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CONCRETE TECHNOLOGY

By
Vikas Yadav

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KCE 051 CONCRETE TECHNOLOGY (L-T-P 3-0-0) Credit – 3

Course Outcomes:

After completion of the course student will be able to:

CO-1 Understand the properties of constituent material of concrete.
CO-2 Apply admixtures to enhance the properties of concrete.
CO-3 Evaluate the strength and durability parameters of concrete.
CO-4 Design the concrete mix for various strengths using difference methods.
CO-5 Use advanced concrete types in construction industry.

Unit 1

Cement : types and cement chemistry. Aggregates: mineralogy, properties, test and standards. Quality of water for use in concrete. **[8]**

Unit 2

Introduction & study of accelerators, retarders, water reducers, air entrainers, water proofers, super plasticizers. Study of supplementary cementing materials like fly ash, silica fume , ground granulated blast furnace slag, metakaoline and pozzolana; their production, properties and effect on concrete properties . **[8]**

Unit 3

Concert production: batching, mixing and transportation of concrete. Workability test: slump test, compacting factor test and Vee Bee test. Segregation, bleeding and Laitance in concrete, curing of concrete and its methods. Determination of compressive and flexural strength as per BIS. Mechanical properties of concrete: elastic modules, poisson's ratio, creep, shrinkage and durability of concrete. **[8]**

Unit 4

Principle of mix proportioning, properties related to mix design, Mix design method (IS method and ACI method). Mix design of concrete, Rheology, mix design examples **[8]**

Unit 5

Study and uses of high strength concrete, self-compacting concrete, fibre reinforced concrete, ferro cement, ready Mix Concrete, recycled aggregate concrete and status in India. **[8]**

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1
UNIT

Cement Production and Aggregates

PART-1

Cement : Production, Composition, Properties, Types and Cement Chemistry, Introduction to Supplementary Cementitious Materials.

CONCEPT OUTLINE : PART-1

Cement : Cement is a material with adhesive and cohesive properties.

Composition of Cement : The component oxides of ordinary portland cement are : CaO, SiO_2 (17-25 %), Al_2O_3 (3-8 %), and Fe_2O_3 (0.5 -6 %), (60 -67 %).

Types of Cement :

1. Ordinary portland cement.
2. Rapid hardening cement.
3. Portland pozzolana cement.
4. Low heat portland cement.
5. Sulphate resisting cement.
6. High Alumina cement etc.

Supplementary Cementing Materials : Supplementary cementing materials, also called mineral additives, contribute to the properties of hardened concrete through hydraulic or pozzolanic activity.
Pozzolanic material can be divided into two groups :

1. Natural Pozzolana :

i. Clay and shales.
ii. Diatomaceous earth.
iii. Volcanic tuffs and pumicites.

2. Artificial Pozzolana :

i. Fly ash.
ii. Blast furnace slag.
iii. Silica fume.
iv. Rice husk ash.
v. Metakaoline.
vi. Surkhi.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.1. **What is cement ? Also give its composition.**

Answer

A. Cement :

1. Cement is a hydraulic binder and is defined as a finely ground inorganic material which, when mixed with water, forms a paste which sets and hardens by means of hydration reactions and processes which, after hardening retains its strength and stability even under water.
2. Cement is the mixture of calcareous, siliceous, argillaceous and other substances.

B. Chemical Composition : Cement has the following approximate chemical composition :

1. The major constituents are :

i. Lime (CaO) : 60- 63 %

ii. Silica (SiO_2) : 17- 25 %

iii. Alumina (Al_2O_3) : 03- 08 %

2. The auxiliary constituents are :

i. Iron oxide (Fe_2O_3) : 0.5-06 %

ii. Magnesia (MgO) : 1.5- 03 %

iii. Sulphur tri oxide (SO_3) : 01- 02 %

iv. Gypsum : 01 to 04 %

Que 1.2. **Describe the function of various constituents of cement.**

Answer

Functions of Cement Manufacturing Constituents :

1. Lime (CaO) :

i. Lime forms nearly two-third (2/3) of the cement.

ii. Sufficient quantity of lime forms di-calcium silicate ($C_2Si\ O_2$) and tri-calcium silicate in the manufacturing of cement.

iii. Lime in excess, causes the cement to expand and disintegrate.

2. Silica (SiO_2) :

i. The quantity of silica should be enough to form di-calcium silicate (C_2SiO_2) and tri-calcium silicate in the manufacturing of cement.

ii. Silica gives strength to the cement.

iii. Silica in excess causes the cement to set slowly.

3. Alumina (Al_2O_3) :

i. Alumina supports to set quickly to the cement.

ii. It also lowers the clinkering temperature.

iii. Alumina in excess reduces the strength of the cement.

4. Iron Oxide (Fe_2O_3) : Iron oxide gives colour to the cement.

5. Magnesia (MgO) :

i. It also helps in giving colour to the cement.

ii. Magnesium in excess makes the cement unsound.

6. Calcium Sulphate (or) Gypsum ($CaSO_4$) : At the final stage of manufacturing, gypsum is added to increase the setting of cement.

Que 1.3. What are Bogue's compound of portland cement ? Also give its properties.

Answer

Bogue's Compound of Cement : Following are the various Bogue's compound of cement :

1. Calcium Silicates :

i. Alite or $3CaO.SiO_2$ or C_3S :

a. It is responsible for early strength.

b. First 7 days strength is due to C_3S.

c. It produces more heat of hydration.

d. A cement with more C_3S content is better for cold weather concreting.

ii. Belite or $2CaO.SiO_2$ or C_2S :

a. The hydration of C_2S starts after 7 days. Hence it gives strength after 7 days.

b. C_2S hydrates and hardens slowly and provides much of the ultimate strength.

c. It is responsible for the later strength of the concrete.

d. It produces less heat of hydration.

2. Calcium Aluminates :

i. Aluminate or $3CaO.Al_2O_3$ or C_3A :

a. The reaction of C_3A with water is very fast.

b. It may lead to an immediate stiffening of paste, and it is called flash set.

c. To prevent this flash set, 2-3 % gypsum is added to at a time of grinding cement clinker.

d. The hydrated C_3A do not contribute to the strength of the concrete.

e. Low C_3A for sulfate resistance Cement.

ii. Ferrite or $4CaO.Al_2O_3.Fe_2O_3$ or C_4AF :

a. C_4AF hydrates rapidly.

b. It does not contribute to strength of the concrete.

c. Controls the color of cement.

3. Gypsum is added to avoid the uncontrolled setting resulting from C_3A reaction with water.

Que 1.4. Explain manufacturing processes of the cement with neat diagram. Give comparison between wet and dry process of manufacturing.

Answer

Manufacturing Processes : Following are the steps of manufacturing of cement :

A. Make Clinkers : In this step, the raw material is converted into fine powder and it is done by following two processes :

1. Dry Process :

i. In this process calcareous material such as limestone (calcium carbonate) and argillaceous material such as clay are ground separately to fine powder in the absence of water and then are mixed together in the desired proportions.

ii. Water is then added to it for getting thick paste and then its cakes are formed, dried and burnt in kilns.

iii. This process is usually used when raw materials are very strong and hard.

iv. In this process, the raw materials are changed to powdered form in the absence of water.

2. Wet Process :

i. In this process, the raw materials are changed to powdered form in the presence of water.

ii. In this process, raw materials are pulverized by using a ball mill, which is a rotary steel cylinder with hardened steel balls.

iii. When the mill rotates, steel balls pulverize the raw materials which form slurry (liquid mixture).

iv. The slurry is then passed into storage tanks, where correct proportioning is done.

v. Proper composition of raw materials can be ensured by using wet process than dry process.

vi. This process is generally used when raw materials are soft because complete mixing is not possible unless water is added.

vii. Corrected slurry is then fed into rotary kiln for burning.

The actual purpose of both processes is to change the raw materials to fine powder.

B. Burning :

i. Corrected slurry is feed to rotary kiln, which is a 150-500 feet long, 8-16 feet in diameter and temperature arrangement is up to 1500-1650 °C.

ii. At this temperature slurry losses moisture and forms into small lumps, after that changes to clinkers.

iii. Clinkers are cooled in another inclined tube similar to kiln but of lesser length.

C. Grinding :

i. Now the final process is applied which is grinding of clinker, it is first cooled down to atmospheric temperature.

ii. Grinding of clinker is done in large tube mills. After proper grinding gypsum (Calcium sulphate $CaSO_4$) in the ratio of 01-04 % is added for controlling the setting time of cement.

iii. Finally, fine ground cement is stored in storage tanks from where it is drawn for packing.

Comparison between Wet and Dry Process :

S. No.	Wet Process	Dry Process
1.	Moisture content of the slurry is 35-50%.	Moisture content of the pellets is 12 %.
2.	Size of the kiln needed to manufacture the cement is bigger.	Size of the kiln needed to manufacture the cement is smaller.
3.	The amount of heat required is higher, so the required fuel amount is higher.	The amount of heat required is lower, so the required fuel amount is lower.
4.	Less economical.	More economical.
5.	The raw materials can be mix easily, so a better homogeneous material can be obtained.	Difficult to control the mixing of raw materials process, so it is difficult to obtain homogeneous material.
6.	The machinery and equipments do not need much maintenance.	The machinery and equipments need more maintenance.

Que 1.5. Explain the various types of cements.

Answer

Following are the various types of cements :

1. Sulphate Resisting Cement :

i. In this cement, the percentage of tricalcium aluminate C_3A is kept below 5 % and it results in the increase in resisting power against sulphates.

2. Rapid Hardening Cement :

i. The initial and final setting times of this cement are same as those of ordinary cement. But it attains high strength in early days.

ii. It contains high percentage of tricalcium silicate C_3S to the extent of about 56 %.

3. White Cement :

i. White cement is prepared from such raw materials which are practically free from colouring oxides of iron, manganese or chromium.

ii. It is white in colour and is used for floor finish, plaster work, ornament work, etc.

4. Coloured Cement :

i. The cement of desired colour may be obtained by intimately mixing mineral pigments with ordinary cement.

ii. The amount of coloring material may vary from 5 to 10 %.

iii. These types of coloured cement are widely used for finishing of floors, external surfaces, artificial marble, window sill slabs, textured panel faces, stair treads, etc.

S.No.	Pigment	Colour
1.	Chromium Oxide	Green
2.	Cobalt Imparts	Blue
3.	Iron Oxide in different proportion	Brown, Red, Yellow
4.	Manganese Dioxide	Black or Brown

5. Pozzolana Cement :

i. Pozzolana is a volcanic powder.

ii. This type of cement is used to prepare mass concrete of lean mix and for marine structures.

iii. It is also used in sewage works and for laying concrete under water.

6. Hydrophobic Cement :

i. It is manufactured by grinding ordinary portland cement clinker with 0.1 to 0.4 % of oleic acid, stearic acid or pentachlorophenol.

ii. This addition forms water repellent film around each particle by the moisture content of atmosphere.

iii. When concrete is prepared using this cement, the water repellent film breaks out which improves the workability of concrete.

7. Quick Setting Cement :

i. When concrete is to be laid under water, quick setting cement is to be used.

ii. This cement is manufactured by adding small percentage of aluminum sulphate (Al_2SO_4) which accelerates the setting action.

iii. The setting action of such cement starts with in 05 minutes after addition of water and it becomes stone hard in less than half an hour.

8. Low Heat Cement :

i. In this cement the heat of hydration is reduced by tricalcium aluminate (C_3A) content.

ii. It contains less percentage of lime than ordinary portland cement.

iii. It is used for mass concrete works such as dams etc.

9. High Alumina Cement :

1. This cement contains high aluminate percentage usually between 35-55 %.

2. It gains strength very rapidly within 24 hours. It is also used for construction of dams and other heavy structures.

3. It has resistance to sulphates and action of frost also.

10. Air Entraining Cement :

1. Air entraining cement is produced by grinding minute air entraining materials with clinker or the materials are also added separately while making concrete.

2. Entrainment of air also improves workability and durability. It is found that entrainment of air or gas bubbles while applying cement, increases resistance to frost action.

3. It is recommended that air contents should be 03-04 % by volume. Natural resins, fats, oils are used as air entraining agents.

Que 1.6. What is hydration of cement ? Explain the process of hydration of cement.

Answer

A. Hydration of Cement :

1. The reaction of cement when mixed with water is called hydration. Both C_3S and C_2S make up nearly 75 % of cement.

2. The hydration of these compounds is responsible for the setting and hardening of cement.

3. The hydration surface reaction starts immediately once cement comes in contact with water. It is an exothermic reaction.

4. The hydration continues as long as heat and moisture are available.

5. All four Bogue's compounds along with gypsum are involved in the hydration reaction and only a very small amount of water is needed for it.

B. Following stages occurred in the process of hydration :

1. **Stage 1 :** A heat generation of rapid order takes place for close to 15 minutes. The calcium and hydrogen ions are released from the surface and when certain levels of critical concentrations are reached, the evolution of calcium hydroxide and calcium silicate hydroxide beings. The initial reactions are dependent on the temperature.
2. **Stage 2 :** This stage tends to be the dormant period and the cement is forced to become plastic for a period of 2 to 4 hours. This process of reaction tends to slow down.
3. **Stage 3 :** This is the acceleration period as the silicate hydrates rapidly along with critical concentration of ions. The entire hardening takes place and the final set is released and the time period is generally for 4 to 8 hours.
4. **Stage 4 :** This is known as the deceleration stage. The overall rate of reaction tends to slow down resulting in an independent diffusion reaction.
5. **Stage 5 :** This is referred to as the steady stage and the temperature has less effect on the hydration stage. The reaction process is constant and is for a period of 12 to 24 hours.

   The individual reaction of minerals tends to be less effective than the combined reaction of the hydration of cement. The hydration of cement can be split into several small components it is observed that the aluminate and the ferrite stage tend to react first and then the reactions tend to carry over to the silicate phase.

Que 1.7. Describe the hydration reaction of important Bogue's compounds indicating the products of hydration.

Answer

Hydration Reaction of Bogue's Compound :

1. Hydration of C_3S :

i. The chemical reaction of C_3S with water can be expressed as

$$C_3S + \text{water} \rightarrow C\text{–}S\text{–}H + C\text{–}H + \text{heat}$$

where, C-S-H is calcium silicate hydrate and C-H is calcium hydrate.

ii. C-S-H, Calcium silicate hydrate constitutes 50-60 % of the solids in the paste. It forms a continuous binding matrix. It is amorphous and fibrous and hence has a large surface area. It is an important factor for the strength development of cement paste.

iii. C-H, Calcium hydrate makes up about 20 % of the solids in the paste. It exists in the form of thick, crystalline hexagonal plates and is embedded in the C-S-H matrix. Its growth fills the pore spaces. It does

not significantly contribute to strength. Its leaching causes white patches and efflorescence.

2. Hydration of C_2S :

i. The hydration of C_2S is similar to the hydration of C_3S. The same products are generated. However, C_2S reacts slowly and hence generates less heat.

ii. It contributes to strength development at later stages.

