vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement.

- The hardened concrete is dense, homogeneous and has the same engineering properties and durability as traditional vibrated concrete.

- Very close to the Kolhapur there is project of steel industry, sand used for the formation of mould when the moulds are opened the waste sand is dumped for the filling the low lying areas while doing this the agriculture areas is converted into barren area.

- Because there is no space for the waste other than the land filling. similar case is in case of aluminium industry where red mud is concluded to be waste, which contains lot amount of bauxite and that is why red mud is also dump in the nearby areas here it is causing big threat for the society and it is disturbing the eco system of the environment.

- So it is the need to use this particular otherwise waste material for the constructive in such fashion in the case of concrete so that concrete which became cost effective as well as eco-friendly.

Types of SSC

1. Powder type of self-compacting concrete:
This is proportioned to give the required selfcompactability by reducing the water-powder ratio and provide adequate segregation resistance.

2. Viscosity agent type self-compacting concrete:
This type is proportioned to provide selfcompaction by the use of viscosity modifying admixture to provide segregation resistance.

3. Combination type self-compacting concrete:
This type is proportioned so as to obtain self-compactability mainly by reducing the water powder ratio.

Fresh SCC Properties

1. Filling ability (excellent deformability)

2. Passing ability (ability to pass reinforcement without blocking)

3. High resistance to segregation.

It has been observed that the compressive strength of self compacting concrete produced with the combination of admixtures goes on increasing up to 2% addition of red mud. • After 2% addition of red mud, the compressive strength starts decreasing, i.e. the compressive strength of self-compacting concrete produced is maximum when 2% red mud is added. The percentage increase in the compressive strength at 2% addition of red mud is +9.11.

The Gunite or Shotcrete

Gunite can be defined as mortar conveyed through a hose and pneumatically projected at a high velocity on to a surface. Recently the method has been further developed by the introduction of small sized coarse aggregate into the mix deposited to obtain considerably greater thickness in one operation and also to make the process economical by reducing the cement content. Normally fresh material with zero slump can support itself without sagging or peeling off. The force of the jet impacting on the surface compact the material. Sometimes use of set accelerators to assist overhead placing is practised. The newly developed "Redi-set cement" can also be used for shotcreting process.

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

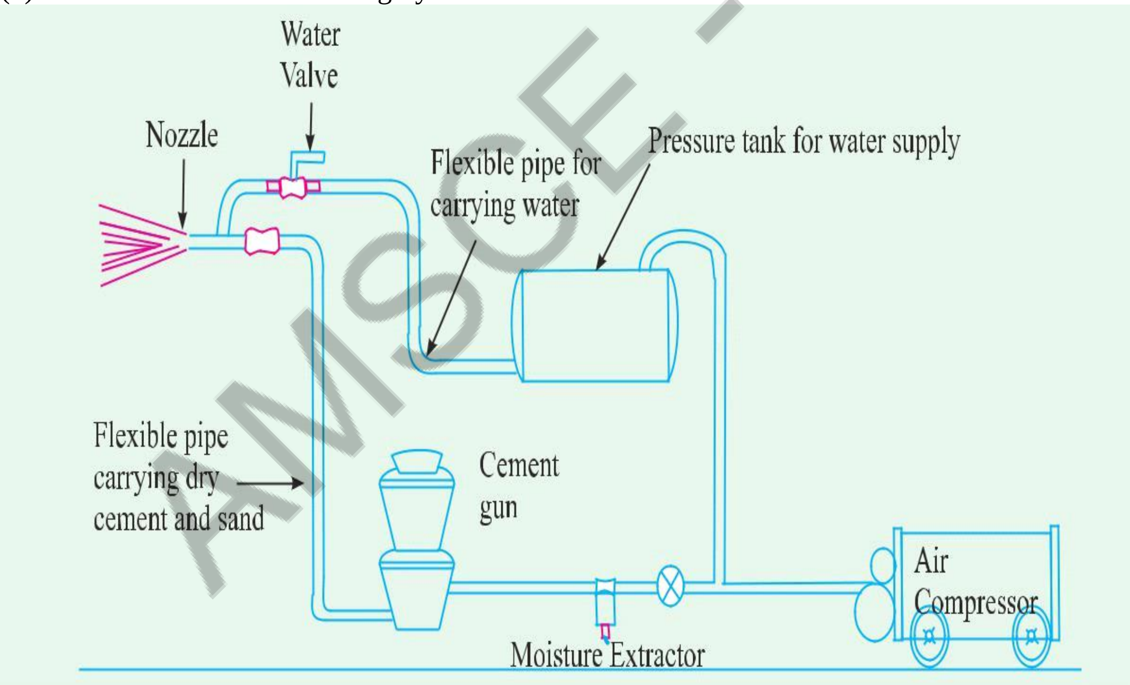
There are two different processes in use, namely the "Wet-mix" process and the "dry-mix" process. The dry mix process is more successful and generally used.

