1. Brief about functions and requirement of water proofing admixtures (MAY 2019)

In practice one of the most important requirements of concrete is that it must be impervious to water under two conditions, firstly, when subjected to pressure of water on one side, secondly, to the absorption of surface water by capillary action. Many investigators are of the opinion that the concrete, carefully designed, efficiently executed with sound materials will be impermeable to water. However, since the usual design, placing, curing and in general the various operations involved at the site of work leave much to be desired, it is accepted that a use of a well chosen admixture may prove to be of some advantage in reducing the permeability.

It is to be noted that the use of admixture should in no case be considered as a substitute for bad materials, bad design or workmanship. In no case can an admixture be expected to compensate for cracks or large voids in concrete causing permeability.

Waterproofing admixtures may be obtained in powder, paste or liquid form and may consist of pore filling or water repellent materials. The chief materials in the pore filling class are silicate of soda, aluminium and zinc sulphates and aluminium and calcium chloride. These are chemically active pore fillers. In addition they also accelerate the setting time of concrete and thus render the concrete more impervious at early age. The chemically inactive pore filling materials are chalk, fullers earth and talc and these are usually very finely ground. Their chief action is to improve the workability and to facilitate the reduction of water for given workability and to make dense concrete which is basically impervious.

Some materials like soda, potash soaps, calcium soaps, resin, vegetable oils, fats, waxes and coal tar residues are added as water repelling materials in this group of admixtures. In some kind of waterproofing admixtures inorganic salts of fatty acids, usually calcium or ammonium stearate or oleate is added along with lime and calcium chloride. Calcium or ammonium stearate or oleate will mainly act as water repelling material, lime as pore filling material and calcium chloride accelerates the early strength development and helps in efficient curing of concrete all of which contribute towards making impervious concrete.

Some type of waterproofing admixtures may contain butyl stearate, the action of which is similar to soaps, but it does not give frothing action. Butyl stearate is superior to soap as water repellent material in concrete.

Heavy mineral oil free from fatty or vegetable oil has been proved to be effective in rendering the concrete waterproof. The use of Asphalt Cut-back oils have been tried in quantities of 2 $\frac{1}{2}$,5 and 10 per cent by weight of cement. Strength and workability of the concrete was not seriously affected.

Production of concrete of low permeability depends to a great extent on successful uniform placing of the material. An agent which improves the plasticity of a given mixture without causing deleterious effects or which limits bleeding and thereby reduces the number of large voids, might also be classified as a permeability reducing admixture. Air entraining agents may also be considered under this, since they increase workability and plasticity of concrete and help to reduce water content and bleeding. An air entrained concrete has lower absorption and capillarity till such time the air content do not exceed about 6 per cent.

The aspect of damp-proofing and waterproofing of concrete is a very complex topic. It embraces the fundamentals of concrete technology. Among many other aspects, the w/c ratio used in the concrete, the compaction, curing of concrete, the admixture used to reduce the w/c ratio, the heat of hydration, the micro-cracking of concrete and many other facets influence the structure of hardened cement paste and concrete, which will have direct bearing on permeability, damp-proofing and waterproofing.

2. Explain the characteristics of GGBS and how it enhances the chemical properties of concrete. (MAY 2019)(MAY 2016)

Ground granulated blast-furnace slag is a nonmetallic product consisting essentially of silicates and aluminates of calcium and other bases. The molten slag is rapidly chilled by quenching in water to form a glassy sand like granulated material. The granulated material when further ground to less than 45 micron will have specific surface of about 400 to 600 m^2/ kg (Blaine). The chemical composition of Blast Furnace Slag (BFS) is similar to that of cement clinker. The performance of slag largely depends on the chemical composition, glass content and fineness of grinding.

In India, we produce about 7.8 million tons of blast furnace slag. All the blast furnace slags are granulated by quenching the molten slag by high power water jet, making 100% glassy slag granules of 0.4 mm size. Indian blast furnace slag has been recently evaluated by Banerjee A.K. and the summary of the same has been reproduced in Table 5.20.

The blast furnace slag is mainly used in India for manufacturing slag cement. There are two methods for making Blast Furnace Slag Cement. In the first method blast furnace slag is interground with cement clinker alongwith gypsum. In the second method blast furnace slag is separately ground and then mixed with the cement.

Clinker is hydraulically more active than slag. It follows then that slag should be ground finer than clinker, in order to fully develop its hydraulic potential. However, since slag is much harder and difficult to grind compared to clinker, it is ground relatively coarser during the process of inter-grinding. This leads to waste of hydraulic potential of slag. Not only that the inter-grinding seriously restricts the flexibility to optimise slag level for different uses.

The hydraulic potential of both the constituents – clinker and slag can be fully exploited if they are ground separately. The level of fineness can be controlled with respect to activity, which will result in energy saving. The present trend is towards separate grinding of slag and clinker to different levels. The clinker and gypsum are generally ground to the fineness of less than 3000 cm^2 /g (Blaine) and slag is ground to the level of 3000–4000 cm^2/g (Blaine) and stored separately. They are blended after weigh batching, using paddle wheel blenders, or pneumatic blenders. Pneumatic blenders give better homogeneity when compared to mechanical blenders.

Just as fly ash is used as an admixture in making concrete Ground Granulated Blast-furnace Slag popularly called GGBS is used as an admixture in making concrete. In other countries its use as an admixture is more common than its use as slag cement. Now in India, since it is available separately as ground granulated blast-furnace slag (GGBS), its use as admixture should become more common. Recently for marine outfall work at Bandra, Mumbai, GGBS has been used as an admixture to replace cement to the tune of 70%. Presently in India, with the growing popularity of RMC, the scope for using GGBS for customer's tailor made requirements should also become popular.