3. Hydration of C_3A :

i. This hydration reaction produces a substance called ettringite as follows :

$$C_3A + \text{gypsum} + \text{water} \rightarrow \text{ettringite} + \text{heat}$$

$$C_3A + \text{ettringite} + \text{water} \rightarrow \text{monosulphoaluminate}$$

ii. If the amount of gypsum is too little, C_3A will react fast and can cause a 'flash set'.

iii. On the other hand, too much gypsum will delay setting and cause undue expansion. It constitutes about 10–20 % of the solid content.

iv. It is a long, slender, and prismatic crystal and is stable only in the presence of gypsum.

v. It plays a minor role in strength development but contributes considerably to durability.

vi. Monosulphoaluminate is a stable hydration product. It is fairly crystalline.

4. Hydration of C_4AF :

i. The hydration of C_4AF is similar to that of C_3A; the same products are formed.

ii. However, C_4AF reacts slowly and hence generates less heat and combines well with gypsum.

Que 1.8. What are the advantages of pozzolona portland cement.

Answer

Advantages :

1. In PPC, costly clinker is replaced by cheaper pozzolanic material and hence economical.
2. Soluble calcium hydroxide is converted into insoluble cementitious products resulting in improvement of permeability. Hence it offers, all round durability characteristics, particularly in hydraulic structures and marine construction.
3. PPC consumes calcium hydroxide and does not produce calcium hydroxide as much as that of OPC.
4. It generates reduced heat of hydration and that too at a low rate.

5. PPC being finer than OPC and also due to pozzolanic action, it improves the pore size distribution and also reduces the microcracks at the transition zone.
6. As the fly ash is finer and of lower density, the bulk volume of 50 kg bag is slightly more than OPC. Therefore, PPC gives more volume of mortar than OPC.
7. The long term strength of PPC beyond a couple of months is higher than OPC if enough moisture is available for continued pozzolanic action.

Que 1.9. **Explain briefly the physical properties of ordinary portland cement and its uses.**

Answer

Physical Properties of Ordinary Portland Cement :

1. Colour greenish grey.
2. One feels cool by thrusting one's hand in the cement bag.
3. It is smooth when rubbed in between fingers.
4. A handful of cement thrown in a bucket of water should float.

Uses of Cement : Following are uses of cement :

1. It is used in concrete for laying floors, roofs and constructing lintels, beams, stairs, pillars etc
2. It is used for making joints for drains and pipes.
3. It is used for water tightness of structure.
4. It is used in mortar for plastering, masonry work, pointing, etc.
5. Cement is a very useful binding material in construction.
6. It is employed for the construction of wells, water tanks, tennis courts, lamp posts, telephone cabins, roads etc
7. It is used in the preparation of foundations, water tight floors, footpaths etc.
8. It is used in the construction of important engineering structures such as bridges, culverts, dams, tunnels, light houses etc
9. It is used for precast pipes manufacturing, piles, fencing posts etc.

Que 1.10. **Describe the pozzolanic materials. What are the advantages of pozzolanic material ?**

Answer

A. Pozzolanic Materials :

1. 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.

2. Pozzolanic reaction is given by

$$\text{Pozzolana} + \text{Calcium hydroxide} + \text{Water} \rightarrow C - S - H \text{ (gel)}$$

B. Advantages of Pozzolanic Materials : Following are the advantages of pozzolanic materials :

1. Lower the heat of hydration and thermal shrinkage.
2. Increase the water-tightness.
3. Reduce the alkali-aggregate reaction.
4. Improve resistance to attack by sulphate soils and sea water.
5. Improve extensibility.
6. Lower susceptibility to dissolution and leaching.
7. Improve workability.
8. Lower costs.

Que 1.11. Describe the various types of pozzolanic materials.

Answer

Types of Pozzolanic Materials : Following are the various types of pozzolanic materials :

1. Fly Ash :

i. Fly ash is finely divided residue resulting from the combustion of powdered coal and transported by the flue gases and collected by electrostatic precipitator.

ii. Fly ash is the most widely used pozzolanic material all over the world.

iii. Fly ash is categorise into two classes :

a. Class F : Fly ash normally produced by burning anthracite or bituminous coal, usually has less than 5 % CaO. Class F fly ash has pozzolanic properties only.

b. Class C : Fly ash normally produced by burning lignite or sub-bituminous coal. Some class C fly ash may have CaO content in excess of 10 %. In addition to pozzolanic properties, class C fly ash possesses cementitious properties.

2. Silica Fume :

i. Silica fume, also referred to as microsilica or condensed silica fume, is another material that is used as an artificial pozzolanic admixture.

ii. Silica fume is very fine pozzolanic material composed of ultrafine, amorphous glassy sphere (average diameter, 0.10 to 0.15 mm) of silicon dioxide (SiO_2) produced during the manufacture of silicon or ferro-silicon by electric arc furnaces at temperature of over 2000°C.

iii. The micro silica is formed when SiO gas produced in the furnace mixes with oxygen, oxidizes to SiO_2, condensing into the pure spherical particles of micro silica that form the major part of the smoke or fume from the furnace.

3. Rice Husk Ash :

i. Rice husk ash is obtained by burning rice husk in a controlled manner without causing environmental pollution. When properly burnt it has high SiO_2 content and can be used as a concrete admixture.

ii. Rice husk ash exhibits high pozzolanic characteristics and contributes to high strength and high impermeability of concrete.

iii. Rice husk ash (RHA) essentially consists of amorphous silica (90 % SiO_2), 5 % carbon and 2 % K_2O.

iv. The specific surface of RHA is between 40 – 100 m^2/g.

4. Surkhi :

i. Surkhi is an artificial pozzolana made by powdering bricks or burnt clay balls.

ii. In some major works, for large scale production of surkhi, clay balls are specially burnt for this purpose and then powdered.

iii. Its characteristics are greatly influenced by the constituent mineral composition of soil, degree of burning and fineness of grinding.

5. Metakaolin :

i. Thermally activated ordinary clay and kaolinitic clay is known as "Metakaolin".

ii. It showed certain amount of pozzolanic properties, they are not highly reactive.

iii. Highly reactive metakaolin is made by water processing to remove unreactive impurities to make 100 % reactive pozzolana. Such a product, white or cream in colour, purified, thermally activated is called High Reactive Metakaolin (HRM).

iv. High reactive metakaolin shows high pozzolanic reactivity and reduction in $Ca(OH)_2$ ever as early as one day.

6. Ground Granulated Blast Furnace Slag (GGBS) :

i. Ground granulated blast-furnace slag is another important mineral admixture like fly ash a nonmetallic product consisting essentially of silicates and aluminates of calcium and other bases.

ii. The molten slag is rapidly chilled by quenching in water to form a glassy sand like granulated material.

iii. The granulated material when further ground to less than 45 micron will have specific surface of about 400 to 600 m^2/kg (Blaine).

PART-2

Aggregate : Mineralogy, Properties, Test and Standards, Quality of Water for Use in Concrete.

CONCEPT OUTLINE : PART-2

Aggregate : These are primarily naturally occurring, inert granular materials such as sand, gravel or crushed stone etc.

Classification of Aggregate : The classification of the aggregate is generally based on their geological origin, shape, size, unit weight etc.

i. Classification According to Geological Origin :
- a. Natural aggregate.
- b. Artificial aggregate.

ii. Classification According to size :
- a. Fine aggregate.
- b. Course aggregate.
- c. All in aggregate.
- d. Single size.

iii. Classification According to Shape :
- a. Rounded aggregate.
- b. Irregular aggregate.
- c. Angular aggregate.
- d. Flaky and elongated aggregates.

iv. Classification Based on Unit Weight :
- a. Normal weight aggregate.
- b. Heavy weight aggregate.
- c. Light weight aggregate.

Test : Aggregates are tested for strength, abrasion, particle shape and texture, poroisity.
- i. Crushing strength test.
- ii. Flakiness and elongated index test.
- iii. Ten percent fines value.
- iv. Impact value test.
- v. Test for hardness and abrasion resistance, etc.

Water Quality : The quality of water used must be checked for ensuring good quality concrete. Water used for mixing and curing should be free from oil, acid and alkalis salt, and organic material.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 1.12. What is meant by aggregate ? Briefly describe their classification.

Answer

A. Aggregate : These are inert materials which are mixed with binding material such as cement or lime for manufacturing of mortar or concrete. Aggregate are used as filler in mortar and concrete and also to reduce their cost.

B. Classification of Aggregate :

1. According to Geological Origin :

i. Natural Aggregate :

1. These aggregates are generally obtained from natural deposits of sand and gravels or from quarries by cutting rocks.
2. The cheapest among them are the natural sand and gravel which have been reduced to their present size by natural agents, such as water, wind and snow, etc.
3. The river deposits are the most common and are good quality.

ii. Artificial Aggregate :

1. The most widely used artificial aggregate are clean broken bricks and air cooled fresh blast-furnace-slag.
2. The broken bricks of good quality provide a satisfactory aggregate for the mass concrete and are not suitable for reinforced concrete work if the crushing strength of brick is less than 30 to 35 MPa.
3. The bricks should be free from lime mortar and lime sulphate plaster.
4. The bricks aggregate is not suitable for waterproof construction.
5. It has poor resistance to wear and hence is not used in concrete for the road work.

2. According to Size :

i. Fine Aggregate :

1. The aggregate which passes through 4.75 mm sieve and retained on 75 micron sieve are known as fine aggregate.

ii. Coarse Aggregate :

1. The aggregate retained on 4.75 mm sieve are known as coarse aggregate.

iii. All-in-Aggregate :

1. It is the combination of both coarse and fine aggregate.

3. According to Shape :

i. Rounded Shape :

a. The aggregate with rounded particles (river or seashore gravel) has minimum voids ranging 32 to 33 %.

b. The only disadvantage is that interlocking between its particles is less and hence the development of bond is poor, making it unsuitable for high strength concrete and pavement.

ii. Irregular Aggregate :

a. The aggregate having partly rounded particles (pit sand and gravel) has higher of voids ranging from 35 to 38 % .

b. It required more cement paste for a given workability.

iii. Angular Aggregate : The aggregate with sharp, angular and rough particles (crushed rocks) has a maximum of voids ranging from 38 to 40 %. The interlocking between the particles is good.

iv. Flaky Aggregate :

a. An aggregate is termed flaky when its least dimension (thickness) is less than three-fifth of its mean dimension.

b. The presence of these particles should be restricted to 10 to 15 %.

4. According to Unit Weight :

i. Normal Weight Aggregate : The commonly used aggregate, *i.e.*, sands and gravels; crushed rocks such as granite, basalt quartz, sandstone and limestone; and brick ballast, etc., which have specific gravities between 2.5 and 2.7 produce concrete with unit weight ranging 23 to 26 kN/m^3 and crushing strength at 28 days between 15 to 40 MPa are termed normal weight concrete.

ii. Heavy Weight or High-Density Aggregate : Concrete having unit weight of about 30, 31, 35, 38, 40, 47 and 57 kN/m^3 can be produced by using typical goethite, limonite, baryte, magnetite, hematite, ferrophosphorus and scrap iron, respectively.

iii. Light Weight Aggregate : The light weight aggregate having unit weight up to12 kN/m^3 are used to manufacture the structural concrete masonry blocks for reduction of the self weight of the structure.

Que 1.13. Discuss the characteristics of good aggregates.

Answer

Following are the characteristics of good aggregate :

1. It should preferably be cubical or spherical in shape and of limiting porosity.
2. It should be chemically inert and not be soft and porous.
3. It should not absorb water more than 5 %.
4. It should have rough surface.
5. It should not react with cement after mixing.
6. It should be durable and strong.

7. It must be clean *i.e.*, it should be free from lumps, organic materials etc.

Que 1.14. **Briefly describe the physical mechanical and thermal properties of aggregates in concrete.**

Answer

A. Physical Properties of Aggregate :

1. **Grading :** It is the particle-size distribution of an aggregate as determined by a sieve analysis using wire mesh sieves with square openings.
2. **Fineness Modulus :** The result of aggregate sieve analysis is expressed by a number called fineness modulus.
3. **Flakiness Index :** It is the percentage by weight of particles in it whose least dimension is less than three-fifth of their mean dimension.
4. **Elongation Index :** It is the percentage of weight of particles whose greatest dimension is greater than 1.8 times their mean dimension.

B. Mechanical Prosperities of Aggregate :

1. **Aggregate Crushing Value :** It gives a relative measure of the resistance of an aggregate to crushing under a gradually applied compressive load.
2. **Aggregate Impact Value :** It gives a relative measure of the resistance of an aggregate to sudden shock or impact.
3. **Aggregate Abrasion Value :** It gives a relative measure of resistance of an aggregate to wear when it is rotated in a cylinder along with some abrasive charge.

C. Thermal Properties of Aggregate : Following are the thermal properties of aggregate :

1. **Coefficient of Thermal Expansion :** The coefficient of thermal expansion of the concrete increase with the coefficient of thermal expansion of aggregate. The coefficient of expansion of the aggregate depends on the parent rock
2. **Specific Heat :** It is a measure of its heat capacity.
3. **Thermal Conductivity :** It is the ability of the aggregate to conduct the heat.

Que 1.15. **Explain the bulking and soundness of aggregates.**

Answer

A. Bulking of Fine Aggregate :

1. The increase in the volume of a given mass of fine aggregate caused by the presence of water is known as bulking.

2. The bulking of fine aggregate is caused by the films of water which push the particles apart.
3. The extent of bulking depends upon the percentage of moisture present in the sand and its fineness.
4. It is seen that bulking increases gradually with moisture content up to a certain point and then begins to decrease with further addition of water due to the merging of films, until when the sand is inundated.
5. With ordinary sands the bulking usually varies between 15-30 %.
6. In extremely fine sand the bulking may be of the order of 40 % at a moisture content of 10 % but such sand is unsuitable for concrete.

B. Soundness of Aggregate :

1. The soundness indicates the ability of the aggregate to resist excessive changes in volume due to changes in environmental conditions, e.g. freezing and thawing, thermal changes, and alternating wetting and drying.
2. The aggregate is said to be unsound when volume changes result in the deterioration of concrete.
3. This may appear in the form of local scaling to extensive surface cracking or to disintegration over a considerable depth, and thus vary from an impaired appearance to a structurally dangerous situation.
4. IS: 2386 (Part-V)-1963 describes a method to determine the resistance to disintegration of aggregates by saturated solution of sodium sulphate (Na_2SO_4) or magnesium sulphate ($MgSO_4$).
5. According to IS: 383-1970 the average loss of weight after ten cycles should not exceed 12 and 18 % when tested with sodium sulphate and magnesium sulphate, respectively.

Que 1.16. What are the effects of the shape and texture of aggregate on the strength and workability of concrete ?

Answer

A. Effect of Shape :

1. Rounded aggregates are suitable to use in concrete because flaky and elongated particles reduce workability, increase water demand and reduce strength.
2. In the case of angular particles, the bond between aggregate particles is higher due to interlocking but due to higher surface area, angular particles increase water demand and therefore reduce workability.

B. Effect of Texture :

1. This affects the bond to the cement paste and also influences the water demand of the mixture.
2. Smooth : It improves workability but bond between cement paste and aggregate is weak.

3. Rough : It reduce workability but bond between cement paste and aggregate is strong.
4. Surface texture is not a very important property from compressive strength point of view but aggregate having rough surface texture perform better under flexural and tensile stresses.

Que 1.17. What is alkali aggregate reaction ? What are the factors which affect this reaction ? How can this reaction be controlled ?