Dry-mix Process

The dry mix process consists of a number of stages and calls for some specialised plant. A typical small plant set-up is shown in Fig. 12.18.

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

(*a*) Cement and sand are thoroughly mixed.



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

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

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

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

The Wet-mix Process

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

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

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

Advantages of Wet and Dry Process

Some of the advantages and disadvantages of the wet and dry processes is discussed below. Although it is possible to obtain more accurate control of the water/cement ratio with the wet process the fact that this ratio can be kept very low with the dry process largely overcomes the objection of the lack of accurate control. The difficulty of pumping light-weight aggregate concrete makes the dry process more suitable when this type of aggregate is used. The dry process on the other hand, is very sensitive to the water content of the sand, too wet a sand causes difficulties through blockade of the delivery pipeline, a difficulty which does not arise with the wet process.

The lower water/cement ratio obtained with the dry process probably accounts for the lesser creep and greater durability of concrete produced in this way compared with concrete deposited by the wet process, but air-entraining agents can be use to improve the durability of concrete deposited by the latter means. Admixtures generally can be used more easily with the wet process except for accelerators. Pockets of lean mix and of rebound can occur with the dry process. It is necessary for the nozzelman to have an area where he can dump unsatisfactory shotcrete obtained when he is adjusting the water supply or when he is having trouble with the equipment. These troubles and the dust hazard are less with the wet process, but wet process does not normally give such a dense concrete as the dry process. Work can be continued in more windly weather with the wet process than with the dry process, Owing to the high capacities obtainable with concrete pumps, a higher rate of laying of concrete can probably be achieved in the wet process than with the dry process.

General Use of Shotcrete

The high cost of shotcrete limits its application to certain special circumstances where considerable savings are accrued and where its peculiar adaptability and technical advantages render it more suitable than conventional placing methods.

Shuttering and formwork need be erected only on one side of the work and it does not have to be so strong as the shuttering for poured concrete.

The saving in shuttering costs makes it particularly applicable for thin sections and although there is no technical reason why unlimited thicknesses cannot be deposited in horizontal and vertical work.

The cost generally limits it to a thickness of 200 mm.

The possible rate of application is low particularly with the dry process. Normally not more than 80 mm thickness can be deposited in overhead work in one day and the possibility of this will depend on the use of a suitable accelerator.

The fact that it can be conveyed over a considerable distance in a small diameter pipe makes this process suitable for sites where access is difficult. The other method that can be adopted in such situation is pumping techniques. It cannot, however, be used in confined spaces as the expansion of the compressed air will cause air turbulences which make accurate placing difficult. Sufficient room is required to hold the nozzle, say 1 m from the work. To accommodate a large radius bend of the delivery hose also requires considerable space. It will bond extremely well to the existing concrete, to masonry and to exposed rock. Suitably prepared steel surface also can be covered with gunited concrete.

The quality of the finished product is liable to be variable and particularly in the dry process the quality is very much dependent on the skill of the nozzleman. Quality control is very difficult and it is not possible to cast reliable test cubes or cylinders. The only way of testing the strength of the work deposited is by taking drill cores or by making a parallel slab by guniting with identical mix. It is difficult to remove rebound material as this tends to collect inside corners and behind reinforcing bars or other obstructions. Pockets of rebound formed as above and due to lack of skill of the nozzleman form weak and porous patches in the finished work. The proportions of the concrete deposited are affected by variation of the water supply and variations in the amount of rebound caused by this and other reasons. Too low an air pressure and surges in the air and water supply also can cause patches of relatively dry material. Defects of this type can result in porous concrete and also contribute to high permeability.

The amount of rebound greatly affects the economics of the shotcrete process as it has all to be discarded and involves labour in collection and disposal. The area surrounding the work will be heavily coated with mortar particularly in windy weather.

It is difficult to obtain a satisfactory surface finish with Shotcrete, particularly with the dry process, because it is almost impossible to trowel due to the low water content. Often it becomes necessary to apply a screed of about 2 cm over the gunited surface.

The application of the shotcrete process is limited to exceptional areas and that too when good nozzleman having the required skill are available. The nozzleman's job is a very strenuous one. It is, therefore, necessary to have relief nozzelmen and for high rates of application some mechanical means of holding the nozzle is required.

The maximum rate of deposition is about 15 m^3. hr for the dry process but this can be exceeded with the wet process.

The low water/cement ratio, the thinness of the section deposited and the fact that normally only one side of the concrete is covered, necessitates careful attention to curing more than with normal concrete.

The normal specifications with respect to cement, aggregate and water, also apply for shotcrete but it is desirable that the aggregate should be rather harder than normal to allow for attrition due to the action of the process. Any cement, provided it does not set too quickly, can be used.