Performance of GGBS in Concrete

Fresh Concrete: The replacement of cement with GGBS will reduce the unit water content necessary to obtain the same slump. This reduction of unit water content will be more pronounced with increase in slag content and also on the fineness of slag. This is because of the surface configuration and particle shape of slag being different than cement particle. In addition, water used for mixing is not immediately lost, as the surface hydration of slag is slightly slower than that of cement.

Reduction of bleeding is not significant with slag of 4000 cm^2/g fineness. But significant beneficial effect is observed with slag fineness of 6000 cm^2/g and above.

Hardened Concrete: Exclusive research works have shown that the use of slag leads to the enhancement of intrinsic properties of concrete in both fresh and hardened conditions. The major advantages recognised are

- Reduced heat of hydration
- Refinement of pore structures
- Reduced permeabilities to the external agencies
- Increased resistance to chemical attack.

3. Write short notes on GGBS and fly ash effects in concrete (MAY 2018)(NOV 2019)

GROUND GRANULATED BLAST FURNACE SLAG

Ground granulated blast-furnace slag is the **granular material** formed when molten iron blast furnace slag (a by-product of iron and steel making) is rapidly chilled (quenched) by immersion in water. It is a granular product, **highly cementitious** in nature and, ground to cement fineness, hydrates like Portland cement.

(Blast-Furnace Slag: A by-product of steel manufacture which is sometimes used as a substitute for Portland cement. In steel industry when iron ore is molted, then in the molted state all the impurities come at its surface which are removed called slag. It consists mainly of the silicates and aluminosilicates of calcium, which are formed in the blast furnace in molten form simultaneously with the metallic iron. Blast furnace slag is blended with Portland cement clinker to form PORTLAND BLASTFURNACE SLAG CEMENT). GGBFS is used to make durable concrete structures in combination with ordinary Portland cement and/or other pozzolanic materials. GGBFS has been widely used in Europe, and increasingly in the United States and in Asia (particularly in Japan and Singapore) for its superiority in concrete durability, extending the lifespan of buildings from fifty years to a hundred years.

Concrete made with GGBFS cement **sets more slowly** than concrete made with ordinary Portland cement, depending on the amount of GGBFS in the cementitious material, but also continues to gain strength over a longer period in production conditions. This results in **lower heat of hydration** and **lower temperature rises**, and makes avoiding **cold joints** easier, but may also affect construction schedules where quick setting is required.

Use of GGBFS significantly reduces the risk of damages caused by alkali-silica reaction (ASR), provides higher resistance to chloride ingress, reducing the risk of reinforcement corrosion, and provides higher resistance to attacks by sulfate and other chemicals.

Benefits:

- **Durability**
    - GGBFS cement is routinely specified in concrete to provide protection against both sulphate attack and chloride attack
    - GGBFS is also routinely used to limit the temperature rise in large concrete pours. The more gradual hydration of GGBFS cement generates both lower peak and less total overall heat than Portland cement.

- **Appearance**
  - In contrast to the stony grey of concrete made with Portland cement, the near-white color of GGBFS cement permits architects to achieve a lighter colour for exposed fair-faced concrete finishes, at no extra cost.
- **Strength**
  - Concrete containing GGBFS cement has a higher ultimate strength than concrete made with Portland cement. It has a higher proportion of the strength-enhancing calcium silicate hydrates (CSH) than concrete made with Portland cement only, and a reduced content of free lime, which does not contribute to concrete strength. Concrete made with GGBFS continues to gain strength over time, and has been shown to double its 28 day strength over periods of 10 to 12 years.

Fly Ash:

The finely divided residue resulting from the combustion of ground or powdered coal. Fly ash is generally captured from the chimneys of coal-fired power plants; it has POZZOLANIC properties, and is sometimes blended with cement for this reason.

Fly ash includes substantial amounts of silicon dioxide (SiO_2) (both amorphous and crystalline) and calcium oxide (CaO). Toxic constituents include arsenic, beryllium, boron, cadmium, chromium, cobalt, lead, manganese, mercury, molybdenum, selenium, strontium, thallium, and vanadium.

Class F Fly Ash:

The burning of harder, older anthracite and bituminous coal typically produces Class F fly ash. This fly ash is pozzolanic in nature, and contains less than 10% lime (CaO). The glassy silica and alumina of Class F fly ash requires a cementing agent, such as Portland cement, quicklime, or hydrated lime, with the presence of water in order to react and produce cementitious compounds.

Class C Fly Ash:

Fly ash produced from the burning of younger lignite or subbituminous coal, in addition to having pozzolanic properties, also has some self-cementing properties. In the presence of water, Class C fly ash will harden and gain strength over time. Class C fly ash generally contains more than 20% lime (CaO). Unlike Class F, self-cementing Class C fly ash does not require an activator. Alkali and sulfate (SO_4) contents are generally higher in Class C fly ashes.

In addition to economic and ecological benefits, the use of fly ash in concrete improves its workability, reduces segregation, bleeding, heat evolution and permeability, inhibits alkali-aggregate reaction, and enhances sulfate resistance. Even though the use of fly ash in concrete has increased in the last 20 years, less than 20% of the fly ash collected was used in the cement and concrete industries.

One of the most important fields of application for fly ash is PCC pavement, where a large quantity of concrete is used and economy is an important factor in concrete pavement construction.