Answer

A. Alkali Aggregate Reaction :

1. The phenomenon is accompanied by extensive expansion and may lead in bad cases to complete disruption and disintegration of the concrete and is known as alkali-aggregate reaction or sometimes concrete cancer.
2. The trouble is due to reaction between silica in aggregate and alkalis in the cement.
3. In some cases alkalis, mainly from the cement supplemented by alkalis in the aggregate, react with carbonates in the aggregate to produce similar result.
4. The types of rocks which contain reactive constituents include traps, andesites, rhyolites, siliceous limestone and certain types of sandstones.
5. The reactive components may be in the form of opals, cherts, chalcedony, volcanic glass (excepting basaltic glasses), zeolites, and tridymite.

B. Factors Affecting Alkali-Aggregate Reaction :

1. **Reactive Type of Aggregates :** Reactive material have been found to have serious effects if present in small quantities but not if it constitutes the whole of the aggregate.
2. **High Alkali Content Cement :** If the cement contains less than 0.4 % alkalis (computed as Na_2O) no expansion or disruptive effect is likely even with a quite highly reactive aggregate, but due to difficulties of manufacture it is not usual to specify an alkali content of less than 0.6 %.
3. **Availability of Moisture :** Progress of the alkali-aggregate reaction takes place only in the presence of water.
4. **Temperature Condition :** The favourable temperature for the reaction is 10-38 °C.

C. Control of Alkali-Aggregate Reaction :

1. **By Selecting Non-Reactive Aggregate :** Aggregate can be identified by petrographic examination. The mortar bar test and the chemical test are used.

2. **By Using Low Alkali Cement :** Cements with alkali less than 0.6 per cent should be used.
3. **By Controlling Moisture :** Old concrete should not be allowed to come in contact with water. The best way is to apply mortar with water proofing agents on concrete surface.
4. **By Pozzolanas :** When fly-ash or surkhi or crushed stone dust is added this optimum condition of silica being in particular proportion and fineness is disturbed and the aggregates turn to be inoffensive.
5. **By Air Entraining Agents :** The alkali-silica-gel imparts osmotic pressure over the set cement gel and this is mainly responsible for formation of cracks. When air entraining agents are added they absorb the osmotic pressure and control the expansion.

Que 1.18. Describe the test conducted to determine the crushing value, impact value and abrasion value of aggregates.

Answer

A. Determination of Crushing Value (IS 2386 Part 4-1963) :

1. Crushing value of aggregate is a relative measure of resistance of an aggregate to crushing under gradually applied compressive load.
2. Aggregate passing through 12.5 mm sieve and retained on 10 mm sieve is taken. About 6.5 kg of surface dry aggregate filled in the standard cylinder in three layers, tamping each layer 25 times by a standard tamping rod. It is leveled off. Its weight found out (A).
3. The plunger is placed on the aggregate taking care that it does not jam the cylinder by becoming tilted.
4. The assembly is then kept under compression testing machine and total load of 40 tonnes is applied uniformly during 10 minutes.
5. The load is released, the aggregate is taken out and sieve on 2.36 mm sieve. The fraction passing through weight is (B).
6. The aggregate crushing value is given by,

   Aggregate crushing value = $B / A \times 100$ %.
7. Aggregate crushing value should not be more than 45 % for aggregate used for concrete other than for wearing surface and 30 % for concrete used for wearing surface such a runway roads, etc.

B. Determination of Impact Value (IS 2386 part 4-1963) :

1. This test gives relative measure of resistance of aggregate to suddenly applied load or impact load.
2. The test sample consists of aggregate passing through 12.5 mm IS sieve and retained on 10 mm IS sieve. The aggregate is oven dried at 110 °C for 4 hours.

3. The aggregate is filled in the cup, (weight A). By lifting the handle, hammer is allowed to fall freely as it is released by the tripping mechanism, on to the aggregate in the cup.
4. 15 such blows are given and then the aggregate is taken out and sieved on 2.36 mm sieve.
5. The fraction passing through is weighed (weight B).
6. The fraction retained is also weighed (weight C). If $(B + C)$ is less than A by more than 1 gram, the result is discarded and a fresh test is made.
7. The aggregate impact value is given by,
   Aggregate impact value = $BA \times 100$
8. Standard value for this test is same as crushing value test.

C. Determination of Abrasion Value (IS 2386 Part 4-1963) :

1. This test gives the relative resistance of aggregate to wearing.
2. There are two methods prescribed in the IS code :
   i. Deval Attrition Test, and
   ii. Los Angeles Abrasion Value.
3. But since LA test gives more realistic results, it is more commonly used.
4. In this method, the specified weight, 5kg or 10 kg, depending on the size of aggregate is taken and is placed in the cylinder of the LA machine along with the abrasive charge.
5. The abrasion charge consists of specific number of steel balls.
6. The cylinder is rotated at 20 to 33 rpm for 500 or 1000 revolution, depending on the grading of the aggregate.
7. The aggregate is removed from the cylinder and sieved on 1.75 mm sieve.
8. The fraction passing through 1.7 mm sieve is expressed as percentage of original weight give the aggregate abrasion value.
9. The percentage of wear should not be more than 16 % for cement concrete aggregate.

Que 1.19. What tests are used to find out the shape of the aggregate ?

Answer

There are mainly two types of test for finding the shape of aggregate, which are as follows :

A. Test for Determination of Flakiness Index :

1. The flakiness index of aggregate is the percentage by weight of particles in it whose least dimension (thickness) is less than three-fifths of their mean dimension. The test is not applicable to sizes smaller than 6.3 mm.
2. This test is conducted by using a metal thickness gauge.
3. A sufficient quantity of aggregate is taken such that a minimum number of 200 pieces of any fraction can be tested.

4. Each fraction is gauged in turn for thickness on the metal gauge.
5. The total amount passing in the gauge is weighed to an accuracy of 0.1 % of the weight of the samples taken.
6. The flakiness index is taken as the total weight of the material passing the various thickness gauges expressed as a percentage of the total weight of the sample taken.

B. Test for Determination of Elongation Index :

1. The elongation index on an aggregate is the percentage by weight of particles whose greatest dimension (length) is greater than 1.8 times their mean dimension.
2. The elongation index is not applicable to sizes smaller than 6.3 mm.
3. This test is conducted by using metal length gauge.
4. A sufficient quantity of aggregate is taken to provide a minimum number of 200 pieces of any fraction to be tested.
5. Each fraction shall be gauged individually for length on the metal gauge.
6. The total amount retained by the gauge length shall be weighed to an accuracy of at least 0.1 % of the weight of the test samples taken.
7. The elongation index is the total weight of the material retained on the various length gauges expressed as a percentage of the total weight of the sample gauged.
8. The presence of elongated particles in excess of 10-15 % is generally considered undesirable.

Que 1.20. Explain the procedure for determination of 'ten percent fines value'.

Answer

Procedure for Determination of Ten Percent Fines Value :

1. The sample of aggregate for this test is the same as that of the sample used for aggregate crushing value test.
2. The apparatus, with the test sample and plunger in position is placed in the compression testing machine.
3. The load is applied at a uniform rate so as to cause a total penetration of the plunger in 10 minutes of about :
   i. 15 mm for rounded or partially rounded aggregates (for example uncrushed gravels)
   ii. 20.0 mm for normal crushed aggregates, and
   iii. 24.0 mm for honeycombed aggregates (e.g., expanded shales and stags).
4. After reaching the required maximum penetration, the load is released and the whole of the material removed from the cylinder and sieved on a 2.36 mm IS sieve.
5. The fines passing the sieve is weighed and the weight is expressed as a percentage of the weight of the test sample.

6. This percentage would fall within the range 7.5 to 12.6, but if it does not, repeat test is made and the load is found out which gives a percentage of fines within the range of 7.5 to 12.5.
7. Load required for 10 % fines

$$= \frac{14 \times X}{Y + 4}$$

where, X = Load in tons, causing 7.5-12.5 % fines, and
Y = Mean percentage fines from two tests at × tons load.

Que 1.21. **What is fineness modulus ? How is sieve analysis conducted for fine aggregates and coarse aggregates ?**

Answer

A. Fineness Modulus (FM) :

1. The FM is an index of the fineness of the aggregate. The higher the FM the coarser the aggregate. FM of fine aggregate is useful in estimating proportions of fine and coarse aggregate in concrete mixtures.
2. The fineness modulus (FM) for both fine and coarse aggregates is obtained by adding the cumulative percentages by mass retained on each of a specified series of sieves and dividing the sum by 100.

$$FM = \frac{\Sigma \text{ (Cumulative \% retained on specified seive)}}{100}$$

Sand	Fineness Modulus
Fine	2.2 – 2.6
Medium	2.6 – 2.9
Coarse	2.9 – 3.2

B. Sieve Analysis :

1. This is the name given to the operation of dividing a sample of aggregate into various fractions each consisting of particles of the same size.
2. The sieve analysis is conducted to determine the particle size distribution in a sample of aggregate, which we call gradation.
3. The aggregates used for making concrete are normally of the maximum size 80 mm, 40 mm, 20 mm, 10 mm, 4.75 mm, 2.36 mm, 600 micron, 300 micron and 150 micron. The aggregate fraction from 80 mm to 4.75 mm is termed as coarse aggregate and the fraction from 4.75 mm to 150 micron is termed as fine aggregate.
4. **As Per IS : 2386(Part-1) :** Fine aggregate : 6 standard sieves with openings from 150 μm to 4.75 mm. (150 μm, 300 μm, 600 μm, 1.18 mm, 2.36 mm, 4.75 mm).
5. **Coarse Aggregate :** 5 sieves with openings from 4.75 mm to 80 mm. (4.75 mm, 10 mm, 12.5 mm, 20 mm, 40 mm).
6. The size 4.75 mm is a common fraction appearing both in coarse aggregate and fine aggregate (CA and FA).

7. Grading pattern of a sample of CA or FA is assessed by sieving a sample successively through all the sieves mounted one over the other in order of size, with larger sieve on the top.
8. The material retained on each sieve after shaking, represents the fraction of aggregate coarser than the sieve in question and finer than the sieve above.
9. Sieving can be done either manually or mechanically.

Que 1.22. Explain different method of measurement of moisture content of aggregates.

Answer

Following are the method of measurement of moisture cement of aggregates :

1. Drying Method :

i. The application of drying method is fairly simple. Drying is carried out in an oven and the loss in weight before and after drying will give the moisture content of the aggregate.

ii. If the drying is done completely at a high temperature for a long time, the loss in weight will include not only the surface water but also some absorbed water.

iii. A fairly quick result can be obtained by heating the aggregate quickly in an open pan.

iv. The process can also be speeded up by pouring inflammable liquid such as methylated spirit or acetone over the aggregate and igniting it.

2. Displacement Method :

i. In the laboratory the moisture content of aggregate can be determined by means of pycnometer or by using Siphon-Can Method.

ii. The principle made use of is that the specific gravity of normal aggregate is higher than that of water and that a given weight of wet aggregate will occupy a greater volume than the same weight of the aggregate when dry.

iii. By knowing the specific gravity of the dry aggregate, the specific gravity of the wet aggregate can be calculated.

iv. From the difference between the specific gravities of the dry and wet aggregates, the moisture content of the aggregate can be calculated.

3. Electrical Meter Method :

i. Recently electrical meters have been developed to measure instantaneous or continuous reading of the moisture content of the aggregate.

ii. The principle that the resistance gets changed with the change in moisture content of the aggregate has been made use of.

4. Automatic Measurement :

1. In modem batching plants surface moisture in aggregates is automatically recorded by means of some kind of sensor arrangement.

2. The arrangement is made in such a way that the quantity of free water going with aggregate is automatically recorded and simultaneously that much quantity of water is reduced.

Que 1.23. **What are the effects of impurities in the mixing water on concrete ?**

OR

Write a short note on the feasibility of use of sea water for mixing concrete.

Answer

Effects of Mixing Water from Different Sources :

1. **Ground Water :** Presence of sulphates in ground waters highly injurious to concrete foundations.
2. **Sea Water :**

i. The sea water generally contains 3.5 % of salts with about 75 % of sodium chloride, about 15 % of chloride and sulphate of magnesium.

ii. It has been found to reduce the strength of concrete by 10-20 % and slightly accelerate the setting time.

iii. Sea water may lead to corrosion of reinforcement.

iv. The chlorides in sea water may cause efflorescence in concrete.

v. The use of sea water is not recommended for prestressed concrete because of stress corrosion and the small diameter wires.

vi. If sea water cannot be avoided for making reinforced concrete, particular precautions should be taken to make the concrete dense by using low water/cement ratio coupled with vibration and to give an adequate cover of at least 7.5 cm.

3. **Industrial Waste Water :** When industrial waste water is used as mixing water in concrete, the reduction in compressive strength is generally less than about 10 %.
4. **Water For Washing Aggregates :**

i. When aggregates are washed with water containing impurities, they get coated with layers of silt, salts and organic matters.

ii. These reduce the bond between the aggregates and cement and markedly affect the strength.

5. **Water for Curing :**

i. Waters containing impurities and leading to stains is objectionable.

ii. When concrete is subjected to prolonged wetting, even a very low concentration of iron and organic matter may cause staining.

iii. Water containing more than 0.08 ppm of iron is not recommended for curing.

Que 1.24. **Enumerate the various impurities in water having deleterious effects on concrete.**

Answer

Impurities in water can be of following types :

1. **Chlorides :**

i. Chlorides can cause corrosion of the steel reinforcement and can accelerate setting.

ii. The water used may be contaminated with chlorides because of it being sea water, the presence of admixtures and de-icing salts, or deliberate chlorination for disinfection.

2. **Sulphates :** Sulphates can lead to the reformation of ettringite as well as reduction of long-term strength levels.

3. **Organic Matter :** The effects of organic matter on concrete are varied. If algae are present in water, it should not be used because it will affect setting and strength development.

4. **Sugar :** Sugar retards the setting time. Too much sugar may 'kill' the concrete (*i.e.*, it will not set).

5. **Wastewater :** It is best not to use wastewater. Alternatively it can be used after proper testing and treatment.

Table gives the typical limits of impurities in water as per IS : 456-2000.

Solids	Permissible limits, max. (mg/L)
Organic	200
Inorganic	3000
Sulphates (as SO_3)	400
Chlorides (as Cl_2) :	
i. For plain concrete	2000
ii. For reinforced concrete	500
Suspended matter	2000

2
UNIT

Chemical and Mineral Admixtures

PART-1

Introduction and Study of Accelerators, Retarders, Water Reducers, Air Entrainers, Water Proofers, Super Plasticizers.

CONCEPT OUTLINE : PART-1

Admixtures : It is defined as a material, other than cement, water and aggregates that is used as an ingredient of concrete and is added to the batch immediately before or during mixing.

Types of Admixtures : According to the effects produced in concrete, the admixtures are classified as :

i. Accelerators.
ii. Water reducing admixtures.
iii. Retarders.
iv. Air-entraining agents.

Accelerators : These are the substances which when added to concrete, mortar or grout, increase the rate of hydration of hydraulic cement, shorten the time of set or increase the rate of hardening or strength development. E.g., sodium chloride.

Retarders : These are the substances which retard the setting of cement. E.g., sugar, soluble zinc salts etc.

Plasticizers : These are the substances which when added to concrete, increase workability without increasing the water content.