Admixtures can be used in shotcrete to produce the same effects as in ordinary concrete. They should be added to the water in the dry process, but some difficulty may be experienced in obtaining correct proportioning due to variations in the rate of feed of the dry materials. On account of the difficulty of precise control, admixtures whose effects are very sensitive to the proportion added should not be used. Great caution should be exercised in using accelerators in the wet process but accelerators causing an initial set within 30 seconds are used in the dry process. This enable the process to be used in very wet conditions and for sealing leakages. But deficulties have sometime been experienced in obtaining adhesion of the concrete to very set surfaces and these very rapid accelerators are very expensive.

There is not much information on the drying shrinkage and creep of shotcrete. The drying shrinkage will depend on the water content and may, therefore, be expected to be fairly low for the dry process. The creep of dry shotcrete is similar to that of high quality normally placed concrete. But shrinkage and creep of wet shotcrete is likely to be high.

The durability or resistance to frost action and other agencies of dry shotcrete is good. It is not so good for wet shotcrete but can be improved to a satisfactory degree by the use of air-entraining agents. About half of the entrained air is likely to be lost while spraying.

Light-weight Aggregate Concrete

Very often light-weight concrete is made by the use of light weight aggregates. We have seen that different light-weight aggregates have different densities. Naturally when this aggregate is used, concrete of different densities are obtained. By using expanded perlite or vermiculite, a concrete of density as low as 300 Kg/m^3 can be produced, and by the use of expanded slag, sintered fly ash, bloated clay etc., a concrete of density 1900 kg/m^3 can be obtained. The strength of the light-weight concrete may also vary from about 0.3 N/mm^2 to 40 N/mm^2. A cement content of 200 kg/m^3 to about 500 kg/m^3 may be used. Fig. 12.1 shows typical ranges of densities of concrete made with different light-weight aggregates, and Table 12.3 gives the typical properties of light-weight aggregate concrete. Strength of light-weight concrete depends on the density of concrete. Less porous aggregate which is heavier in weight produces stronger concrete particularly with higher cement content. The grading of aggregate, the water/cement ratio, the degree of compaction also effect the strength of concrete

Most of the light-weight aggregate with the exception of bloated clay and sintered fly ash are angular in shape and rough in texture. They produce a harsh mix. Particular care should be taken to improve workability with the addition of excess of fine material, pozzolanic material or some other plasticizing admixtures. The strength of aggregate will also be influenced by the type of fine aggregates. For increasing the strength, for improving the workability and for reducing the water requirement, sometimes natural sand is used instead of crushed sand made out of light-weight aggregate. Use of air-entrainment will greatly improve the workability, and the tendency for bleeding in the light-weight concrete. But the use of air-entrainment will result in further reduction in strength also.

Most of the light-weight aggregates have a high and rapid absorption quality. This is one of the important difficulties in applying the normal mix design procedure to the light-weight concrete. But it is possible to water-proof the light-weight aggregate by coating it with Bitumen or such other materials by using a special process. The coating of aggregate by Bitumen may reduce the bond strength between aggregate and paste. Coating of aggregate by silicon compounds does not impair the bond characteristics but at the same time makes it non-absorbant.

Light-weight concrete being comparatively porous, when used for reinforced concrete, reinforcement may become prone to corrosion. Either the reinforcement must be coated with anticorrosive compound or the concrete must be plastered at the surface by normal mortar to inhibit the penetration of air and moisture inside. Some of the aggregates like clinker or cinder which has more sulphur in themselves cause corrosion of reinforcement. In such cases coating of steel by corrosion inhibiting admixtures is of vital importance.

Structural Light Weight Concrete

The structural light weight concrete is going to be one of the important materials of construction. A concrete which is light in weight and sufficiently strong to be used in conjunction with steel reinforcement will be a material which is more economical than the conventional concrete. Therefore, a concrete which combines strength and lightness will have the unquestionable economic advantage.

Structural light-weight aggregate concrete is a concrete having 28 day compressive strength more than 17 MPa and 28 day air dried unit weight not exceeding 1850 kg/m^3. The concrete may consist entirely of light-weight aggregates (all light-weight concrete) or combination of light weight and normal-weight aggregates. For practical reasons, it is common practice to use normal sand as fine aggregate and light-weight coarse aggregate of maximum size 19 mm. Such light-weight concrete is termed as “sanded light-weight concrete”, in contrast to “all light-weight concrete”.

Workability

Considerable attention is required to be given to the workability aspect for structural light weight concrete. In case of high slump and overvibration, the mortar goes down and aggregate tends to float. This phenomenon is reverse of that of normal weight concrete. In case of floor, or deck slab, the finishing operation will be difficult.