4. **What are chemical admixtures and explain any four of them. (MAY 2018)**

There are other chemicals not used as admixtures but used to enhance the performance of concrete, or used in concrete related activities in the field of construction. Such chemicals are called construction chemicals or building chemicals. The following is the list of some of the construction chemicals commonly used

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- Concrete Curing Compounds
- Polymer Bonding Agents
- Polymer Modified Mortar for Repair and Maintenance
- Mould Releasing Agents
- Installation Aids
- Floor Hardners and Dustproofers
- Non-Shrink High Strength Grout
- Surface Retarders
- Bond-aid for plastering
- Ready to use Plaster
- Guniting Aid
- Construction Chemicals for Waterproofing
  - ✓ Integral Waterproofing Compounds
  - ✓ Acrylic Based Polymer Coating
  - ✓ Mineral based polymer modified coatings
  - ✓ Protective and Decorative coatings
  - ✓ Chemical DPC
  - ✓ Waterproofing Adhesive for Tiles, Marble and Granite
  - ✓ Silicon Based Water Repellent Material
  - ✓ Injection Grout for Cracks
  - ✓ Joint Sealants

Polymer Bonding Agents

It is one of the well known fact that there will not be perfect bond between old concrete and new concrete. Quite often new concrete or mortar is required to be laid on old concrete surface. For example, for providing an overlay on an existing pavement, in providing a screed over roof for waterproofing or repair work etc. The bonding characteristics can be greatly improved by providing a bond coat between old and new concrete surface or mixing the bonding agent with the new concrete or mortar. The use of bonding agent distinctly improves the adhesion of new concrete or mortar to old surface. The mixing of bonding agents with concrete or mortar improves the workability also at lower water cement ratio and thereby reduces the shrinkage characteristic. It also helps in water retention in concrete to reduce the risk of early drying. It further improves the water- proofing quality of the treated surface. Nafufull and Nafufill BB_2, Nitobond EP, Nitobond PVA, Sikadur 32, Sikadur 41, Roff Bond ERB, Roff Bond Super are some of the commercial products available as bonding agents.

Polymer Modified Mortar for Repair and Maintenance

Sometime concrete surfaces require repair. The edge of a concrete column may get chipped off; or ceiling of concrete roof may get peeled off, or a concrete floor may get pitted in course of time. Hydraulic structures often require repairing. Prefabricated members such as pipes, poles, posts and roofing elements often gets chipped off while stripping formwork, handling and transportation. In the past cement mortar was used for any kind of repair and as an universal repair materials. Cement mortar is not the right kind of material for repair. Now there are many kinds of repair materials, mostly polymer modified, available for effective repair. They adhere very firmly to the old concrete surface on account of greatly improved bond characteristics. These materials are often stronger than the parent materials. They are also admixed with some other materials which make them set and harden very rapidly. Sometime the material added eliminates the requirement for curing. Zentrifix F 82, Nafuquick, Zentrifix AS are some of the materials manufactured by Mc-Bauchemie.

Mould Releasing Agents

Wooden planks, ordinary plywood, shuttering plywood, steel plates etc., are used as shuttering materials. Concrete when set and harden adhere to the surface of the formwork and make it difficult to demould. This affects the life and quality of shuttering materials and that of concrete. At times when extra force is used to demould from the form work, concrete gets damaged. Sometime mould surface could be cement plastered surface, in which case the demoulding or stripping of concrete member becomes all the more difficult. In the past to reduce the bond between formwork and concrete, some kind of materials such as burnt engine oil, crude oil, cowdung wash, polythylene sheet etc. were used. All the above are used on account of non availability of specially made suitable and effective mould releasing materials. Now we have specially formulated mould releasing agents, separately for absorptive surfaces like timber and plywood and for non absorbent surface like steel sheet are available. Nafuplan K and Nafuplan

UST are the materials manufactured by Mc-Bauchemie. Reebol Formcote, Reebol spl, Reebol Emulsion are the materials supplied by Fosroc. Separol Sika Form oil are the materials from Sika Qualcrete.

Installation Aids

Many a time we leave holes or make holes in walls, staircases, gate pillars etc., for fixing wash basin, lamp shades, hand rails or gates etc. Invariably, the holes made or kept, is larger than required. The extra space is required to be plugged subsequently. Material used in the past is cement mortar. Cement mortar takes a long time to set and harden, remain vulnerable for damage and it also shrinks. We have now specially manufactured materials which will harden to take load in a matter of 10-15 minutes and work as an ideal material from all points of view for the purpose of fixing such installations. Fig. 5.34 shows a few situations where fast curing installation aid could be used. They can also be used for fitting of antennae, fixing of pipes and sanitary appliances etc. Emfix is the name of the material manufactured by Mc-Bauchemie.

Water tanks, deep pump houses, basements, pipes carrying water or sewage, sometimes develop cracks and leaks. Such leakages can be plugged by using a material called Mc-Fix ST manufactured by Mc-Bauchemie (India) Pvt. Ltd. Mc-Fix ST is a polymer modified, ready to use mortar for quick and reliable sealing and plugging of any kind of leaks. The mortar plug develops very high strength and is stone hard within about 5 to 7 minutes. Mc-Fix ST is mixed with a small quantity of water and kneaded into stiff mortar. This stiff mortar is kept pressed against the crack for 5 to 7 minutes.

5. Describe about the role of accelerators and retarders in concrete.(MAY 2017)(NOV 2017) (NOV 2016) (NOV 2019)

Retarders

A retarder is an admixture that slows down the chemical process of hydration so that concrete remains plastic and workable for a longer time than concrete without the retarder. Retarders are used to overcome the accelerating effect of high temperature on setting properties of concrete in hot weather concreting. The retarders are used in casting and consolidating large number of pours without the formation of cold joints. They are also used in grouting oil wells. Oil wells are sometimes taken upto a depth of about 6000 meter deep where the temperature may be about

200°C. The annular spacing between the steel tube and the wall of the well will have to be sealed with cement grout. Sometimes at that depth stratified or porous rockstrata may also require to be grouted to prevent the entry of gas or oil into some other strata. For all these works cement grout is required to be in mobile condition for about 3 to 4 hours, even at that high temperature without getting set. Use of retarding agent is often used for such requirements.