Air-entraining Agents : These are the admixtures which cause air to be incorporated in the form of minute bubbles in concrete during mixing to increase the workability and resistance to freezing and thawing and disruptive action of deicing salts.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.1. What is admixture ? Why is it used with concrete ? Also give its types.

Answer

A. Admixture :

i. Admixtures are materials used to modify the properties of fresh hardened concrete.

ii. They are classified as chemical and mineral admixtures.

iii. Chemical admixtures are used in the construction industry for building strong, durable, and waterproof structures.

B. Reason for using Admixtures with Concrete :

Following are the purposes for which the admixtures could be used with concrete :

1. To accelerate the initial set of concrete, *i.e.*, to speed up the rate of development of strength at early ages.
2. To retard the initial set of concrete, *i.e.*, to keep concrete workable for a longer time for placement.
3. To enhance the workability.
4. To improve the penetration (flowability) and pumpability of concrete.
5. To reduce the segregation in grout and concrete mixtures.
6. To increase the strength of concrete by reducing the water content and by densification of concrete.
7. To decrease the capillary flow of water through concrete and to increase in impermeability to liquids.
8. To inhibit the corrosion of reinforcement in concrete.
9. To increase the resistance to chemical attack.
10. To increase the bond between old and new concrete surfaces.

C. Types of Admixtures : Following are the types of admixtures :

1. Accelerators.
2. Water reducing admixtures.
3. Retarders.
4. Air-entraining agents.

Que 2.2. Explain the accelerators with suitable example. Also give the functions of accelerators.

Answer

Accelerator : An admixture is use to speed up the initial set of concrete is called accelerator.

Examples : Calcium chloride, sodium nitrate, calcium nitrate, etc.

Functions : Following are the functions of accelerators :

1. These are added to concrete either :

i. To increase the rate of hydration of hydraulic cement, and hence to increase the rate of development to strength.

ii. To shorten the setting time.

2. An increase in the rate of early strength development may help in :

i. Earlier removal of forms,

ii. Reduction of required period of curing, and

iii. Earlier placement of structure in service.

3. Accelerating admixtures are also used when the concrete is to be placed at low temperatures.

4. The benefits of reduced time of setting may include :

i. Early finishing of surface,

ii. Reduction of pressure on forms or of period of time during which the forms are subjected to hydraulic pressure, and

iii. More effective plugging of leaks against hydraulic pressure.

5. With the availability of powerful accelerators, the under-water concreting, the basement waterproofing operations, the repair work of the waterfront structures in the tidal zones have become easy.

Que 2.3. Describe the accelerator effect on the concrete properties.

Answer

Following are the accelerator effect on the concrete properties :

1. The general action of accelerators is to cause a more rapid dissolution of compounds of cement, particularly tricalcium silicate, in water and hence facilitate more rapid hydration of these compounds.

2. The use of 2 % calcium chloride by mass of cement can reduce the setting time by one-third and raise the one to seven day compressive strength by 3 to 8 MPa.

3. An increase in flexural strength of 40 to 80 % of one day and up to 12 % at 28 days in obtained.

4. Large doses of $CaCl_2$ result in flash set of concrete and the ambient temperature.

5. Calcium formate (a fine powder), which is somewhat less soluble than calcium chloride and is less effective does not have the same adverse effect on corrosion of embedded steel as $CaCl_2$. It is added in the same dosages.

Que 2.4. Explain the role of admixtures in concrete technology.

Answer

Following are the role of admixtures in concrete technology :

1. To Modify Fresh Property :

i. Increase the workability without increasing the water cement ratio or decrease the water content at the same workability.

ii. Retard or accelerate the time of initial setting.

iii. Reduce or prevent the settlement or create slight expansion.

iv. Modify the rate or capacity of bleeding.

2. To Modify Harden Property :

i. Reduce the heat of evolution.

ii. Accelerate the rate of strength development at early stages.

iii. Increase the durability.

iv. Decrease the permeability of concrete.

Que 2.5. What is air-entrained concrete ? What are the air-entraining agents ? What are factors affecting the air-entrainment in the concrete ?

Answer

A. Air-Entrained Concrete :

1. Air-entrainment is the internal creation of tiny air bubbles in concrete. A concrete maker introduces the bubbles by adding to the mix an air entraining agent. The air bubbles are created during mixing of the plastic concrete and most of them survive to be part of the hardened concrete.
2. It contains billions of microscopic air cells per cubic foot. These air pockets relieve internal pressure on the concrete by providing tiny chambers for water to expand into when it freezes.
3. It is produced using air-entraining Portland cement, or by the introduction of air-entraining agents, under careful engineering supervision, as the concrete is mixed on the job.
4. The amount of entrained air is usually between four to seven percent of the volume of the concrete.

B. Air-entraining Agents : Following are the air-entrainment agent used in the concrete :

1. Natural wood resins.
2. Animal and vegetable fats and oils such as tallow, olive oil and their fatty acids such as stearic and oleic acids.
3. Various wetting agents such as alkali salts or sulphonated organic compounds.
4. Water soluble soaps of resins acid.
5. Miscellaneous materials such as sodium salts of petroleum sulphonic acids, hydrogen peroxide and aluminium powder, etc.

C. Factor Affecting Air Entrainment : Following are the factor affect the air entrainment :

1. Type and quantity of air entraining agents used.
2. Water cement ratio of mix.

3. Type and grading of aggregates.
4. Mixing time.
5. Temperature.
6. Type of cement.
7. Influence of compaction.
8. Admixtures other than air entraining agents used.

Que 2.6. What are the effects of air entrainment admixture on the properties of concrete ?

Answer

Effect of Air Entrainment on Concrete Properties : Following are the effect of air entrainment on concrete properties :

1. Reduction in strength.
2. Improvement in workability.
3. Increased resistance to freezing and thawing.
4. Reduces the tendencies of segregation.
5. Reduces the bleeding and laitance.
6. Decreases the permeability.
7. Increases the resistance to chemical attack.
8. Permits reduction in sand content, water content, cost and heat of hydration.
9. Reduces unit weight, alkali aggregate reaction and modulus of elasticity.
10. Enhance the durability of concrete against cycles of climatic freezing and thawing and against the effects of de-icing salts.

Que 2.7. What are the different types of superplasticizers ?

Answer

Types of Superplasticizers : Different types of superplasticizers are as follows :

1. **Lignosulphonates :** These are derived from neutralization, precipitation, and fermentation processes of the waste liquor obtained during production of paper-making pulp from wood
2. **Sulphonated Melamine Formaldehyde (SMF) :** It is manufactured by normal resinification of melamine - formaldehyde.
3. **Sulphonated Napthalene Formaldehyde (SNF) :** Produced from naphthalene by oleum or SO_3 sulphonation; subsequent reaction with formaldehyde leads to polymerization and the sulphonic acid is neutralized with sodium hydroxide or lime.

4. **Polycarboxylic Ether (PCE) :** Free radical mechanism using peroxide initiators is used for polymerization process in these systems.

Que 2.8. Discuss the role of plasticizers when used as an admixture for concrete.

Answer

Role of Plasticizers : Admixtures are used for following purposes :

1. To achieve a higher strength by decreasing the water cement ratio at the same workability.
2. To achieve the same workability by decreasing the cement content so as to reduce the heat of hydration in mass concrete.
3. Water reduction more than 5 % but less than 12 %.
4. To increase the workability so as to ease placing inaccessible locations.

Que 2.9. Describe the effect of superplasticizer on the properties of fresh and hardened concrete.

Answer

A. Effect on Fresh Concrete :

1. Superplasticizers enhance workability. The effect depends on type, dosage, and time of addition (best with mixing water). Water requirement is reduced by 15 to 30 %. Resulting concrete has higher strength and lower permeability.
2. Superplasticizers produce higher than normal workability for 30-60 min and there will be rapid loss of workability.
3. Generally bleeding is decreased (less water). If flowing concrete is made, precautions are needed not to induce bleeding and segregation.

B. Effect on Hardened Concrete :

1. Water reduction allows producing high-strength concrete.
2. Shrinkage of superplasticized concrete is comparable to or less than normal concrete.
3. Creep of superplasticized concrete is similar to that of a reference concrete.
4. The use of superplasticizers allows improvements in the bond between concrete and reinforcing steel.

C. Effect on Durability :

1. Lower water/cement ratio leads to lower permeability and enhanced strength and durability.
2. In normal concrete, the critical spacing between air bubbles is 200 μm. In superplasticized concrete, that value is exceeded. Better freeze-thaw durability can be expected for air entrained superplasticized concrete.

3. Durability to sulphate attack depends on the particular mechanism of sulphate attack and exposure type. For expansion, lower permeability (less surface penetration) can lead to better durability.
4. Lower water/cement ratio leads to lower permeability and improved resistance to chloride penetration and corrosion of steel.
5. Lower water/cement ratio leads to lower moisture penetration, which could enhance resistance to alkali expansion.

PART-2

Study of Supplementary Cementing Materials Like Fly Ash, Silica Fume, Ground Granulated Blast Furnace Slag, Metakaolin and Pozzolana ; Their Production, Properties and Effect on Concrete properties.

CONCEPT OUTLINE : PART-2

Material Additives : It also called supplementary cementing materials are finely grounds siliceous materials which do not possess cementing property in themselves, but react chemically with calcium hydroxide released from the hydration of portland cement at normal temperature to form compounds of low solubility having cementing properties.

Types of Pozzolana :

i. Natural Pozzolana.
ii. Artificial Pozzolana

Fly Ash : The fly ash or pulverized fuel ash is the residue from the combustion of pulverized coal collected by mechanical dust collectors or electrostatic precipitators or separators from the fuel gases of thermal power plants.

Granulated Blast-Furnace Slag : It is a waste industrial by product obtained during the production of iron. The plant furnace slag is non metallic product having oxide composition similar to that of Portland cement clinker.

Silica Fume : It is a light to dark grey or pink or white cementing material composed of at least 85 % ultra fine amorphous non crystalline spherical silicon dioxide particles.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 2.10. **Discuss fly ash in concrete. Give the advantages and disadvantages of fly ash.**

Answer

A. **Fly Ash :** Fly ash is one of the residues generated in combustion, and comprises the fine particles that rise with the flue gases. In an industrial context, fly ash usually refers to ash produced during combustion of coal.

B. **Advantages of Fly Ash in Concrete :** Following are the advantages of fly ash :

1. Lower permeability and better resistance to sulphate attack.
2. Lower shrinkage and porosity as a result of the lower water content.
3. Improved long term strength and durability performance.
4. The rate of bleeding is reduced while workability is increased.
5. Reduced water content for a given workability or improved workability at the same water content.

C. **Disadvantages of Fly Ash in Concrete :** Following are the disadvantages of fly ash :

1. It is more difficult to control the colour of concrete containing fly ash than mixtures with Portland cement only.
2. Fly ash reduces the amount of air entrainment, and concrete mixtures high in fly ash often require more air- entraining admixture.
3. Fly ash admixtures can lengthen the time it takes for concrete to set.
4. Concrete changes from a liquid to a solid a few hours after pouring, but the curing process may take much longer.

Que 2.11. **What are the classifications of fly ash ? Also give the use of fly ash concrete.**

Answer

A. **Types of Fly Ash :** Following are the two types of fly ash :

1. **Class C Fly Ash :**

i. This class of fly ash has a high CaO content and used as a standalone stabilizing agent.

ii. The strength characteristics of class C fly ash having a CaO less than 25 percent can be improved by adding lime.

2. **Class F Fly Ash :**

i. This class of fly ash has a low CaO content.

ii. Class F fly ash has an insufficient CaO content for the pozzolanic reaction to occur.

iii. It is not effective as a stabilizing agent by itself however, when mixed with either lime or lime and cement, the fly ash mixture becomes an effective agent.

B. Uses of Fly Ash Concrete : Fly ash concrete are used in :

1. Pumped concrete.
2. Road stabilization.
3. Tunnelling concrete.
4. Self compacting concrete.
5. Water retaining structure.
6. Marine environment concretes.
7. Ready mix and precast application.
8. Mass concrete section.

Que 2.12. What are the effects of fly ash on various properties of concrete ?

Answer

Effects of Fly Ash on Concrete : Following are the effects of fly ash on concrete :

1. On Amount of Mixing Water :

i. The use of fly ash in limited amounts as a replacement for cement or as an addition to cement requires a little more water for the same slump because of fineness of the fly ash.

ii. It is generally agreed that the use of fly ash, particularly as an admixture rather than as a replacement of cement, reduces, segregation and bleeding.

iii. If the sand is coarse the addition of fly ash produces beneficial results; for fine sands, its addition may increase the water requirement for a given workability.

2. On Compressive Strength : An addition of fly ash up to 30 per cent may result in lower strength at 7 and 28 days, but may be about equal at 3 months and may further increase at ages greater than 3 months provided curing is continued.

3. On Modulus of Elasticity : It is lower at early ages and higher at later ages.

4. On Curing Condition : It is similar to Portland cement concrete.

5. On Shrinkage of Concrete : Coarse fly ash and those having high carbon content are more liable to increase drying shrinkage than the finer fly ashes and those having low carbon content.

6. On Permeability : The permeability of concrete reduces on addition of fly ash to cement.

7. **On Resistance to Chemical Attack :** Fly ash slightly improves the resistance of concrete to sulphate attack.
8. **On Heat of Hydration :** Fly ash reduces the heat of hydration in concrete. A substitution of 30 % fly ash may result in a reduction of 50-60 % heat of hydration.
9. **On Air Entrainment :** The presence of fly ash reduces the amount of air entraining agent.
10. **On Setting Time :** A 30 % substitution of fly ash may result in an increase of initial setting time up to 2 hours.

Que 2.13. **What is silica fume ? How is it produced ? Give the chemical composition of it.**

Answer

A. Silica Fume :

i. Silica fume, also known as micro silica, is a byproduct of the reduction of high-purity quartz with coal in electric furnaces in the production of silicon and ferrosilicon alloys.

ii. Silica fume is also collected as a byproduct of the production of other silicon alloys such as ferrochromium, ferromanganese, ferro magnesium, and calcium silicon.

B. Chemical Composition:

1. It is mostly made of silica having silica percent more than 80.
2. The other chemical composition includes Fe_2O_3, Al_2O_3, CaO, MgO, Na_2O, K_2O in small percentages.

Que 2.14. **What is the physical characteristics and functions of silica fume ?**

Answer

A. Physical Characteristics : Following are the physical properties of silica fume :

1. It should be in premium white and standard grey colour.
2. The specific gravity of the silica fume concrete is 2.2.
3. Particle size is less than 1 micron with average diameter of 0.1 micron.
4. Its specific surface area is to be 20,000 m^2 / kg.
5. The shape of the particle is spherical.
6. It should be in amorphous in nature.

B. Functions of Silica Fume : Following are the various functions of silica fume :

1. The hydration of Portland cement produces many components, including calcium silicate hydrates (CSH) and calcium hydroxide (CH).
2. The additional calcium silicate hydrates produced by the silica fume is more resistant to attack from aggressive chemicals then the weaker calcium hydroxide.
3. The silica fume is added to the calcium hydroxide for produce the additional calcium silicate hydrates to obtain a very good compressive strength can exceed 15000 psi.

Que 2.15. Explain the effects of silica fume on concrete properties.