To avoid this difficulty it is usual to limit the maximum slump to 100 mm. It should be remembered that there is going to be higher slump loss on account of continued absorption of water by aggregate.
Light-weight concrete exhibits higher moisture movement than the normal weight concrete. Concrete while wetting swells more and the concrete while drying shrinks more. The higher magnitude of drying shrinkage coupled with lower tensile strength makes the light weight aggregate concrete to undergo shrinkage cracks. But the higher extensibility and lower modulus of elasticity help to reduce the tensile cracks.
Since light-weight concrete contains large per cent of air, it is naturally a better material with respect to sound absorption, sound proofing and for thermal insulations.
The coefficient of thermal expansion of concrete made with light-weight aggregate is generally much lower than ordinary concrete.

Light-weight aggregate concrete exhibits a higher fire resistance property than the normal concrete. Light weight concrete particularly made with slag or pumice or brick bats as aggregate shows higher fire resistance property.

Design of Light -weight Aggregate Concrete Mix

Mix design methods applying to normal weight concrete are generally difficult to use with light weight aggregate concrete. The lack of accurate value of absorption, specific gravity, and the free moisture content in the aggregate make it difficult to apply the water/cement ratio accurately for mix proportioning.
Light-weight concrete mix design is usually established by trial mixes. The proportions of fine to coarse aggregate and the cement and water requirement are estimated based on the previous experiences with particular aggregate. Various degree of water absorption by different light-weight aggregates is one of the serious difficulties in the design of mix proportions. A reliable information of saturated, surface-dry bulk specific gravity becomes difficult.
Sometimes the aggregate is saturated before mixing so that it does not take up the water used for mixing. The quality of concrete does not get altered on account of absorption by aggregate. It has been seen that the strength of the resulting concrete is about 5 to 10 per cent lower than when dry aggregate is used for the same content and workability. This is due to the fact that in the latter case some of the mixing water is absorbed prior to setting.
This water having contributed to the workability at the time of placing gets absorbed later, thus reducing the bad effect of excess of water. Moreover, the density of concrete made with saturated aggregate is higher and the durability of such concrete, especially its resistance to frost is lower.
On the other hand, when aggregate with high absorption is used, it is difficult to obtain a sufficiently workable and yet cohesive mix, and generally aggregates with absorption of over 10 per cent are presoaked.

Mixing Procedure

Mixing procedure for light-weight concretes may vary with different types of aggregates. The general practice for structural light-weight concrete is to mix the aggregate and about 2/3 of the mixing water for a period upto one minute prior to the addition of cement and the balance mixing water.
Mixing is done continuously as required for homogeneity. Usually 2 or more minutes are required to get uniform mixing. In case of some insulating concrete, the aggregate is added at the end of mixing to minimise degradation.
Mix design data have been prepared for several, proprietary light-weight aggregates available in the United Kingdom. The parameters obtained from these charts cannot be taken as final answers. However, they may give information for first trial

High Strength Concrete

Concrete is generally classified as Normal Strength Concrete (NSC), High Strength Concrete (HSC) and Ultra High Strength Concrete (UHSC). There are no clear cut boundary for the above classification. Indian Standard Recommended Methods of Mix Design denotes the boundary at 35 MPa between NSC and HSC. They did not talk about UHSC. But elsewhere in the international forum, about thirty years ago, the high strength lable was applied to concrete having strength above 40 MPa. More recently, the threshold rose to 50 to 60 MPa. In the world scenario, however, in the last 15 years, concrete of very high strength entered the field of construction, in particular construction of high-rise buildings and long span bridges. Concrete strengths of 90 to 120 MPa are occasionally used. Table 7.8 shows the kind of high strength produced in RMC plant.

The advent of Prestressed Concrete Technology Techniques has given impetus for making concrete of higher strength. In India, there are cases of using high strength concrete for prestressed concrete bridges. The first prestressed concrete bridge was built in 1949 for the

Ready Mixed Concrete has taken its roots in India now. The manufacture of high strength concrete will grow to find its due place in concrete construction for all the obvious benefits. In the modern batching plants high strength concrete is produced in a mechanical manner. Of course, one has to take care about mix proportioning, shape of aggregates, use of supplementary cementitious materials, silica fume and superplasticizers. With the modern equipments, understanding of the role of the constituent materials, production of high strength concrete has become a routine matter.

2. Explain about polymer concrete in detail.(MAY 2018)(NOV 2017)

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

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

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

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

Type of Polymer Concrete

Four types of polymer concrete materials are being developed presently. They are:

(*a*) Polymer Impregnated Concrete (PIC).

(*b*) Polymer Cement Concrete (PCC).

(*c*) Polymer Concrete (PC).

(*d*) Partially Impregnated and surface coated polymer concrete.

Polymer Impregnated Concrete (PIC)

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

Mainly the following types of monomer are used:

(*a*) Methylmethacrylate (MMA),

(*b*) Styrene,

(*c*) Acrylonitrile,

(*d*) *t*-butyl styrene,

(*e*) Other thermoplastic monomers.

The amount of monomer that can be loaded into a concrete specimen is limited by the amount of water and air that has occupied the total void space. It is necessary to know the concentration of water and air void in the system to determine the rate of monomer penetration. However, the main research effort has been towards obtaining a maximum monomer loading in concrete by the removal of water and air from the concrete by vacuum or thermal drying, the latter being more practicable for water removal because of its rapidity.