Sometimes concrete may have to be placed in difficult conditions and delay may occur in transporting and placing. In ready mixed concrete practices, concrete is manufactured in central batching plant and transported over a long distance to the job sites which may take considerable time. In the above cases the setting of concrete will have to be retarded, so that concrete when finally placed and compacted is in perfect plastic state.

Retarding admixtures are sometimes used to obtain exposed aggregate look in concrete. The retarder sprayed to the surface of the formwork, prevents the hardening of matrix at the interface of concrete and formwork, whereas the rest of the concrete gets hardened. On removing the formwork after one day or so, the unhardened matrix can be just washed off by a jet of water which will expose the aggregates. The above are some of the instances where a retarding agent is used.

Perhaps the most commonly known retarder is calcium sulphate. It is interground to retard the setting of cement. The appropriate amount of gypsum to be used must be determined carefully for the given job. Use of gypsum for the purpose of retarding setting time is only recommended when adequate inspection and control is available, otherwise, addition of excess amount may cause undesirable expansion and indefinite delay in the setting of concrete.

In addition to gypsum there are number of other materials found to be suitable for this purpose. They are: starches, cellulose products, sugars, acids or salts of acids. These chemicals may have variable action on different types of cement when used in different quantities. Unless experience has been had with a retarder, its use as an admixture should not be attempted without technical advice. Any mistake made in this respect may have disastrous consequences.

Common sugar is one of the most effective retarding agents used as an admixture for delaying the setting time of concrete without detrimental effect on the ultimate strength. Addition of excessive amounts will cause indefinite delay in setting. At normal temperatures addition of sugar 0.05 to 0.10 per cent have little effect on the rate of hydration, but if the quantity is increased to 0.2 per cent, hydration can be retarded to such an extent that final set may not take place for 72 hours or more. Skimmed milk powder (casein) has a retarding effect mainly due to sugar content.

Other admixtures which have been successfully used as retarding agents are Ligno sulphonic acids and their salts, hydroxylated carboxylic acids and their salts which in addition to the retarding effect also reduce the quantity of water requirement for a given workability.

This also increases 28 days compressive strength by 10 to 20 per cent. Materials like mucic acid, calcium acetate and a commercial products by name “Ray lig binder” are used for set retarding purposes. These days admixtures are manufactured to combine set retarding and water reducing properties. They are usually mixtures of conventional water reducing agents plus sugars or hydroxylated carboxylic acids or their salts. Both the setting time and the rate of strength build up are effected by these materials.

Retarding Plasticizers

It is mentioned earlier that all the plasticizers and superplasticizers by themselves show certain extent of retardation. Many a time this extent of retardation of setting time offered by admixtures will not be sufficient. Instead of adding retarders separately, retarders are mixed with plasticizers or superplasticizers at the time of commercial production. Such commercial brand is known as retarding plasticizers or retarding superplasticizers. ASTM type D is retarding plasticizers and ASTM type G is retarding superplasticizer. In the commercial formulation we have also retarding and slump retaining version.

Retarding plasticizers or superplasticizers are important category of admixtures often used in the Ready mixed concrete industry for the purposes of retaining the slump loss, during high temperature, long transportation, to avoid construction or cold joints, slip form construction and regulation of heat of hydration.

One must be careful in the selection of such ready made retarding admixtures. On account of heterogeneous nature and different molecular weight of retarders used with plasticizers, they tend to separate out. It happens when sugar solution is used as cheap retarders. When retarders like gluconate is used such separation or settlement of retarders do not happen. It is cautioned that such retarding plasticizers should always be shaken thoroughly or well stirred before use. There are cases that settlement of retarders from rest of the ingredients causing excessive retardation and failure of structures.

Accelerators

Accelerating admixtures are added to concrete to increase the rate of early strength development in concrete to

- permit earlier removal of formwork;
- reduce the required period of curing;
- advance the time that a structure can be placed in service;
- partially compensate for the retarding effect of low temperature during cold weather concreting;
- in the emergency repair work.

Accelerating Plasticizers

Certain ingredients are added to accelerate the strength development of concrete to plasticizers or superplasticizers. Such accelerating superplasticizers, when added to concrete result in faster development of strength. The accelerating materials added to plasticizers or superplasticizers are triethenolamine chlorides, calcium nutrite, nitrates and flousilicates etc. The accelerating plasticizers or accelerating superplasticizers manufactured by well known companies are chloride free.

12.(b) Explain the effect of concrete properties while adding fly ash,silica fumes and GGBS.(MAY 2017)(MAY 2016)(NOV 2017)(NOV 2016)(NOV 2018)(NOV 2019)

Silica Fume

Silica fume, also referred to as microsilica or condensed silica fume, is another material that is used as an artificial pozzolanic admixture. It is a product resulting from reduction of high purity quartz with coal in an electric arc furnace in the manufacture of silicon or ferrosilicon alloy. Silica fume rises as an oxidised vapour. It cools, condenses and is collected in cloth bags. It is further processed to remove impurities and to control particle size. Condensed silica fume is essentially silicon dioxide (more than 90%) in noncrystalline form. Since it is an airborne material like fly ash, it has spherical shape. It is extremely fine with particle size less than 1 micron and with an average diameter of about 0.1 micron, about 100 times smaller than average cement particles. Silica fume has specific surface area of about 20,000 m^2/kg, as against 230 to 300 m^2/kg.

Silica fume as an admixture in concrete has opened up one more chapter on the advancement in concrete technology. The use of silica fume in conjunction with superplasticizer has been the backbone of modern High performance concrete. In one article published in 1998 issue of 'Concrete International' by Michael Shydlowski, President, Master Builder, Inc states "Twenty five years ago no one in the concrete construction industry could even imagine creating and placing concrete mixes that would achieve in place compressive strengths as high as 120 MPa . The structures such as Key Tower in Cleaveland with a design strength of 85 MPa, and Wacker Tower in Chicago with specified concrete strength of 85 MPa, and two Union Square in Seattle with concrete that achieved 130 MPa strength – are testaments to the benefits of silica fume technology in concrete construction".