Answer

A. Effect of Silica Fume on the Properties of Fresh Concrete :

1. Workability :

i. Reduced workability.

ii. Water demand increases in proportion to silica fume added. Water demand is 1 % for every 1 % replacement of cement.

iii. Lower slump and more cohesive mix.

2. Bleeding and Segregation :

i. Bleeding is reduced as silica fume particles find their way in between two cement grains.

ii. Segregation is reduced has the concrete mix is more cohesive due to increase in number of solid to solid contact points.

3. Time of Setting : The initial setting time and final setting time is not greatly influenced. The increase may be 30 min or so.

4. Plastic Shrinkage : Since silica fume concrete show no bleeding, fresh concrete is subjected to plastic shrinkage.

B. Effects of Silica Fume on the Properties of Hardened Concrete :

1. Drying Shrinkage : Long term shrinkage of concrete is not affected significantly by the addition of silica fume.

2. Creep : The creep of concrete containing silica fume will be lower than corresponding Portland cement concrete.

3. Chemical Resistance : A major reason for the improved resistance of concrete to acidic and sulphate waters is the reduction in the $Ca(OH)_2$ content of the cement paste, which decreases linearly with the amount of silica fume added.

4. Alkali Aggregate Reaction : Less than 10 % of silica fume is found adequate for reducing the alkali aggregate expansion as compared to fly ash which requires 30 %-40 % replacement.

5. Strength : Strength of 62-80 MPa can be easily achieved.

6. **Permeability :** Silica fume reduce the size of voids in hydrated cement paste, thus making them almost impermeable even at early ages with 10 % addition of silica fume by weight of cement.
7. **Freeze and thaw Effect :** The effect of silica fume concrete on freeze-thaw affect is not very significant.

Que 2.16. **What are the advantages, disadvantages and uses of silica fume ?**

Answer

A. Advantages of Silica Fume : Following are the advantages of silica fume :

1. Lowers concrete permeability.
2. Significantly increases concrete durability.
3. Increases ultimate strength gain.
4. Beneficial in all types of high strength concrete applications.
5. Improves bond strength to steel.
6. Significantly reduces alkali-silica reactivity.
7. Provides excellent resistance to sulphate or seawater attack.
8. Reduces steel corrosion.
9. Improves freeze/thaw durability of concrete.

B. Disadvantages of Silica Fume : Following are the disadvantages of silica fume :

1. Silica fume concrete shrinkage rate is a large.
2. Silica fume concrete workability is poor.
3. It is easy to produce temperature cracks.

C. Uses of Silica Fume :

1. For production of high strength concrete, corrosion- resistant concrete, abrasion-resistant concrete, and low permeability concrete.
2. Used to make sewer and manhole repair products. Reduces rebound in shotcrete application.

Que 2.17. **What is ground granulated blast furnace slag (GGBS) ? What are its benefits and also write down the chemical composition of the slag GGBS.**

Answer

A. Ground Granulated Blast Furnace Slag (GGBS) :

1. The blast furnace slag is a byproduct of the iron manufacturing industry. Iron ore, coke and limestone are fed into the furnace and the resulting molten slag floats above the molten iron at a temperature of about 1500 °C to 1600 °C.

2. The molten slag has a composition of about 30 % to 40 % SiO_2 and about 40 % CaO, which is close to the chemical composition of Portland cement.

B. Benefits of GGBS in Concrete :

1. **Heat of Hydration :** Gradual hydration of GGBS with cement generates lower heat than Portland cement. This reduces thermal gradients in the concrete.
2. **Water Demand :** GGBS is a glassy material and its smoother surface requires less water to adequately cover the particles.
3. **Setting Time :** Increased setting time may be advantageous in extending the time for which the concrete remains workable and, may reduce the risk of cold joints.
4. **Appearance :**

i. GGBS cement also produces a smoother, more defect free surface, due to the fineness of the GGBS particles.

ii. GGBS is effective in preventing efflorescence when used at replacement levels of 50 % to 60 %.

5. **Bleeding :** GGBS reduce bleeding than that of Portland cement and therefore reduces risk of delaminations.
6. **Workability :** GGBS particles are less water absorptive than Portland cement particles and thus GGBS concrete is more workable than Portland cement concrete. For equivalent workability, a reduction in water content of up to 10 % is possible.
7. **Sulphate Resistance :** GGBS is a sulphate-resisting, specifying GGBS at 50 %-70 % content gives optimum protection against sulphate attack.
8. **Alkali Aggregate Reaction (AAR) :** GGBS reduce the deleterious effect of AAR due to its low reactive alkali content and its ability to inhibit AAR.

C. Chemical and Mineralogical Composition of the Slag :

Parameter	Percentage
SiO_2	37.73 %
Al_2O_3	14.42 %
Fe_2O_3	1.11 %
CaO	37.34 %
MgO	8.71 %
MnO	0.02 %
Sulphide sulphur	0.39 %
Glass content (%)	92 – 95 %

Que 2.18. What are the effects of using GGBS in concrete ?

Answer

A. Effects of GGBS on the Properties of Fresh Concrete :

1. The cementitious material containing GGBS exhibited greater workability due to the increased paste content and increased cohesiveness of the paste.
2. Usually, an increase in time of setting can be expected when GGBS is used as replacement for part of the Portland cement in concrete mixtures.
3. GGBS is finer than the Portland cement and is substituted on an equal-mass basis, bleeding is reduced;
4. When the GGBS is coarser, the rate and amount of bleeding may increase.

B. Effects of GGBS on the Properties of Hardened Concrete :

1. Decrease strength and rate of strength gain.
2. Increase the resistance to freezing and thawing.
3. Increase the resistance to deicing chemicals.
4. Increase the resistance to the corrosion of reinforcement.
5. Reduction of expansion due to alkali-silica reaction (ASR).
6. Increase the resistance to sulfate attack.
7. Reduce the permeability.

Que 2.19. What is the use of GGBS in concrete ?

Answer

Following are the uses of GGBS in concrete :

1. GGBS is used to make durable concrete structures in combination with ordinary Portland cement and/or other pozzolanic materials.
2. Two major uses of GGBS are in the production of quality- improved slag cement, namely Portland Blast Furnace Cement (PBFC) and High-Slag Blast-Furnace Cement (HSBFC), with GGBS content ranging typically from 30 to 70 %; and in the production of ready-mixed or site-batched durable concrete.

Que 2.20. Describe the metakaolin. Discuss the advantages and disadvantages of metakaolin.

Answer

A. Metakaolin :

1. Metakaolin is an admixture used as an partial replacement of cement in HSC (high strength concrete).

2. A concrete is said to be high strength concrete if its compressive strength is more than 40MPa.
3. Metakaolin is prepared by calcination of kaolin (clay mineral) at an temperature of 650-800°C. It has pozzolanic properties.
4. Chemical formula of Metakaolin is $Al_2O_3.2SiO_2.2H_2O$
5. It reacts with $Ca(OH)_2$ one of the by-products of hydration reaction of cement and results in additional C-S-H gel which results in increased strength.

B. Advantages of Metakaolin : Following are the advantages of metakaolin :

1. Strength and durability of concrete increases.
2. Accelerates initial setting time of concrete.
3. Compressive strength of concrete increases by 20 %.
4. Cross section of structure can be reduced safely *i.e.*, amount of concrete used can be reduced.
5. Reduces shrinkage in concrete.
6. Eco-friendly by reducing amount of CO_2 emission.
7. Reduces heat of hydration leading to shrinkage and crack control.

C. Disadvantages of Metakaolin : Following are the disadvantages of metakaolin :

1. Increased cost price.
2. Higher water ratio.
3. Workability.
4. Additional raw material.
5. At low addition rate increase shrinkage.

Que 2.21. What are the chemical compositions of metakaolin ? Also write is physical properties.

Answer

A. Chemical Composition of Metakaolin :

Chemical Composition	Percentage (%)
Silica (SiO_2)	54.3
Alumina (Al_2O_3)	38.3
Ferric oxide (Fe_2O_3)	4.28
Calcium oxide (CaO)	0.39
Magnesium oxide (MgO)	0.08
Sodium oxide (Na_2O)	0.12
Potassium oxide (K_2O)	0.50

B. Physical Properties of Metakaolin :

1. Physical form – powder
2. Fineness of metakaolin – 700 to 900 m^2/kg
3. Color of metakaolin – white/grey
4. Specific gravity – 2.50
5. Specific surface – 8 to 15 m^2/g.

Que 2.22. Write down the application of metakaoline.

Answer

Application of Metakaolin : It can be used in constructions of :

1. Nuclear power stations.
2. Mass concreting.
3. Off shore structures.
4. High rise building.
5. Water retaining structures
6. Bridges.
7. Dams.

Que 2.23. What are the difference between fly ash and GGBS ?

Answer

	Fly Ash	GGBS
Source	It is obtain from the combustion of powdered coal in electric generating plants.	It is obtain by quenching molten iron blast furnace slag in water or stream.
Consistency	It is a byproduct of electric power generation that varies from source to source.	It is a co-product of a controlled process, iron production, which results in a very uniform composition from source to source.
Chemical composition	Fly ash usually contains very high SiO_2 and Al_2O_3, but very low in CaO (< 2 %)	It has very similar chemical compositions to ordinary portland cement. Such as 30-40 % CaO, 35-38 % SiO_2, 10-18 % Al_2O_3 , 10 – 18 % MgO etc.
Permitted replacement ratio	In OPC is 15-30 % but not more than 30 % concrete	GGBS in OPC or concrete is 25-78 %
Hydration activity	Fly ash does not take part in hydration activity.	GGBS take part in hydration activity.

3
UNIT

Mix Design and Rhealogy of Concrete

PART-1

Principle of Mix Proportioning, Properties Related to Mix Design, Mix Design Method (ACI and IS), Mix Design of Concrete, Packing Density.

CONCEPT OUTLINE : PART-1

Principles of Mix Proportions : According to IS 456 : 2000 and IS 1343 – 1980 the design of concrete mix should be based on following principles :

i. Grade designation.
ii. Type and grade of cement.
iii. Minimum nominal size of aggregate.
iv. Grading of combined aggregate.
v. Water cement ratio.
vi. Workability.
vii. Durability.
viii. Quality control.

Concrete Mix Design : It is a process of selecting suitable ingredients for concrete and determining their proportions which would produce, as economically as possible, *i.e.*, concrete having a certain minimum compressive strength, workability and durability.

Factors of Mix Proportioning :

i. Water-cement ratio.
ii. Cement Content or cement-aggregate ratio.
iii. Gradation of the aggregate.
iv. Consistency.

Methods of Mix Design : Following are the various method of concrete mix design :

i. ACI mix design method.
ii. Indian standard recommended method for mix design.
iii. Rapid method for mix design etc.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.1. What do you mean by 'mix design' in concrete ? Explain its types and objectives.

Answer

Concrete Mix Design : Mix Design is the science of determining the relative proportions of the ingredients of concrete to achieve the desired properties in the most economical way.

Types of Mixes : Following are the types of mixes :

1. **Nominal Mixes :** In the specifications for concrete prescribed the proportions of cement, fine and coarse aggregates. These mixes of fixed cement aggregate ratio which ensures adequate strength are termed nominal mixes
2. **Standard Mixes :** IS 456-2000 has designated the concrete mixes into a number of grades as M10, M15, M20, M25, M30, M35 and M40. In this designation the letter M refers to the mix and the number to the specified 28 day cube strength of mix in N/mm^2.
3. **Design Mixes :** In these mixes the performance of the concrete is specified by the designer but the mix proportions are determined by the producer of concrete, except that the minimum cement content can be laid down

Objective of Mix Design : Following are the objective of mix design :

1. To achieve the designed/desired workability in the plastic stage.
2. To achieve the desired minimum strength in the hardened stage.
3. To achieve the desired durability in the given environment conditions.
4. To produce concrete as economically as possible.

Que 3.2. What are the various principles of proportioning of mix design ?

Answer

Principles of Mix Design : Following are the various principles of mix design :

1. The environment exposure condition for the structure.
2. The grade of concrete, their characteristic strength's and standard deviations.
3. The type of cement.
4. The types and sizes of aggregates and their sources of supply.
5. The nominal maximum sizes of aggregates.
6. Maximum and minimum cement content in kg/m^3.
7. Water cement ratio.
8. The degree of workability of concrete based on placing conditions.
9. Air content inclusive of entrained air.

10. The maximum/minimum density of concrete.
11. The maximum/minimum temperature of fresh concrete.
12. Type of water available for mixing and curing.
13. The source of water and the impurities present in it.

Que 3.3. Discuss the Abram's water / cement ratio law and its validity. How strength of concrete is estimated by Abram's law.

Answer

Abram's Water / Cement Ratio Law :

1. According to Abram's law the strength of fully compacted concrete is inversely proportional to the water-cement ratio.
2. Here the water-to-cement ratio is the relative weight of the water to the cement in the mixture. For most applications, water-to-cement should be between 0.4 and 0.5, lower for lower permeability and higher strength.

Validity : If not properly compacted, the concrete mix will contain large valids, which contribute to porosity. Thus, at low water/cement ratio where full compaction is hard to achieve, Abram's law is not valid.

Expression :

1. According to Abram's law, compressive strength can be expressed as :

$$F = \frac{A_1}{B_1^x}$$

$$\log F = \log A_1 - x \log B_1$$

where, F = Compressive strength of concrete.

A_1, B_1 = Constant.

x = Water cement ratio by weight.

Que 3.4. What are the different factors in the choice of mix proportions ?

Answer

Factors Influencing Choice of Mix Design : According to IS 456:2000 and IS 1343:1980 following are the factor affecting the design of concrete mix :

1. Grade of Concrete :

i. The grade of concrete gives characteristic compressive strength of concrete.

ii. The grade M20 denotes characteristic compressive strength f_{ck} of 20 N/mm^2.

iii. Depending upon the degree of control available at site, the concrete mix is to be designed for a target mean compressive strength (f_{ck}) applying suitable standard deviation.

2. Type of Cement :

i. The higher the strength of cement used in concrete, lesser will be the cement content.

ii. The use of 43 grade and 53 grade of cement, gives saving in cement consumption as much as 15 % and 25 % respectively, as compared to 33 grade of cement.

3. Maximum Nominal Size of Aggregates :

i. It is designated by the sieve size higher than larger size on which 15 % or more of the aggregate is retained.

ii. The maximum nominal size of aggregate should not be more than one-fourth of minimum thickness of the member.

iii. For heavily reinforced concrete members as in the case of ribs of main beams, the nominal maximum size of the aggregate should usually be restricted to sum less than the minimum clear distance between the main bars or 5 mm less the minimum cover to the reinforcement, whoever is smaller.

4. Grading of Combined Aggregates :

i. The relative proportions of the fine and coarse aggregate in a concrete mix is one of the important factors affecting the strength of concrete.

ii. For dense concrete, it is essential that the fine and coarse aggregate be well graded.

5. Maximum Water/Cement Ratio : The lower the water/cement ratio, the greater is the compressive strength.

6. Workability : Workability of fresh concrete determines the case with which a concrete mixture can be mixed, transported, placed, compacted and finished without harmful segregation and bleeding.

7. Durability :

i. Durability require low water/cement ratio.

ii. It is usually achieved not by increasing the cement content, but by lowering the water demands at given cement content.

iii. Water demand can be lowered by through control of the aggregate grading and by using water reducing admixtures.

Que 3.5. Write short note on quality control of concrete.