Another parameter to consider is evacuation of the specimen prior to soaking in monomer. This eliminates the entrapment of air towards the centre of the specimen during soaking which might otherwise prevent total or maximum monomer loading. The application of pressure is another technique to reduce monomer loading time.

Polymer Cement Concrete (PCC)

Polymer cement concrete is made by mixing cement, aggregates, water and monomer. Such plastic mixture is cast in moulds, cured, dried and polymerised. The monomers that are used in PCC are:

(*a*) Polyster-styrene.

(*b*) Epoxy-styrene.

(*c*) Furans.

(*d*) Vinylidene Chloride.

However, the results obtained by the production of PCC in this way have been disappointing and have shown relatively modest improvement of strength and durability. In many cases, materials poorer than ordinary concrete are obtained. This behaviour is explained by the fact that organic materials (monomers) are incompatible with aqueous systems and sometimes interfere with the alkaline cement hydration process.

Polymer Concrete (PC)

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

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

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Partially Impregnated (or Coated in Depth CID) and Surface Coated (SC) Concrete

Partial impregnation may be sufficient in situations where the major requirement is surface resistance against chemical and mechanical attack in addition to strength increase. Even with only partial impregnation, significant increase in the strength of original concrete has been obtained. The partially impregnated concrete could be produced by initially soaking the dried specimens in liquid monomer like methyl methacrylate, then sealing them by keeping them under hot water at 70°C to prevent or minimise loss due to evaporation. The polymerisation can be done by using thermal catalytic method in which three per cent by weight of benzoyl peroxide is added to the monomer as a catalyst. It is seen that the depth of monomer penetration is dependent upon following:

(*a*) Pore structure of hardened and dried concrete.

(*b*) The duration of soaking, and

(*c*) The viscosity of the monomer.

The potential application of polymer impregnated concrete surface treatment (surface coated concrete, SC) is in improving the durability of concrete bridge decks. Bridge deck deterioration is a serious problem everywhere, particularly due to a abrasive wear, freeze-thaw deterioration, spalling and corrosion of reinforcement. Excellent penetration has been achieved by ponding the monomer on the concrete surface. Due care should be taken to prevent evaporation of monomer when ponded on concrete surface. A 5 cms thick slab, on being soaked by MMA for 25 hours produced a polymer surface coated depth of 2.5 cms. Significant increases in the tensile and compressive strengths, modulus of elasticity and resistance to acid attack have been achieved.

The application of monomer for field application like in bridge decks poses more problems than laboratory application. A typical surface treatment in the field can be done in the following manner.

(*a*) The surface is dried for several days with electrical heating blanket.

(*b*) Remove the heating blanket and cover the slab with 0.64 m^3 oven-dried light-weight aggregate per 100 sq.m.

(*c*) Apply initially 2,000 to 3,000 ml of the monomer system per square metre.

(*d*) Cover the surface with polyethylene to retard evaporation.

(*e*) Shade the surface to prevent temperature increase which might initiate polymerisation prematurely, that may reduce penetration into the concrete.

(*f*) Add periodically additional monomer to keep the aggregate moist for minimum soak time of 8 hours.

(*g*) Apply heat to polymerise the monomer. Heating blanket, steam or hot water can be used for this purpose.

Some of the promising monomer systems for this purpose are:

(*a*) Methylmethacrylate (MMA), 1% Benzoyl peroxide (BP), 10% Trimethylopropane trimethacrylate (TMPTMA).

(*b*) Isodecyl methacrylate (IDMA), 1% BP, 10% TMPTMA.

(*c*) Isobutyl methacrylate (IBMA), 1% BP, 10% TMPTMA.

BP acts as a catalyst and TMPTMA is a cross linking agent which helps in polymerisation at low temperature of 52%C.

3. Explain in detail about fibre reinforced concrete (MAY 2018)(NOV 2017)

Fibre Reinforced Concrete

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

In the past, attempts have been made to impart improvement in tensile properties of concrete members by way of using conventional reinforced steel bars and also by applying restraining techniques. Although both these methods provide tensile strength to the concrete members, they however, do not increase the inherent tensile strength of concrete itself.

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

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

It has been recognised that the addition of small, closely spaced and uniformly dispersed fibres to concrete would act as crack arrester and would substantially improve its static and dynamic properties. This type of concrete is known as Fibre Reinforced Concrete.

Fibre reinforced concrete can be defined as a composite material consisting of mixtures of cement, mortar or concrete and discontinuous, discrete, uniformly dispersed suitable fibres. Continuous meshes, woven fabrics and long wires or rods are not considered to be discrete fibres.