It should be realised that silica fume by itself, do not contribute to the strength dramatically, although it does contribute to the strength property by being very fine pozzolanic material and also creating dense packing and pore filler of cement paste. Really speaking, the high strengths of high performance concrete containing silica fume are attributable, to a large degree, to the reduction in water content which becomes possible in the presence of high dose of superplasticizer and dense packing of cement paste.

Indian Scenario

Silica fume has become one of the necessary ingredients for making high strength and high performance concrete. In India, silica fume has been used very rarely. Nuclear Power Corporation was one of the first to use silica fume concrete in their Kaiga and Kota nuclear power projects.

Silica fume was also used for one of the flyovers at Mumbai where, for the first time in India 75 MPa concrete was used (1999). Silica fume is also now specified for the construction of proposed Bandra-Worli sea link project at Mumbai.

At present, India is not producing silica fume of right quality. Recently, Steel Authority of India has provided necessary facilities to produce annually about 3000 tons of silica fume at their Bhadravathi Complex. It appears that the quality of silica fume produced by them needs upgradation.

- Since silica fume or microsilica is an important new material, microsilica is initially produced as an ultrafine undensified powder
- at least 85% SiO_2 content

- mean particle size between 0.1 and 0.2 micron
- minimum specific surface area is 15,000 m^2/kg
- spherical particle shape.

Available forms

- Microsilica is available in the following forms:
- Undensified forms with bulk density of 200–300 kg/m^3
- Densified forms with bulk density of 500–600 kg/m^3
- Micro-pelletised forms with bulk density of 600–800 kg/m^3
- Slurry forms with density 1400 kg/m^3.
- Slurry is produced by mixing undensified microsilica powder and water in equal proportions by weight. Slurry is the easiest and most practical way to introduce microsilica into the concrete mix
- Surface area 15–20 m^2/g
- Standard grade slurry pH value 4.7, specific gravity 1.3 to 1.4, dry content of microsilica 48 to 52%.

Pozzolanic Action

Microsilica is much more reactive than fly ash or any other natural pozzolana. The reactivity of a pozzolana can be quantified by measuring the amount of $Ca(OH)_2$ in the cement paste at different times. In one case, 15% of microsilica reduced the $Ca(OH)_2$ of two samples of cement from 24% to 12% at 90 days and from 25% to 11% in 180 days. Most research workers agree that the C – S – H formed by the reaction between microsilica and $Ca(OH)_2$ appears dense and amorphous.

Influence on Fresh Concrete

Water demand increases in proportion to the amount of microsilica added. The increase in water demand of concrete containing microsilica will be about 1% for every 1% of cement substituted. Therefore, 20 mm maximum size aggregate concrete, containing 10% microsilica, will have an increased water content of about 20 litres/m^3. Measures can be taken to avoid this increase by adjusting the aggregate grading and using superplasticizers. The addition of microsilica will lead to lower slump but more cohesive mix. The microsilica make the fresh concrete sticky in nature and hard to handle. It was also found that there was large reduction in bleeding and concrete with microsilica could be handled and transported without segregation.

It is reported that concrete containing microsilica is vulnerable to plastic shrinkage cracking and, therefore, sheet or mat curing should be considered. Microsilica concrete produces more heat of hydration at the initial stage of hydration. However, the total generation of heat will be less than that of reference concrete.

Influence on Hardened Concrete

Concrete containing microsilica showed outstanding characteristics in the development of strength. Fig. 5.30 shows that 60 to 80 MPa can be obtained relatively easily. It has been also found out that modulus of elasticity of microsilica concrete is less than that of concrete without microsilica at the same level of compressive strength.

As regards, the improvement in durability aspects many published reports, of this investigation carried out, indicate improvement in durability of concrete with microsilica. There are some investigations indicating contradiction, particularly with reference to resistance against frost damage.

With regard to whether or not, silica fume is effective for alkali-aggregate reaction, some research workers report that it is effective, others conclude that while it is effective, addition of silica fume in small quantities actually increases the expansion.

Mixing

By far the most popular application of microsilica is in the 50 : 50 slurry form; as it is easy to store and dispense. There are conflicting views on whether microsilica is best added in powder or slurry form. The work by Hooton among others showed that, for equivalent microsilica additions, slurry produced significantly higher compressive and tensile strengths.

Curing

Curing is probably the most important aspect of microsilica concrete as the material undergoes virtually zero bleeding. If the rate of evaporation from the surface is faster than the rate of migration of water from interior to the surface, plastic shrinkage takes place. In the absence of bleeding and slow movement of water from interior to the surface, early curing by way of membrane curing is essential.

Ground Granulated Blast Furnace Slag (GGBS)

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Performance of GGBS in Concrete

Fresh Concrete: The replacement of cement with GGBS will reduce the unit water content necessary to obtain the same slump. This reduction of unit water content will be more pronounced with increase in slag content and also on the fineness of slag. This is because of the surface configuration and particle shape of slag being different than cement particle. In addition, water used for mixing is not immediately lost, as the surface hydration of slag is slightly slower than that of cement.

Reduction of bleeding is not significant with slag of 4000 cm^2/g fineness. But significant beneficial effect is observed with slag fineness of 6000 cm^2/g and above.

Hardened Concrete: Exclusive research works have shown that the use of slag leads to the enhancement of intrinsic properties of concrete in both fresh and hardened conditions. The major advantages recognised are

- Reduced heat of hydration
- Refinement of pore structures
- Reduced permeabilities to the external agencies
- Increased resistance to chemical attack.