Answer

1. The strength of concrete varies from batch to batch over a period of time.

2. The sources of variability in the strength of concrete may be considered due to variation in the quality of the constituent materials, variations in mix proportions due to batching process, variations in the quality of batching and mixing equipment available, the quality of supervision and workmanship.
3. These variations are inevitable during production to varying degrees.
4. Controlling these variations is important in lowering the difference between the minimum strength and characteristic mean strength of the mix and hence reducing the cement content.
5. The factor controlling this difference is quality control.
6. The degree of control is ultimately evaluated by the variation in test results usually expressed in terms of the coefficient of variation.

Que 3.6. **Discuss the statistical quality control of concrete. Explain common terminology used in statistical quality control of concrete.**

Answer

A. Statistical Quality Control of Concrete :

1. Statistical quality control method provides a scientific approach to the concrete designer to understand the realistic variability of the materials so as to lay down design specifications with proper tolerance to cater for unavoidable variations.
2. The acceptance criteria are based on statistical evaluation of the test result of samples taken at random during execution. By devising a proper sampling plan it is possible to ensure a certain quality at a specified rise.
3. Thus the method provides a scientific basis of acceptance when is not only realistic but also restrictive as required by the design requirements for the concrete construction.

Common Terminology : The common terminologies that are used in the statistical quality control of concrete.

1. **Mean Strength :** This is the average strength obtained by dividing the sum of strength of all the cubes by the number of cubes.

$$\bar{x} = \frac{\Sigma x}{n}$$

where, $\bar{x}$ = Mean strength.

Σx = Sum of the strength of cubes.

n = Number of cubes.

2. **Variance :** This is the measure of variability or difference between any observed data from the mean strength.

3. Standard Deviation :

i. This is the root mean square deviation of all the results, is denoted by s or σ. Numerically it can be explained as,

$$\sigma = \sqrt{\frac{\Sigma(x - \bar{x})^2}{n - 1}}$$

where, σ = Standard deviation.

n = Number of observations.

x = Particular value of observations.

$\bar{x}$ = Arithmetic mean.

ii. Standard deviation increases with increasing variability.

iii. The characteristics of the normal distribution curve are fixed by the average value and the standard deviation.

4. Coefficient of Variation :

i. It is an alternative method of expressing the variation of result.

ii. It is a non-dimensional measure of variation obtained by dividing the standard deviation by the arithmetic mean and is expressed as :

$$V = \frac{\sigma}{\bar{x}} \times 100$$

where, V = Coefficient of variation.

Que 3.7. Step by step explain the American Concrete Institute method of mix design.

Answer

Following are the steps in American Concrete Institute method :

1. Data to be Collected :

i. Fineness modulus of selected fine aggregate.

ii. Unit weight of dry rodded coarse aggregate.

iii. Specific gravity of coarse and fine aggregates in SSD condition

iv. Absorption characteristics of both coarse and fine aggregates.

v. Specific gravity of cement.

2. From the minimum strength specified, estimate the average design strength by using standard deviation.

3. Find the water/cement ratio from the strength and durability points of view. Adopt the lower value.

4. Decide the maximum size of aggregate to be used. Generally for RCC work 20 mm and pre-stressed concrete 10 mm size are used.

5. Decide workability in terms of slump for the given job.

6. The total water in kg/m^3 of concrete is determined, corresponding to the selected slump and selected maximum size of aggregate.
7. Cement content is computed by dividing the total water content by the water/cement ratio.
8. Select the bulk volume of dry rodded coarse aggregate per unit volume of concrete, for the particular maximum size of coarse aggregate and fineness modulus of fine aggregate.
9. The weight of CA per cubic meter of concrete is calculated by multiplying the bulk volume with bulk density.
10. The solid volume of coarse aggregate in one cubic meter of concrete is calculated by knowing the specific gravity of CA.
11. Similarly the solid volume of cement, water and volume of air is calculated in one cubic meter of concrete.
12. The solid volume of FA is computed by subtracting from the total volume of concrete the solid volume of cement, CA, water and entrapped air.
13. Weight of fine aggregate is calculated by multiplying the solid volume of fine aggregate by specific gravity of FA.

Que 3.8. Step by step explain the IS method of mix proportioning.

Answer

Following are the steps of IS method of mix design :

Step 1 : Calculation of Target Strength of Concrete :

Target strength is denoted by f_t which is obtained by characteristic compressive strength of concrete at 28 days (f_{ck}) and value of standard deviation (σ)

$$f_t = f_{ck} + 1.65 \times \sigma$$

Standard deviation can be taken from below table 3.8.1.

Table 2.8.1.

Grade of concrete	Standard deviation (N/mm^2)
M10	3.5
M15	3.5
M20	4.0
M25	4.0
M30 ..... so on	5.0

Step 2 : Selection of Water-Cement Ratio :

Water cement ratio is selected from the below curve for 28 days characteristic compressive strength of concrete.

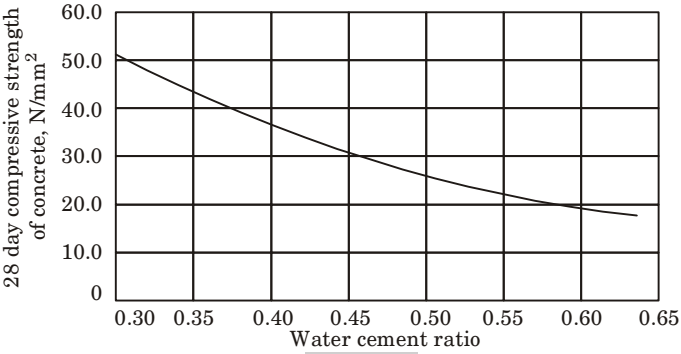


Fig. 3.8.1.

Step 3 : Determination of Aggregate Air Content :

i. Air content in the concrete mix is determined by the nominal maximum size of aggregate used.

ii. Below table will give the entrapped air content in percentage of volume of concrete.

Table 3.8.2.

Nominal Maximum Size of Aggregate	Air Content (% of Volume of Concrete)
10 mm	5 %
20 mm	2 %
40 mm	1 %

Step 4 : Selection of Water Content for Concrete :

i. Select the water content which is useful to get required workability with the help of nominal maximum size of aggregate as given in below table 3.8.3.

ii. The table given below is used when only angular shaped aggregates are used in concrete as well as the slump should be 25 to 50 mm.

Table 3.8.3.

Nominal Maximum Size of Aggregate	Maximum Water Content
10 mm	208
20 mm	186
40 mm	165

Step 5 : Selection of Cement Content for Concrete : Water-cement ratio is determined in step 2 and quantity of water is determined in

step-4. So, we can easily calculate the quantity of cement from these two conditions. But, the value obtained should satisfy the minimum conditions as given in the table 3.8.4. The greater of the two values is decided as quantity of cement content.

Table 3.8.4. Cement Content for PCC and RCC

Exposure	Minimum Cement Content kg/m^3		Max Free water Cement Ratio		Minimum Grade of Concrete	
	PCC	RCC	PCC	RCC	PCC	RCC
Mild	220	300	0.6	0.55	–	M20
Moderate	240	300	0.6	0.5	M15	M25
Severe	250	320	0.5	0.45	M20	M30
Very severe	260	340	0.45	0.45	M20	M35
Extreme	280	360	0.4	0.4	M25	M40

Step 6 : Calculation of Aggregate Ratio : For the given nominal maximum size of aggregate, we can calculate the ratio of volumes of coarse aggregate and volume of total aggregates for different zones of fine aggregates from the below table.

Table 3.8.5.

Nominal maximum size of aggregate	Ratio of volume of coarse aggregate and volume of total aggregate for different zones of fine aggregate			
	Zone-1	Zone-2	Zone-3	Zone-4
10 mm	0.44	0.46	0.48	0.50
20 mm	0.6	0.62	0.64	0.66
40 mm	0.69	0.71	0.73	0.75

Step 7 : Calculation of Aggregate Content for Concrete : We already determine the coarse aggregate volume ratio in the total aggregate volume. So, it is very easy that, 1- volume of coarse aggregate will give the volume of fine aggregate.
Mass of fine aggregate is calculated from below formula

$$V = \left[W + \frac{C}{G_c} + \left(\frac{1}{(1-P)} X \frac{FA}{G_f} \right) \right] \times \frac{1}{1000}$$

Similarly, mass of coarse aggregate is calculated from below formula.

$$V = \left[W + \frac{C}{G_c} + \left(\frac{1}{p} X \frac{CA}{G_{ca}} \right) \right] \times \frac{1}{1000}$$

where, V = Volume of concrete.
W = Water content.
C = Cement content.
G_c = Specific gravity of cement.
P = Aggregate ration obtained in step 6.
FA and CA = Masses of fine and coarse aggregates.
G_f and G_{ca} = Specific gravities of fine and coarse aggregates.

Step 8 : Trial Mixes for Testing Concrete Mix Design Strength : Based on the values obtained above, conduct a trail test by making at least 3 cubes of 150 mm size as per above standards. Test that cubes and verify whether the required strength is gained or not. If not, redesign the mix with proper adjustments until required strength of cube occurs.

PART-2

Rheology, Mix Design Example.

CONCEPT OUTLINE : PART-2

Rheology : It may be defined as the science of the deformation and flow of materials, and is concerned with relationship between stress, strain rate of strain and time.

Effective factors of rheology properties of concrete :

i. Hardening and stiffening.
ii. Aggregate shape and texture.
iii. Aggregate grading.
iv. Admixtures.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 3.9. What do you mean by Rheology of fresh concrete ? Explain the parameters of Rheology.

Answer

1. **Rheology :** It may be defined as the science of the deformation and flow of materials, and concerned with relationships between stress, strain, rate of strain, and time.
2. The term rheology deals with the materials whose flow properties are more complicated than of simple fluids (liquids or gases).

Parameters of Rheology : Following are the parameter of rheology :

1. Stability :

i. It is defined as a condition in which the aggregate particles are held in homogeneous dispersion by matrix, and random sampling shows the same particle size distribution during transportation, placing and compaction.

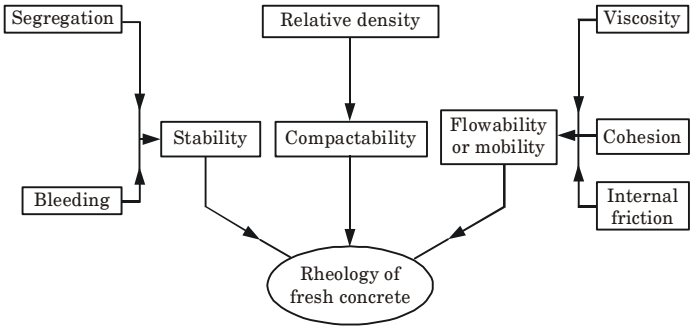


Fig. 3.9.1. Parameters the rheology of fresh concrete.

ii. The stability of concrete is measured by its segregation and bleeding characteristics.

2. Mobility :

i. The mobility of fresh concrete is its ability to flow under momentum transfer, *i.e.*, under mechanical stresses. The flow is restricted by cohesive, viscous and frictional forces.

ii. The cohesive force develops due to adhesion between the matrix and aggregate particles. It provides tensile strength of fresh concrete that resists segregation.

iii. The viscosity of the matrix contributes to the ease with which the aggregate particles can move and rearrange themselves within the matrix.

iv. The internal friction occurs when a mixture is displaced and the aggregate particles translate and rotate.

v. The resistance to deformation depends on the shape and texture of the aggregate, the richness of the mixture, the water-cement ratio, and the type of cement used.

3. Compactability :

i. It measures the ease with which fresh concrete is compacted.

ii. Compacting consist of expelling entrapped air and repositioning the aggregate particles in a dense mass without causing segregation.

iii. Compactability is measured by the compacting factor test.

Que 3.10. Describe the Bingham model of Rheology of fresh concrete.

Answer

1. The flow behaviour of fresh concrete does not conform to Newtonian liquid.
2. The ratio of shear stress to shear rate is not constant but depends upon the shear rate at which it is measured, and may also depend on the shear history of the concrete sample being investigated.
3. However, at low shear rates that are important in practice, the behaviour can be represented by a straight line which does not pass through-the origin, *i.e.*, which has an intercept on the stress axis.
4. The intercept indicates the minimum stress below which no flow occurs.
5. The fact that concrete can stand in a pile (as in the case of the slump test) suggests that there is some minimum stress necessary for flow to occur at all.
6. The minimum stress is called yield stress and designated by the symbol τ_0. Thus the simplest flow equation of concrete illustrated in Fig. 3.10.1 can be written as :

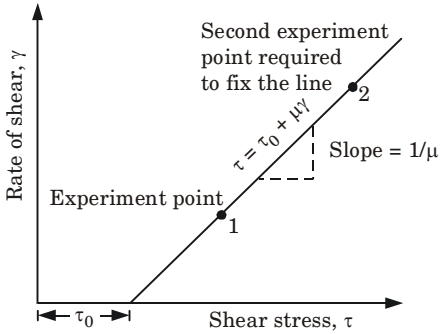


Fig. 3.10.1. Bingham model.

$$\tau = \tau_0 + \mu\gamma$$

where, τ_0 = Yield value indicating the cohesion of the material.

μ = Constant having the dimensions of viscosity and termed plastic viscosity.

7. This mathematical relationship is called the Bingham model.
8. Bingham model relates the shear stress of the material expressed in terms of its cohesion to plastic viscosity, and the rate at which the shear load is applied.

9. To establish a straight line, at least two points are required. Accordingly, the workability of concrete cannot be defined by the single-point tests that determine only one parameter, *i.e.*, produce only single point, and therefore have to be used in combination with other tests to achieve a better understanding of concrete rheology.
10. For example, the Vee-Bee test can be used with compacting factor test to measure mobility and compactability.

Que 3.11. Explain the affective factors of rheological properties of concrete.

Answer

Following are the affecting factors of rheological properties of concrete :

1. **Mix Proportion :** A concrete mix having an excess amount of coarse aggregate will lack sufficient mortar to fill the void system, resulting in a loss of cohesion and mobility.
2. **Consistency :** The consistency of concrete, as measured by the slump test, is an indicator of the relative water content in the concrete mix.
3. **Hardening and Stiffening :**

i. Elevated temperature, use of rapid-hardening cement, cement deficient in gypsum, and use of accelerating admixtures, increase the rate of hardening which reduces the mobility of concrete.

ii. The dry and porous aggregate will rapidly reduce workability by absorbing water from the mixture or increasing the surface area to be wetted.

4. **Aggregate Shape and Texture :**

i. The rough and highly angular aggregate particles will result in higher percentage of voids being filled by mortar, requiring higher fine aggregate contents and correspondingly higher water content.

ii. Similarly, an angular fine aggregate will increase internal friction in the concrete mixture and require higher water content than well-rounded natural sand.

5. **Aggregate Grading :** A well-graded aggregate gives good workability. These effects are greater in the fine aggregate than in coarse aggregate.
6. **Maximum Aggregate Size :** An increase in the maximum size of aggregate will reduce the fine aggregate content required to maintain a given workability, and will thereby reduce the surface area to be wetted.
7. **Admixtures :** The admixtures which have significant effect on the rheology of concrete are plasticizers and super-plasticizers, air-entraining agents, accelerators and retarders.

Que 3.12. Describe the effect of rheological properties on different types of concrete.