Fibres Used

Although every type of fibre has been tried out in cement and concrete, not all of them can be effectively and economically used. Each type of fibre has its characteristic properties and limitations. Some of the fibres that could be used are steel fibres, polypropylene, nylons, asbestos, coir, glass and carbon.

Fibre is a small piece of reinforcing material possessing certain characteristic properties. They can be circular or flat. The fibre is often described by a convenient parameter called “aspect ratio”. The aspect ratio of the fibre is the ratio of its length to its diameter. Typical aspect ratio ranges from 30 to 150.

Steel fibre is one of the most commonly used fibre. Generally, round fibres are used. The diameter may vary from 0.25 to 0.75 mm. The steel fibre is likely to get rusted and lose some of its strengths. But investigations have shown that the rusting of the fibres takes place only at the surface. Use of steel fibre makes significant improvements in flexural, impact and fatigue strength of concrete, It has been extensively used in various types of structures, particularly for overlays of roads, airfield pavements and bridge decks. Thin shells and plates have also been constructed using steel fibres.Polypropylene and nylon fibres are found to be suitable to increase the impact strength. They possess very high tensile strength, but their low modulus of elasticity and higher elongation do not contribute to the flexural strength.

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

Glass fibre is a recent introduction in making fibre concrete. It has very high tensile strength 1020 to 4080 N/mm^2. Glass fibre which is originally used in conjunction with cement was found to be effected by alkaline condition of cement. Therefore, alkali-resistant glass fibreby trade name “CEM-FIL” has been developed and used. The alkali resistant fibre reinforced concrete shows considerable improvement in durability when compared to the conventional E-glass fibre.

Carbon fibres perhaps posses very high tensile strength 2110 to 2815 N/mm^2 and Young’s modulus. It has been reported that cement composite made with carbon fibre as reinforcement will have very high modulus of elasticity and flexural strength. The limited studies have shown good durability. The use of carbon fibres for structures like clading, panels and shells will have promising future.

Factors Effecting Properties of Fibre Reinforced Concrete

Fibre reinforced concrete is the composite material containing fibres in the cement matrix in an orderly manner or randomly distributed manner. Its properties would obviously, depend upon the efficient transfer of stress between matrix and the fibres, which is largely dependent on the type of fibre, fibre geometry, fibre content, orientation and distribution of the fibres, mixing and compaction techniques of concrete, and size and shape of the aggregate. These factors are briefly discussed below:

Relative Fibre Matrix Stiffness

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

Interfacial bond between the matrix and the fibres also determine the effectiveness of stress transfer, from the matrix to the fibre. A good bond is essential for improving tensile strength of the composite. The interfacial bond could be improved by larger area of contact, improving the frictional properties and degree of gripping and by treating the steel fibres with sodium hydroxide or acetone.

Volume of Fibres

The strength of the composite largely depends on the quantity of fibres used in it. Fig. 12.5 and Fig. 12.6 show the effect of volume on the toughness and strength. It can be seen from Fig. 12.6 that the increase in the volume of fibres, increase approximately linearly, the tensile strength and toughness of the composite[12.7]. Use of higher percentage of fibre is likely to cause segregation and harshness of concrete and mortar.

Aspect Ratio of the Fibre

Another important factor which influences the properties and behaviour of the composite is the aspect ratio of the fibre. It has been reported that upto aspect ratio of 75, increase in the aspect ratio increases the ultimate strength of the concrete linearly. Beyond 75, relative strength and toughness is reduced. Table 12.10 shows the effect of aspect ratio on strength and toughness.

Orientation of Fibres

One of the differences between conventional reinforcement and fibre reinforcement is that in conventional reinforcement, bars are oriented in the direction desired while fibres are randomly oriented. To see the effect of randomness, mortar specimens reinforced with 0.5 per cent volume of fibres were tested. In one set specimens, fibres 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 fibres aligned parallel to the applied load offered more tensile strength and toughness than randomly distributed or perpendicular fibres.

Workability and Compaction of Concrete

Incorporation of steel fibre decreases the workability considerably. This situation adversely affects the consolidation of fresh mix. Even prolonged external vibration fails to compact the concrete.

The fibre volume at which this situation is reached depends on the length and diameter of the fibre.

Another consequence of poor workability is non-uniform distribution of the fibres. 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.

4. Explain the following.(MAY 2017)(MAY 2016)(NOV 2018)(NOV 2016)

- **Light weight concrete**
- **Fibre reinforced concrete**
- **Polymer concrete**
- **High strength concrete**
- **Ferrocement concrete**
- **Shotcrete**
- **Geopolymer concrete**
- **High performance concrete**
- **Ready mix concrete**

Light weight concrete

The concrete mixture is made with a lightweight coarse aggregate. In some cases a portion or the entire fine aggregates may be a lightweight product.

Lightweight aggregates used in structural lightweight concrete are typically expanded shale, clay or slate materials that have been fired in a rotary kiln to develop a porous structure. Other products such as air-cooled blast furnace slag are also used.