6. Explain the plasticizers and its types in concrete (MAY 2016)(NOV 2019)

Requirement of right workability is the essence of good concrete. Concrete in different situations require different degree of workability. A high degree of workability is required in situations like deep beams, thin walls of water retaining structures with high percentage of steel reinforcement, column and beam junctions, tremie concreting, pumping of concrete, hot weather concreting, for concrete to be conveyed for considerable distance and in ready mixed concrete industries. The conventional methods followed for obtaining high workability is by improving the gradation, or by the use of relatively higher percentage of fine aggregate or by increasing the cement content. There are difficulties and limitations to obtain high workability in the field for a given set of conditions. The easy method generally followed at the site in most of the conditions is to use extra water unmindful of the harm it can do to the strength and durability of concrete. It has been stressed time and again in almost all the chapters of this book to the harmful effect of using extra water than necessary. It is an abuse, a criminal act, and unengineering to use too much water than necessary in concrete. At the same time, one must admit that getting required workability for the job in hand with set conditions and available materials is essential and is often difficult. Therefore, engineers at the site are generally placed in conflicting situations. Often he follows the easiest path and that is adding extra water to fluidise the mix. This addition of extra water to satisfy the need for workable concrete is amounting to sowing the seed of cancer in concrete.

These plasticizers can help the difficult conditions for obtaining higher workability without using excess of water. One must remember that addition of excess water, will only improve the fluidity or the consistency but not the workability of concrete. The excess water will not improve the inherent good qualities such as homogeneity and cohesiveness of the mix which reduces the tendency for segregation and bleeding. Whereas the plasticized concrete will improve the desirable qualities demanded of plastic concrete. The practice all over the world now is to use plasticizer or superplasticizer for almost all the reinforced concrete and even for mass concrete to reduce the water requirement for making concrete of higher workability or flowing concrete. The use of superplasticizer has become almost an universal practice to reduce water/cement ratio for the given workability, which naturally increases the strength. Moreover, the reduction in water/cement ratio improves the durability of concrete. Sometimes the use of plasticizers is employed to reduce the cement content and heat of hydration in mass concrete.

The organic substances or combinations of organic and inorganic substances, which allow a reduction in water content for the given workability, or give a higher workability at the same water content, are termed as plasticizing admixtures. The advantages are considerable in both cases : in the former, concretes are stronger, and in the latter they are more workable.

The basic products constituting plasticizers are as follows:

(*i*) Anionic surfactants such as lignosulphonates and their modifications and derivatives, salts of sulphonates hydrocarbons.

(*ii*) Nonionic surfactants, such as polyglycol esters, acid of hydroxylated carboxylic acids and their modifications and derivatives.

(*iii*) Other products, such as carbohydrates etc.

Among these, calcium, sodium and ammonium lignosulphonates are the most used. Plasticizers are used in the amount of 0.1% to 0.4% by weight of cement. At these doses, at constant workability the reduction in mixing water is expected to be of the order of 5% to 15%. This naturally increases the strength. The increase in workability that can be expected, at the same w/c ratio, may be anything from 30 mm to 150 mm slump, depending on the dosage, initial slump of concrete, cement content and type.

A good plasticizer fluidizes the mortar or concrete in a different manner than that of the air-entraining agents. Some of the plasticizers, while improving the workability, entrains air also. As the entrainment of air reduces the mechanical strength, a good plasticizer is one which does not cause air-entrainment in concrete more than 1 or 2%.

One of the common chemicals generally used, as mentioned above is Lignosulphonic acid in the form of either its calcium or sodium salt. This material is a natural product derived from wood processing industries. Admixtures based on lignosulphonate are formulated from purified product from which the bulk of the sugars and other interfering impurities are removed to low levels. Such a product would allow adsorption into cement particles without any significant interferences with the hydration process or hydrated products. Normal water reducing admixtures may also be formulated from wholly synthetic raw materials. It is also observed that at a recommended dose, it does not affect the setting time significantly. However, at higher dosages than prescribed, it may cause excessive retardation. It must be noted that if unrefined and not properly processed lignosulphonate is used as raw material, the behaviour of plasticizer would be unpredictable. It is some times seen that this type of admixture has resulted in some increase in air-entrainment. It is advised that users should follow the instructions of well established standard manufacturers of plasticizers regarding dosage.

Action of Plasticizers

The action of plasticizers is mainly to fluidify the mix and improve the workability of concrete, mortar or grout. The mechanisms that are involved could be explained in the following way:

Dispersion. Portland cement, being in fine state of division, will have a tendency to flocculate in wet concrete. These flocculation entraps certain amount of water used in the mix and thereby all the water is not freely available to fluidify the mix.

When plasticizers are used, they get adsorbed on the cement particles. The adsorption of charged polymer on the particles of cement creates particle-to-particle repulsive forces which overcome the attractive forces. This repulsive force is called Zeta Potential, which depends on the base, solid content, quantity of plasticizer used. The overall result is that the cement particles are deflocculated and dispersed. When cement particles are deflocculated, the water trapped inside the flocs gets released and now available to fluidify the mix. Fig. 5.1 explains the mechanism.

When cement particles get flocculated there will be interparticles friction between particle to particle and floc to floc. But in the dispersed condition there is water in between the cement particle and hence the interparticle friction is reduced.

Retarding Effect. It is mentioned earlier that plasticizer gets adsorbed on the surface of cement particles and form a thin sheath. This thin sheath inhibits the surface hydration reaction between water and cement as long as sufficient plasticizer molecules are available at the particle/solution interface. The quantity of available plasticizers will progressively decrease as the polymers become entrapped in hydration products.

Many research workers explained that one or more of the following mechanisms may take place simultaneously:

- Reduction in the surface tension of water.
- Induced electrostatic repulsion between particles of cement.
- Lubricating film between cement particles.
- Dispersion of cement grains, releasing water trapped within cement flocs.
- Inhibition of the surface hydration reaction of the cement particles, leaving more water to fluidify the mix.
- Change in the morphology of the hydration products.
- Induced steric hindrance preventing particle-to-particle contact.