Answer

Effect of Rheological Properties on Different Types of Concrete.

1. Different types of concrete :

i. Fig. 3.12.1 shows the three-dimensional relationship between different types of concrete and the rheological parameters.

For Example :

i. Compared to reference concrete, a wet concrete can be produced by decreasing both yield stress and plastic viscosity, whereas a stiffer concrete can be produced by increasing the yield stress.

ii. Initially, addition of silica fume decreases viscosity (fine particle content increases the flow), whereas higher dosage increases the yield stress as well as viscosity.

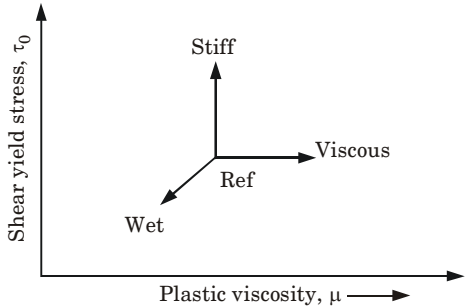


Fig. 3.12.1. Different types of concrete with respect to flow characteristics.

2. Different Additives : The effect of air, water, and other mineral admixtures on rheological parameters of concrete is shown in Fig. 3.12.2.

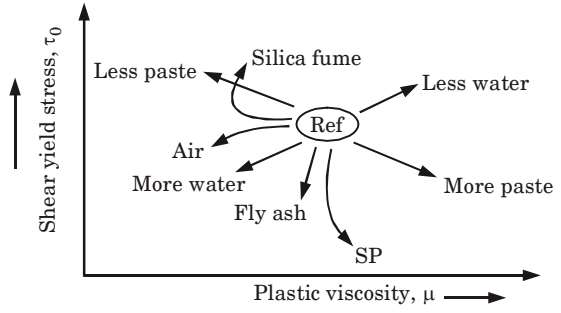


Fig. 3.12.2. Effect of air, water, and mineral admixtures on flow characteristics of concrete,

3. Rheological Properties of Different Concretes :

i. Shear yield stress of self-compacting concrete is in the range of 0-50 Pa, whereas for normal concrete it is high in the range of 100-300 Pa as shown in Fig. 3.12.3.

ii. Plastic viscosity of normal concrete is in the range of 0-40 Pa-s.

iii. However, plastic viscosity for self-compacting concrete is fairly high having a range of 50-90 Pa-s.

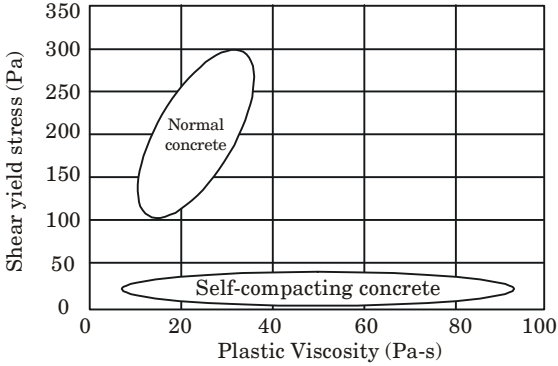


Fig. 3.12.3. Rheological properties of normal and self-compacting concrete.

Que 3.13. Design a concrete mix (by ACI method) for construction of an elevated water tank. The specified design strength of concrete (characteristic strength) is 30 MPa at 28 days measured on standard cylinders. Standard deviation can be taken as 4 MPa. The specific gravity of fine aggregate and coarse aggregate are 2.65 and 2.7 respectively. The dry rodded bulk density of coarse aggregate is 1600 kg/m^3, and fineness modulus of fine aggregate is 2.80. Ordinary Portland cement (Type I) will be used. A slump of 50 mm is necessary. Coarse aggregate is found to be absorptive to the extent of 1 % and free surface moisture in sand is found to be 2 %. Assume any other essential data.

Answer

1. Assuming 5 per cent of results are allowed to fall below specified design strength. The mean strength,

$$f_m = f_{min} + k\sigma$$
$$= 30 + 1.64 \times 4 = 36.56 \approx 36.5 \text{ MPa}$$

2. Since OPC is used, from ACI 211.1 : 1991, the estimated w/c ratio is 0.47.

i. This w/c ratio from strength point of view is to be checked against maximum w/c ratio given for special exposure condition given in ACI 211.1 : 1991 and minimum of the two is to be adopted.

ii. From exposure condition ACI 211.1 : 1991 the maximum w/c ratio is 0.50

Therefore, adopt w/c ratio of 0.47.

3. From ACI 211.1 : 1991, for a slump of 50 mm, 20 mm maximum size of aggregate, for non-air-entrained concrete, the mixing water content is 185 kg/m^3 of concrete. Also the approximate entrapped air content is 2 %.

The required cement content = $\frac{185}{0.47} \simeq 394$ kg/m^3

4. From ACI 211.1 : 1991, for 20 mm coarse aggregate, for fineness modulus of 2.80, the dry rodded bulk volume of coarse aggregate is 0.62 per unit volume of concrete.
5. Therefore the weight of coarse aggregate = 0.62 × 1600 = 992 kg/m^3.
6. From ACI 211.1 : 1991, the first estimate of density of fresh concrete for 20 mm maximum size of aggregate and for non-air-entrained concrete = 2355 kg/m^3.
7. The weight of all the known ingredient of concrete

Weight of water = 185 kg/m^3
Weight of cement = 394 kg/m^3
Weight of CA = 992 kg/m^3
Weight of FA = 2355 – (185 + 394 + 992) = 784 kg/m^3

8. Alternatively the weight of FA can also be found out by absolute volume method which is more accurate, as follows :

Item number	Ingredients	Weight kg/m^3	Absolute volume cm^3
1.	Cement	394	$\frac{394}{3.15} \times 10^3 = 125 \times 10^3$
2.	Water	185	$\frac{185}{1} \times 10^3 = 185 \times 10^3$
3.	Coarse aggregate	992	$\frac{992}{2.7} \times 10^3 \simeq 367 \times 10^3$
4.	Air		$\frac{2}{100} \times 10^6 = 20 \times 10^3$

Total absolute volume = 697 × 10^3 cm^3

Therefore absolute volume of FA = (1000 – 697) × 10^3 = 303 × 10^3 cm^3

Weight of FA = 303 × 2.65 ≃ 803 kg/m^3

9. Estimated quantities of materials per cubic meter of concrete are :

Cement = 394 kg
FA = 803 kg
CA = 992 kg
Water = 185 kg

Density of fresh concrete 2374 kg/m^3 as against 2355 read from ACI 211.1 : 1991.

10. Proportions :

Cement	Fine Aggregate	Coarse Aggregate	Water
394	803	992	185
1	2.04	2.52	0.47

Weight of materials for one bag mix in kg = 50 : 102 : 126 : 23.5

The above quantity is on the basis that both FA and CA are in saturated and surface dry condition.

11. The proportions are required to be adjusted for the field conditions. FA has moisture of 2 per cent.

i. Total free surface moisture in FA = $\frac{2}{100} \times 803 = 16.06$ kg/m^3

ii. Weight of FA in field condition
$= 803 + 16.06 = 819.06$ kg/m$^3 \approx 819$ kg/m^3

iii. CA absorbs 1 % water

Quantity of water absorbed by CA = $\frac{1}{100} \times 992 = 9.92$ kg/m^3

iv. Weight of CA in field condition
$= 992 - 9.92 = 982.08$ kg/m$^3 \approx 982.0$ kg/m^3

v. With regard to water, 16.06 kg of water is contributed by FA and 9.92 kg of water is absorbed by CA.
Therefore 16.06 – 9.92 = 6.14 kg of extra water is contributed by aggregates. This quantity of water is deducted from total water
$185.00 - 6.14 = 178.86$ kg/m$^3 \approx 179$ kg/m^3

12. Quantities of materials to be used in the field duly corrected for free surface moisture in FA and absorption characteristic of CA

Cement = 394 kg/m^3
FA = 819 kg/m^3
CA = 982 kg/m^3
Water = 179 kg/m^3

Field density of fresh concrete = 2374 kg/m^3

Que 3.14. Design a concrete mix for M45 grade of concrete with the following data :

1.	**Type of cement**	**OPC 43 grades**
2.	**Maximum size of aggregate**	**20 mm**
3.	**Exposure Condition**	**Severe (RCC)**
4.	**Workability**	**125 mm slump**
5.	**Minimum cement content**	**320 kg / m^3**
6.	**Maximum W/C ratio**	**0.45**
7.	**Method of placing concrete**	**Pumping**
8.	**Degree of supervision**	**Good**
9.	**Type of aggregate**	**Crushed angular Agg.**
10.	**Super plasticizer will be used**	
11.	**Specific gravity of coarse aggregate**	**2.80**

12. Specific gravity of fine aggregate **2.70**

13. Water absorption

Coarse aggregate **0.5 percent**

Fine aggregate **1.0 percent**

14. Free surface moisture

Coarse aggregate **Nil**

Fine aggregate **Nil**

15. Grading of coarse aggregate conforming to Table 2 of IS 383.

16. Grading of fine aggregate conforming to grading Zone II.

Answer

1. Target Mean Strength :

Characteristic strength $f_{ck} = 45$

Target mean strength, $f'_{ck} = f_{ck} + 1.65 \times \sigma = 45 + 1.65 \times 5 = 53.25$ N/mm^2

Where σ is the standard deviation taken as 5 N/mm^2.

2. Water/Cement Ratio :

i. Water / Cement ratio is taken from the experience of the mix designer based on his experience of similar work elsewhere.

W/C ratio = 0.42

ii. This water cement ratio is to be selected both from strength consideration and maximum w/c denoted in Table 5 of IS 456 and lesser of the two is to be adopted durability requirement.

iii. W/C proposed is 0.42. This being lesser than 0.45, we should adopt W/C ratio as 0.42.

3. Selection of Water Content :

i. Maximum water content as per table 3.8.3 is 186 litre. This is for 50 mm slump.

ii. Estimated water content for 125 mm slump

$$= 186 \times \frac{9}{100} + 186 \approx 203 \text{ litre}$$

(3 % increase for every 25 mm slump over and above 50 mm slump)

iii. Really speaking separate trials are required to be done to find out the efficiency of plasticizers.

iv. In the absence of such trial, it is assumed that the efficiency of super plasticizer used 25 percent. Therefore actual water to be used

$$= 203 \times 0.75 \approx 152 \text{ litre.}$$

4. Calculation of Cement Content :

i. W/C ratio = 0.42

Water used = 152 litre

ii. $$\text{Cement content} = \frac{W}{C} = 0.42$$

$$C = \frac{152}{0.42} = 362 \text{ kg/m}^3$$

iii. This cement content is to be checked against minimum cement content given in table 5 of IS 456 for durability requirement.

iv. As the calculated cement 362 kg/m^3 is more than minimum cement mentioned in table 5 of IS 456 *i.e.*, 320 kg/m^3, the cement content of 362 kg/m^3 should be accepted. Adopt cement content of 362 kg/m^3.

5. Calculation of Coarse and Fine Aggregate Content :

i. From Table 3.8.5 volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate zone II, for w/c ratio of 0.50 is found out to be 0.62.

ii. In the present case w/c 0.42 *i.e.*, it is less by 0.08. As the w/c is reduced it is desirable to increase the coarse aggregate proportion to reduce the fine aggregate content.

iii. The coarse aggregate is increased at the rate of 0.01 for every decrease in w/c ratio of 0.05.

$$\therefore \quad \frac{0.01}{0.05} \times 0.08 = 0.016$$

$$\text{Volume of CA} = 0.62 = \frac{0.016}{0.636}$$

iv. Corrected proportion of volume of CA = 0.636
Since it is angular aggregate and the concrete is to be pumped, the coarse aggregate can be reduced by 10 %.

v. Final volume of coarse aggregate
$$= 0.636 \times 0.9 = 0.572 \text{ say } 0.57$$

vi. Volume of fine aggregate = 0.43

6. Calculation of Mix Proportions :

i. Volume of concrete =1 m^3

ii. Absolute volume of cement = $\frac{362}{3.15} \times \frac{1}{1000}$ m^3 = 0.115 m^3

iii. Volume of water = 152 litre = 0.152 m^3

iv. Volume of chemical admixture
$$= \frac{1.2 \times 362}{100 \times 1.1} \times \frac{1}{1000} = \frac{362 \times 1.2}{110 \times 1000} = 0.004 \text{ m}^3$$
(Assuming dosage of 1.2 % by weight of cementitious material and assuming specific gravity of admixture as 1.1.)

v. Absolute volume of all the materials except total aggregates
$$= 0.115 + 0.152 + 0.004 = 0.271 \text{ m}^3$$

vi. Absolute volume of total aggregate
$$= 1 - 0.271 = 0.729 \text{ m}^3$$

vii. Weight of coarse aggregate
$$= 0.729 \times 0.57 \times 2.80 \times 1000 \simeq 1163 \text{ kg/m}^3$$

viii. Weight of fine aggregate
$$= 0.729 \times 0.43 \times 2.70 \text{ x } 1000 \simeq 846 \text{ kg/m}^3$$

7. Mix Proportions for Trial Number 1

Cement	362 kg/m^3
Water	152 kg/m^3
Fine aggregate	846 kg/m^3
Coarse aggregate	1163 kg/m^3

Chemical admixture	4 kg/m^3
Wet density of concrete	2527 kg/m^3
w/c ratio	0.42

8. Site Correction :

i. Absorption of fine aggregate = 1.0 %

$$= \frac{1}{100} \times 846 = 8.46 \text{ litre}$$

ii. Absorption of coarse aggregate

$$= \frac{0.5}{100} \times 1163 = 5.82 \text{ litre}$$

iii. Total absorption = 14.28 litres

iv. Actual amount of water to be used = 152 + 14.28 = 166.28 litres

v. Actual weight of FA to be used = 846 –8.46 = 837.5 kg/m^3

vi. Actual weight of CA to be used = 1163 – 5.82 = 1157.20 kg/m^3

vii. Proportion of materials at the site

Cement	362 kg/m^3
Water	166.28 kg/m^2
CA	1157.2 kg/m^3
FA	837.5 kg/m^3
Admixture	4.0 kg/m^3

viii. With the above proportion of materials carry out trial mix number-1 and see the quality of concrete.

ix. If it is not satisfactory carry out trial mix number 2, 3 and 4 as indicated earlier under trial mixes. Arrive at the final proportions of concrete mix to satisfy the required parameters.

Que 3.15. Design a concrete mix for M 35 grade using fly ash (as per IS 10262 : 2009). Other data are given below :

1.	**Type of cement**	**OPC 43 grade**
2.	**Type of fly ash**	**F type conforming to IS 3812 (Part I)**
3.	**Max size of aggregate (MSA)**	**20 mm**
4.	**Minimum cement contact**	**320 kg / m^3**
5.	**Maximum w/c ratio**	**0.45**
6.	**Workability**	**100 mm slump**
7.	**Exposure condition**	**Severe (RCC)**
8.	**Method of placing concrete**	**Pumping**
9.	**Degree of supervision**	**Good**
10.	**Chemical admixture**	**Superplasticizer**
11.	**Specific gravity of cement**	**3.15**
12.	**Specific gravity of fly ash**	**2.2**
13.	**Specific gravity of CA**	**2.78**
14.	**Specific gravity of FA**	**2.70**
15.	**Water absorption**	
	i. CA	**0.5 %**
	ii. FA	**Nil**

16. Free surface moisture

i.	**CA**	**Nil**
ii.	**FA**	**1.5 %**

17. Grading of CA is conforming to Table 2 of IS 383 and grading of FA is falling in Zone I.

Answer

1. Target Mean Strength :

$$f'_{ck} = f_{ck} + 1.65 \times \text{Standard deviation}$$
$$= 35 + 1.65 \times 5 = 35 + 8.25 = 43.25 \text{ N/mm}^2$$

2. Selection of w/c Ratio : From the experience of designer, 43.25 N/mm^2 can be achieved in 28 days by using a w/c ratio of 0.46. But as per table 5 of IS 456, a maximum w/c ratio permitted is 0.45.