Fiber-reinforced concrete

Fiber-reinforced concrete (FRC) is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibers that are uniformly distributed and randomly oriented. Fibers include steel fibers, glass fibers, synthetic fibers and natural fibers – each of which lend varying properties to the concrete. In addition, the character of fiber-reinforced concrete changes with varying concretes, fiber materials, geometries, distribution, orientation, and densities.

Polymer concrete

Polymer concrete is an ordinary concrete produced with OPC (Ordinary portland cement) wet cured and inseminated with liquid or vaporous chemical compound (Methyl methacrylate monomer) and polymerized by gamma radiation or with chemical initiated implies, i.e by utilizing thermal catalytic method (Adding 3% Benzoyl peroxide) to the monomer as a catalyst. The impregnation is helped by drying the concrete at an extreme temperature by evacuations and absorbing the monomer under limited pressure.

High strength concrete

High strength concrete (HSC) may be defined as concrete with a specified characteristic cube strength between 60 and 100 N/mm^2, although higher strengths have been achieved and used. Strength levels of 80 to 100 N/mm^2 and even higher are being used for both precast and in-situ work

Ferrocement concrete

The term ferro-cement implies the combination of ferrous product with cement. Generally this combination is in the form of steel wires meshes embedded in a portland cement mortar. Wire mesh is usually of 0.8 to 1.00 m diameter steel wires at 5 mm to 50 mm spacing and the cement mortar is of cement sand ratio of 1:2 or 1:3. 6 mm diameter bars are also used at large spacing, preferably in the corners. Sand may be replaced by baby jelly. The water cement ratio used is between 0.4 to 0.45

Shotcrete

Shotcrete is usually an all-inclusive term for both the wet-mix and dry-mix versions. In pool construction, however, **shotcrete** refers to wet mix and gunite to dry mix. In this context, these terms are not interchangeable. **Shotcrete** is placed and compacted at the same time, due to the force with the nozzle.

Geopolymer concrete

Geopolymer cement concrete is made from utilization of waste materials such as fly ash and ground granulated blast furnace slag(GGBS). Fly ash is the waste product generated from thermal power plant and ground granulate blast furnace slag is generated as waste material in steel plant.

Both fly ash and GGBS are processed by appropriate technology and used for concrete works in the form of geopolymer concrete. The use of this concrete helps to reduce the stock of wastes and also reduces carbon emission by reducing Portland cement demand.

The main constituent of geopolymers source of silicon and aluminium which are provided by thermally activated natural materials (e.g. kaolinite) or industrial byproducts (e.g. fly ash or slab) and an alkaline activating solution which polymerizes these materials into molecular chains and networks to create hardened binder. It is also called as alkali-activated cement or inorganic polymer cement.

High performance concrete

High-performance means that the **concrete** has one or more of the following properties: low shrinkage, low permeability, a **high** modulus of elasticity, or **high strength**. ... **High-strength concrete** is typically recognized as **concrete** with a 28-day cylinder compressive **strength** greater than 6000 psi or 42 Mpa.

Slurry Infiltrated fibre Concrete

Slurry infiltrated fibre concrete (SIFCON) was invented by Lankard in 1979. Steel fibre bed is prepared and cement slurry is infiltrated. With this techniques, macro-fibre contents up to about 20% by volume can be achieved, with a consequent enormous increase in both flexural load carrying capacity and toughness. With such high fibre volume, a very high compressive strength is also achieved. SIFCON can be used for blast resistant structures and burglar proof safe vaults in banks and residential buildings.

Ready mix concrete :

Ready-mix concrete is concrete that is manufactured in a factory or batching plant, according to a set recipe, and then delivered to a work site by truck mounted in– transit mixers. This results in a precise mixture, allowing specialty concrete mixtures to be developed and implemented on construction sites. The first readymix factory was built in the 1930s, but the industry did not begin to expand significantly until the 1960s, and it has continued to grow since then.

Ready-mix concrete is often preferred over on-site concrete mixing because of the precision of the mixture and reduced work site confusion. Ready-mix concrete, or RMC as it is popularly called, refers to concrete that is specifically manufactured for delivery to the customer's construction site in a freshly mixed and plastic or unhardened state. Concrete itself is a mixture of Portland cement, water and aggregates comprising sand and gravel or crushed stone.

Uses

1. It is used in the construction of bridge, dam etc.
2. It is used in the construction overhead roads, pools, multistories building etc.
3. It can be directly used at the construction site.
4. It help greater element of automation and precision concrete mixing.

5. Explain geopolymer concrete in detail (MAY 2016)

Geopolymer concrete is an innovative and eco-friendly construction material and an alternative to Portland cement concrete. Use of geopolymer reduces the demand of Portland cement which is responsible for high CO_2 emission.

Geopolymer was the name given by Daidovits in 1978 to materials which are characterized by chains or networks or inorganic molecules.