It may be noted that all plasticizer are to some extent set retarders, depending upon the base of plasticizers, concentration and dosage used.

7. **What are the air entrainment materials used in concrete and their action? (MAY2016)**

The following types of air entraining agents are used for making air entrained concrete

- Natural wood resins
- Animal and vegetable fats and oils, such as tallow, olive oil and their fatty acids such as stearic and oleic acids
- Water soluble soaps of resin acids, and animal and vegetable fatty acids
- Miscellaneous materials such as the sodium salts of petroleum sulphonic acids hydrogen peroxide and aluminium powder, etc

There are a number of air entraining agents available in the market. The common air entraining agents in United States are Vinsol resin, Darex, N Tair, Airalon, Orvus, Teepol, Petrosan and Cheecol. Out of these the most important air entraining agents which at one time enjoyed world-wide market are Vinsol resin and Darex.

In India, large scale use of air entrained concrete is not being practised, primarily due to the fact that frost scaling of concrete is not a serious problem in our country so far. However, the advantages of the use of air entrained concrete have been realised for the construction of multi-purpose dams. Air entrained concrete has been used in the construction of Hirakud dam, Koyna dam, Rihand dam etc. In these dams, to start with, American air entraining agents such as Vinsol resin, Darex etc. were used. Later on in 1950's certain indigenous air entraining agents were developed. They are Aerosin—HRS., Rihand A.E.A., Koynaea, Ritha powder, Hico, etc. Now modern admixture manufacturing companies are manufacturing a number of commercial air entraining agents. MC-Mischoel LP, MC-Michoel AEA, Complast AE 215, Roff AEA 330 are some of the commercial brands available in India.

8. **Explain about super plasticizers (NOV 201**7)(NOV 2019)

Superplasticizers constitute a relatively new category and improved version of plasticizer. They are chemically different from normal plasticiszers. Use of superplasticizers permit the reduction of water to the extent upto 30 per cent without reducing workability in contrast to the possible reduction up to 15 per cent in case of plasticizers.

The use of superplasticizer is practiced for production of flowing, self levelling, self compacting and for the production of high strength and high performance concrete.

The mechanism of action of superplasticizers are more or less same as explained earlier in case of ordinary plasticizer. Only thing is that the superplasticizers are more powerful as dispersing agents and they are high range water reducers. They are called High Range Water Reducers in American literature. It is the use of superplasticizer which has made it possible to use w/c as low as 0.25 or even lower and yet to make flowing concrete to obtain strength of the order 120 Mpa or more. It is the use of superplasticizer which has made it possible to use fly ash, slag and particularly silica fume to make high performance concrete.

The use of superplasticizer in concrete is an important milestone in the advancement of concrete technology. Since their introduction in the early 1960 in Japan and in the early 1970 in Germany, it is widely used all over the world. India is catching up with the use of superplasticizer in the construction of high rise buildings, long span bridges and the recently become popular Ready Mixed Concrete Industry. Common builders and Government departments are yet to take up the use of this useful material.

Superplasticizers can produce:

- at the same w/c ratio much more workable concrete than the plain ones,
- for the same workability, it permits the use of lower w/c ratio,
- as a consequence of increased strength with lower w/c ratio, it also permits a reduction of cement content.

The superplasticizers also produce a homogeneous, cohesive concrete generally without any tendency for segregation and bleeding.

Classification of Superplasticizer

Following are a few polymers which are commonly used as base for superplasticizers.

lignosulphonate (LS) based admixtures, which have an effective fluidizing action, but at the relatively high dosages, they can produce undesirable effects, such as accelerations or delay in setting times. Moreover, they increase the air-entrainment in concrete.

Plasticizers and superplasticizers are water based. The solid contents can vary to any extent in the products manufactured by different companies. Cost should be based on efficiencies and solid content, but not on volume or weight basis. Generally in projects cost of superplasticizers should be worked for one cubic meter of concrete. Consistency in the quality of superplasticizers supplied over a period of time can be tested and compared by "Infrared Spectrometry".

Effects of Superplasticizers on Fresh Concrete

It is to be noted that dramatic improvement in workability is not showing up when plasticizers or superplasticizers are added to very stiff or what is called zero slump concrete at nominal dosages. A mix with an initial slump of about 2 to 3 cm can only be fluidised by plasticizers or superplasticizers at nominal dosages. A high dosage is required to fluidify no slump concrete. An improvement in slump value can be obtained to the extent of 25 cm or more depending upon the initial slump of the mix, the dosage and cement content. It is often noticed that slump increases with increase in dosage. But there is no appreciable increase in slump beyond certain limit of dosage. As a matter of fact, the overdosage may sometime harm the concrete.

Compatibility of Superplasticizers and Cement

It has been noticed that all superplasticizers are not showing the same extent of improvement in fluidity with all types of cements. Some superplasticizers may show higher fluidizing effect on some type of cement than other cement. There is nothing wrong with either the superplasticizer or that of cement. The fact is that they are just not compatible to show maximum fluidizing effect. Optimum fluidizing effect at lowest dosage is an economical consideration. Giving maximum fluidizing effect for a particular superplasticizer and a cement is very complex involving many factors like composition of cement, fineness of cement etc.