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Following materials are required to produce this concrete:

- Fly ash – A byproduct of thermal power plant
- GGBS – A byproduct of steel plant

- Fine aggregates and coarse aggregates as required for normal concrete.
- Alkaline activator solution for GPCC as explained above. Catalytic liquid system is used as alkaline activator solution. It is a combination of solutions of alkali silicates and hydroxides, besides distilled water. The role of alkaline activator solution is to activate the geopolymeric source materials containing Si and Al such as fly ash and GGBS.

Mechanical Properties of Geopolymer Concrete

Compressive strength of geopolymer concrete have been found up to 70 MPa (N/mm^2). The concrete gains its compressive strength rapidly and faster than ordinary Portland cement concrete.

The concrete strength after 24 hours have been found to be more than 25 MPa. Compressive strength after 28 days have been found to be 60 to 70 MPa. -Ref. Paper by – James Aldred And John Day and Test results by SERC Chennai.

Other Properties of Geopolymer Concrete:

- The drying shrinkage of is much less compared to cement concrete. This makes it well suited for thick and heavily restrained concrete structural members.
- It has low heat of hydration in comparison with cement concrete.
- The fire resistance is considerably better than OPC based concrete. .
- This concrete jas chloride permeability rating of ‘low’ to ‘very low’ as per ASTM 1202C. It offers better protection to reinforcement steel from corrosion as compared to traditional cement concrete.
- This concrete are found to possess very high acid resistance when tested under exposure to 2% and 10% sulphuric acids.

6. Describe high performance concrete. (NOV 2018)(NOV 2017)

High performance concrete” is used for concrete mixture which possess high workability, high strength, high modulus of elasticity, high density, high dimensional stability, low permeability and resistance to chemical attack.

There is a little controversy between the terms high-strength and high-performance concrete. High-performance concrete is also, a high-strength concrete but it has a few more attributes specifically designed as mentioned above. It is, therefore, logical to describe by the more widely embracing term “High Performance Concrete” (HPC).

It may be recalled that in normal concrete, relatively low strength and elastic modulus are the result of high heterogeneous nature of structure of the material, particularly the porous and weak transition zone, which exists at the cement paste-aggregate interface. By densification and strengthening of the transition zone, many desirable properties can be improved many fold. This aspect has been already discussed in detail. A substantial reduction of quantity of mixing water is the fundamental step for making HPC. Reduction of w/c ratio will result in high strength concrete. But reduction in w/c ratio to less than 0.3 will greatly improve the qualities of transition zone to give inherent qualities expected in HPC.

To improve the qualities of transition zone, use of silica fume is also found to be necessary. Silica fumes becomes a necessary ingredient for strength above to 80 MPa. The best quality fly ash and GGBS may be used for other nominal benefits. Inspite of the fact that these pozzolanic materials increase the water demand, their benefits will out weigh the disadvantages. The crux of whole problem lies in using very low w/c ratio, consistant with high workability at the time of placing and compacting. Neville opines that the lowest w/c ratio that could be used is 0.22.

Adopting w/c ratio in the range of 0.25 to 0.3 and getting a high slump is possible only with the use of superplasticizer. Therefore, use of appropriate superplasticizer is a key material in making HPC. The associated problem is the selection of superplasticizer and that of cement so that they are compatible and retain the slump and rheological properties for a sufficiently long time till concrete is placed and compacted.

Aggregates for HPC

In normal strength concrete, the strengths of aggregate by itself plays a minor role.Any aggregate available at the site could be used with little modification of their grading. The situation is rather different with HPC, where the bond between aggregate and hydrated cement paste is so strong that it results in significant transfer of stress across the transition zone. At the same time, the strength of the cement paste phase, on account very low w/c ratio is

so high that sometimes it is higher than the strength of aggregate particles. Observation of fractured surface in HPC has shown that they pass through the coarse aggregate particles as often as, if not more often than, through the cement paste itself. Indeed in many instances, the strength of aggregate particles has been found to be the factor that limits the compressive strength of HPC.

n the basis of practical experience it is seen that for concrete strength up to 100 MPa, maximum size of 20 mm aggregate could be used. However, for concrete in excess of 100 MPa, the maximum size of coarse aggregate should be limited to 10 to 12 mm.

Regarding the shape of the aggregate, crushed aggregate can be used, but utmost care should be taken to see that aggregates are cubic in shape, with minimum amount of flaky or elongated particles. The latter would effect not only the strength but also adversely affect the workability. In one site in Mumbai even for 60 MPa concrete they had to go for well processed and well graded cubic shaped, coarse aggregate from the point of view of workability. For HPC shape and size of the aggregate becomes an important parameter. Table No. 7.11. gives the composition and stength of HPC that are used in some important buildings in USA and other countries.

In India, it is reported, that HPC of the strength 60 MPa was used for the first time for the construction of containment dome at Kaiga and Rajasthan Atomic Power Projects.