Although compatibility problem looks to be very complex, it could be more or less solved by simple rough and ready field method. Incidentally this simple field test shows also the optimum dose of the superplasticizer to the cement. Following methods could be adopted

- **Explain mineral admixtures in detail.(NOV 2017)**

Pozzolanic or Mineral Admixtures

The use of pozzolanic materials is as old as that of the art of concrete construction. It was recognised long time ago, that the suitable pozzolans used in appropriate amount, modify certain properties of fresh and hardened mortars and concretes. Ancient Greeks and Romans used certain finely divided siliceous materials which when mixed with lime produced strong cementing material having hydraulic properties and such cementing materials were employed in the construction of acquaducts, arch, bridges etc. One such material was consolidated volcanic ash or tuff found near Pozzuoli (Italy) near Vesuvius. This came to be designated as Pozzuolana, a general term covering similar materials of volcanic origin found in other deposits in Italy, France and Spain. Later, the term pozzolan was employed throughout Europe to designate any materials irrespective of its origin which possessed similar properties.

Specimens of concrete made by lime and volcanic ash from Mount Vesuvius were used in the construction of Caligula Wharf built in the time of Julius Caesar nearly 2000 years ago is now existing in a fairly good condition. A number of structures stand today as evidence of the superiority of pozzolanic cement over lime. They also attest the fact that Greeks and Romans made real advance in the development of cementitious materials.

After the development of natural cement during the latter part of the 18th century, the Portland cement in the early 19th century, the practice of using pozzolans declined, but in more recent times, Pozzolans have been extensively used in Europe, USA and Japan, as an ingredient of Portland cement concrete particularly for marine and hydraulic structures.

It has been amply demonstrated that the best pozzolans in optimum proportions mixed with Portland cement improves many qualities of concrete, such as:

(*a*) Lower the heat of hydration and thermal shrinkage;

(*b*) Increase the watertightness;

(*c*) Reduce the alkali-aggregate reaction;

(*d*) Improve resistance to attack by sulphate soils and sea water;

(*e*) Improve extensibility;

(*f*) Lower susceptibility to dissolution and leaching;

(*g*) Improve workability;

(*h*) Lower costs.

In addition to these advantages, contrary to the general opinion, good pozzolans will not unduly increase water requirement or drying shrinkage.

Pozzolanic Materials

Pozzolanic materials are siliceous or siliceous and aluminous materials, which in themselves possess little or no cementitious value, but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide liberated on hydration, at ordinary temperature, to form compounds, possessing cementitious properties.

It has been shown in Chapter I that on hydration of tri-calcium silicate and di-calcium silicate, calcium hydroxide is formed as one of the products of hydration. This compound has no cementitious value and it is soluble in water and may be leached out by the percolating water. The siliceous or aluminous compound in a finely divided form react with the calcium hydroxide to form highly stable cementitious substances of complex composition involving water, calcium and silica. Generally, amorphous silicate reacts much more rapidly than the crystalline form. It is pointed out that calcium hydroxide, otherwise, a water soluble material is converted into insoluble cementitious material by the reaction of pozzolanic materials.

The reaction can be shown as

Pozzolan + Calcium Hydroxide + Water → C – S – H (Gel)

This reaction is called pozzolanic reaction. The characteristic feature of pozzolanic reaction is firstly slow, with the result that heat of hydration and strength development will be accordingly slow. The reaction involves the consumption of $Ca(OH)_2$ and not production of $Ca(OH)_2$. The reduction of $Ca(OH)_2$ improves the durability of cement paste by making the paste dense and impervious.

Pozzolanic materials can be divided into two groups: natural pozzolana and artificial pozzolana.

Natural Pozzolans

- Clay and Shales
- Opalinc Cherts
- Diatomaceous Earth
- Volcanic Tuffs and Pumicites.

9. Explain the effect of admixtures on fresh concrete. (NOV 2018)

Effects of Superplasticizers on Fresh Concrete

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The Effect of Air Entrainment on the Properties of Concrete

Air entrainment will effect directly the following three properties of concrete:

(*a*) Increased resistance to freezing and thawing.

(*b*) Improvement in workability.

(*c*) Reduction in strength.

Incidentally air entrainment will also effect the properties of concrete in the following

ways:

(*a*) Reduces the tendencies of segregation.

(*b*) Reduces the bleeding and laitance.

(*c*) Decreases the permeability.

(*d*) Increases the resistance to chemical attack.

(*e*) Permits reduction in sand content.

(*f*) Improves placeability, and early finishing.

(*g*) Reduces the cement content, cost, and heat of hydration.

(*h*) Reduces the unit weight.

(*i*) Permits reduction in water content.

(*j*) Reduces the alkali-aggregate reaction.

(*k*) Reduces the modulus of elasticity.

Performance of GGBS in Concrete

Fresh Concrete: The replacement of cement with GGBS will reduce the unit water content necessary to obtain the same slump. This reduction of unit water content will be more pronounced with increase in slag content and also on the fineness of slag. This is because of the surface configuration and particle shape of slag being different than cement particle. In addition, water used for mixing is not immediately lost, as the surface hydration of slag is slightly slower than that of cement.

Reduction of bleeding is not significant with slag of 4000 cm^2/g fineness. But significant beneficial effect is observed with slag fineness of 6000 cm^2/g and above.

Influence on Fresh Concrete

Water demand increases in proportion to the amount of microsilica added. The increase in water demand of concrete containing microsilica will be about 1% for every 1% of cement substituted. Therefore, 20 mm maximum size aggregate concrete, containing 10% microsilica, will have an increased water content of about 20 litres/m^3. Measures can be taken to avoid this increase by adjusting the aggregate grading and using superplasticizers. The addition of microsilica will lead to lower slump but more cohesive mix. The microsilica make the fresh concrete sticky in nature and hard to handle. It was also found that there was large reduction in bleeding and concrete with microsilica could be handled and transported without segregation.

It is reported that concrete containing microsilica is vulnerable to plastic shrinkage cracking and, therefore, sheet or mat curing should be considered. Microsilica concrete produces more heat of hydration at the initial stage of hydration. However, the total generation of heat will be less than that of reference concrete.