$\therefore$ Adopt w/c ratio of 0.45.

3. Selection of Water Content :

i. From table 3.8.3, maximum water content for MSA 20 mm aggregate is 186 litre (for stump to 50 mm and w/c ratio of 0.5)

ii. Estimated water content for 100 mm slump

$$= 186 + 186 \times \frac{6}{100} \simeq 197 \text{ litre}$$

iii. As superplasticizer is used, it is assumed that water content can be reduced to the extent of 25 percent.

$\therefore$ Net amount of water required to be used = 197 x 0.75 $\simeq$ 148 litres

4. Calculation of Cement and Fly Ash Content :

i. w/c ratio = 0.45

ii. Cementitious material (cement + fly ash) content

$$= \frac{148}{0.45} \simeq 329 \text{ kg/m}^3$$

Since 329 > 320 it is OK.

iii. IS 456 table number 5 permits minimum cement content 320 kg/m^3 for severe expose condition.

iv. Since fly ash is not as active as that of cement, it is usual to increase the cementitious material by some percentage, based on experience and trials.

v. Cementitious material an increase of 10 % in considered.

$\therefore$ Cementitious material content

$$= 329 \times 1.1 = 362 \text{ kg/m}^3$$

vi. Let us take the percentage of fly ash as 25 %

$$\therefore \text{ Fly ash content } = \frac{25}{100} \times 362 \simeq 91 \text{ kg/m}^2$$

vii. $$\text{Cement} = 362 - 91 = 271 \text{ kg/m}^3$$

viii. $$\text{Water/cementitious ratio} = \frac{148}{362} \simeq 0.41$$

5. Proportion of Volume of CA and FA Content :

i. From Table 3.8.5, volume of coarse aggregate for 20 mm MSA and fine aggregate falling on zone I and w/c of 0.5 = 0.60.

ii. In the present case w/c is 0.45. Therefore volume of CA is required to be increased to decrease the FA content.

iii. As the w/c is lower by 0.05 the proportion of volume of coarse aggregate is increased by,

$$\frac{0.01}{3.15} \times 0.05 = 1.587 \times 10^{-4} \simeq 0.01.$$

iv. Therefore corrected proportion of volume of coarse aggregate for the water cement ratio of

$$0.45 = 0.60 + 0.01 = 0.61$$

v. For pumpable concrete, CA may be reduced by 10 per cent.

a. Volume of CA = $0.61 \times 0.9 = 0.55$

b. Volume of FA = $1 - 0.55 = 0.45$

6. Mix Calculation :

i. Volume of concrete = $1\ m^3$

ii. Absolute volume of cement

$$= \frac{271}{3.15} \times \frac{1}{1000} = 0.086\ m^3$$

iii. Absolute volume of fly ash

$$= \frac{91}{2.2} \times \frac{1}{1000} = 0.041\ m^3$$

iv. Volume of water = $0.148\ m^3$

v. Volume of chemical admixture, assuming
Dosage of 1.2 % by weight of cementitious material and specific gravity of 1.1

$$= \frac{1.2}{100} \times 362 = 4.34\ kg/m^3$$

$$= \frac{4.34}{1.1} \times \frac{1}{1000} = 0.004\ m^3$$

vi. Total volume of all in aggregate

$$= 1 - \{0.086 + 0.041 + 0.148 + 0.004\}$$
$$= 1 - (0.279) = 0.721\ m^3$$

vii. Weight of coarse aggregate

$$= 0.721 \times 0.55 \times 2.78 \times 1000$$
$$= 1102\ kg/m^3$$

viii. Weight of fine aggregate

$$= 0.721 \times 0.45 \times 2.70 \times 1000 = 876\ kg/m^3$$

7. Mix proportion for Trial Number 1 :

Cement	$271\ kg/m^3$
Fly ash	$91\ kg/m^3$
Water	$148\ kg/m^3$
Fine aggregate	$876\ kg/m^3$
Coarse aggregate	$1102\ kg/m^3$
Chemical admixture	$4.00\ kg/m^3$
Wet density	$2492\ kg/m^3$

Water/Cementitious ratio = $\frac{148}{362} = 0.41$

Coarse aggregate can be further divided into 10 mm size and 20 mm size, depending upon the grading required.

We may divide the total aggregate into 40 percent of 10 mm size and 60 percent of 20 mm size.

In that case quantity of 10 mm size

$$= 1102 \times \frac{40}{100} = 440 \text{ kg/m}^3$$

Quantity of 20 mm size = $1102 \times \frac{60}{100} = 662 \text{ kg/m}^3$

8. Field Correction :

i. Fine aggregate quantity = 876 kg/m^3.
Absorption = Nil
Surface moisture = 1.5 %

ii. Quantity of surface moisture

$$= \frac{1.5}{100} \times 876 = 13.14 \text{ kg}$$

iii. Weight of fine aggregate in field condition
$= 876 + 13.14 = 889 \text{ kg/m}^3$

iv. Absorption of CA = $1102 \times \frac{0.5}{100} = 5.51 \text{ kg/m}^3$

v. Weight of CA in field condition = $1102 - 5.51 \approx 1097 \text{ kg/m}^3$

vi. As regard to water, 13.14 kg of water is contributed by FA and 5.51 kg is absorbed by CA Therefore 13.14 – 5.51 = 7.63 kg of extra water is contributed. This quantity of water is to be deducted from total water
i.e., 148 – 7.63 = 140.37 say 140 kg/m^3

vii. Quantities of materials to be used in the field is duly corrected for free surface moisture in FA and absorption characteristic of CA.

Cement	271 kg/m^3
Fly ash	91 kg/m^3
Water	140 kg/m^3
Fine aggregate	889 kg/m^3
Coarse aggregate 10 mm	439 kg/m^3
Coarse aggregate 20 mm	658 kg/m^3
Chemical admixture	4.00 kg/ m^3
Wet density	2492 kg / m^3

9. With the above proportion of materials carry out trial mix number 1. See the quality of concrete. If not satisfactory carry out trial mix number 2, 3 and 4 as indicated earlier under trial mixes. Arrive at the final proportion of concrete mix to satisfy the required parameter.

4
UNIT

Concrete Production, Properties and Testing

PART-1

Concrete Production, Batching, Mixing and Transportation of Concrete, Workability, Test for Workability(Slump Test, Compacting Factor Test and Vee-Bee Test).

CONCEPT OUTLINE : PART-1

The various stages in the manufacturing of concrete are given below :

i. Batching. ii. Mixing.
iii. Transporting. iv. Placing.
v. Compacting. vi. Curing.
vii. Finishing.

Batching : It is the process of measuring specified quantities of cement, aggregate, water and admixture as per the mix proportions for a specified grade of concrete.

Mixing : It is done by :

i. Hand, and ii. Machines.

Transpoting : Following are the methods used for transportation of concrete.

i. Dumper and trucks. ii. Cranes and cable ways.
iii. Conveyors system. iv. Concrete bucket.

Workability : It is the property of freshly mixed concrete or mortar which determines the ease and homogeneity with which it can be mixed, placed, compacted and finished.

Test for workability :

i. Slump test. ii. Compacting factor test.
ii. Flow test. iv. Vee-Bee test.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.1. Explain the various steps in the manufacturing of concrete.

Answer

The various stages in the manufacture of concrete are as follows :

1. **Batching of Concrete :** Batching is the process of measuring concrete mix ingredients by either mass or volume and introducing them into the mixer . To produce concrete of uniform quality, the ingredients must be measured accurately for each batch.

The two methods of batching are as follows :

i. Volume Batching :

a. Volume batching is not a good method because of the inaccuracies it introduces in the measurement of granular materials.

b. Loose sand in a moist condition occupies more volume than dry compacted sand due to the phenomenon of bulking. Hence, the effect of bulking must be considered while measuring sand.

c. Despite drawbacks, for less important non-engineered small works, this method is adopted because of its ease in application. However, it is unscientific and hence not recommended for important works.

ii. Weigh Batching :

a. Weigh batching is the correct method of measuring the materials that are used to make concrete.

b. Use of weigh batching system facilitates accuracy, flexibility, and simplicity.

c. For large works, a weigh batching plant is used.

2. Mixing : The mixing should ensure that the mass becomes homogeneous, uniform in colour and consistency.

Methods of Mixing :

i. Hand mixing.

ii. Machine mixing.

3. Transporting : It is the process of transferring of concrete from the mixing plant to the construction site. It can be done by following equipments :

i. Mortar Pan : Concrete is carried in small quantities.

ii. Wheelbarrows and Buggies : Short flat hauls on all types of onsite concrete construction.

iii. Cranes and Buckets : Used for work above ground level , buckets use with cranes, cableways, and helicopters.

4. Compaction of Concrete :

i. Compaction of concrete is process adopted for expelling the entrapped air from the concrete.

ii. In the process of mixing, transporting and placing of concrete air is likely to get entrapped in the concrete.

iii. It has been found from the experimental studies that 1 % air in the concrete approximately reduces the strength by 6 %.

5. Curing :

i. It is the process in which the concrete is protected from loss of moisture and kept within a reasonable temperature range.

ii. The result of this process is increased strength and decreased permeability.

iii. Curing is also a key player in mitigating cracks in the concrete, which severely impacts durability.

6. Finishing :

i. The finish can be strictly functional or decorative.

ii. Finishing makes concrete attractive and serviceable.

iii. The final texture, hardness, and joint pattern on slabs, floors, sidewalks, patios, and driveways depend on the concrete's end use.

Que 4.2. Explain the mixing and transporting operations of concrete in a work site.

Answer

A. Methods of Mixing : Concrete is mixed either by hand mixing or by machine mixing, based on the quantity of concrete required.

1. Hand Mixing :

i. Mixing by hand is employed only for specific cases where quality is not of much importance, either because of the unimportant nature of the work or because the quantity of concrete required is less.

ii. Hand mixing generally does not produce uniform concrete and hence should not be normally used, unless it is for very small domestic works.

2. Mechanical Mixing :

i. Mechanical mixers can be divided into two main types : batch mixer and continuous mixers.

ii. Batch mixers produce concrete batch by batch, one batch at a time. The operation is intermittent. The raw material is loaded at one end and the concrete is discharged at the other end. This constitutes a cycle of operation which is repeated until enough quantity of concrete is produced.

iii. Continuous mixers produce concrete at a specified rate. The raw materials are continuously entered at one end and mixed concrete exits from the delivery end.

B. Transportation of Concrete : The following methods are used for transporting concrete :

1. Direct Discharge into Forms by Short Chutes :

i. Short chutes in a semi-circular shape stiffened at intervals are simple and economical to use.

ii. Free fall of concrete from a height of more than 2 m must be avoided.

2. Barrows :

i. Manual wheelbarrows of approximately 80 kg capacity can be used for long horizontal distances.

ii. For major works, power barrows of 800 kg capacity, up to 300 m hauls are used.

3. Dumpers and Trucks :

i. These are used for horizontal long hauls.

ii. Because of jolting, especially if the terrain is rough, the concrete during transit has the risk of segregation.

4. Elevating Towers and Hoist : In multi-storied buildings, elevating towers are used for lifting concrete buckets. The lifted concrete is then distributed by either chutes or barrows. This type of transportation can be used where high lifts are required.

5. Monorail System :

i. In tunnels and in dam sites, a single track is laid to carry a monorail power wagon which moves at a speed of 80 m/min.

ii. This type of transportation can be used for covering long distances.

6. Cranes and Cableways :

i. When concreting is to be done in a large project covering mountains and valleys, cranes and cableways are used to provide three-dimensional transport enabling both horizontal and vertical movement.

ii. Depending on the site condition, the type of crane can be chosen. It may be a derrick, crawler, or wheel mounted.

7. Belt Conveyor :

i. It can be used when hauling concrete over long distances.

ii. It is not very much recommended because of its vulnerability to segregation.

iii. The initial setting-up cost is also high. Discharge can be as high as 115 m^3/h.

8. Concrete Bucket and Skip : The capacity of the skip varies from about 0.2 m^3 to 10 m^3.

Que 4.3. What are the precautions to be taken while transporting concrete ? What are the advantages and disadvantages of concrete pump ?

Answer

A. Precautions in Transporting of Concrete : Following precautions should be used during transporting of concrete :

1. While water is added to cement, the procedure of hydration starts and with the passage of time, so concrete should be transported as fast as possible to the formwork within the initial setting time of cement.

2. The procedure of mixing, transporting, placing and compacting concrete should not take more than 90 minutes in any case.

3. No water shall be lost from the mix during transportation.
4. The concrete combine should be protected from drying in hot weather and from rain during transport from the place of mixing to the position of placing.
5. Segregation of concrete should be avoided under all circumstances.
6. The concrete shall be kept agitated in truck mixer in order to avoid it from becoming stiff if more time is likely to be spent during transportation.

B. Advantages of Concrete Pump :

1. Concrete pumping is a faster and easier method to complete a project.
2. Concrete pumping reduces labour costs.
3. It reduces site congestion as there are less construction workers.
4. It provides a steady work pace, increasing productivity.
5. It is effective and economical for various sized projects, including residential and commercial.
6. Several pumps can pour simultaneously for larger projects.

C. Disadvantages of Concrete Pump :

1. Possibility of a concrete pump breaking down.
2. Risk of injury to construction workers and damage to property.
3. During busy periods it is not always easy to find a concrete pump that is available.

Que 4.4. Define workability. What are the factors affecting the workability of concrete ?

Answer

A. Workability of Concrete :

i. A concrete is said to be workable if it is easily transported, placed, compacted and finished without any segregation.

ii. Workability is a property of freshly mixed concrete, and a concrete is a mixture of cement, aggregate, water and admixture.

B. Factors Affecting of Workability of Concrete : Following are the factors affecting of workability of concrete :

1. Water Content : Workability of concrete increases with increase in water content.

2. Aggregate/Cement Ratio : The higher the aggregate/cement ratio, the leaner is the concrete, resulting in lesser workability.

3. Size of Aggregate : For a given quantity of water and paste, bigger size of aggregates will give higher workability.

4. Shape of Aggregate : Better workability is ensured to rounded aggregate than angular, elongated or flaky aggregate.

5. **Grading of Aggregate :** This is one of the factors which will have maximum influence on workability. A well graded aggregate can lead to good workability.
6. **Surface Texture of Aggregate :** Rough textured aggregate will show poor workability and smooth or glassy textured aggregate will give better workability.
7. **Use of Admixture :** The right way of improving workability is to use chemical admixtures such as plasticizers, super plasticizers, air entraining agents, etc.

Que 4.5. **Mention the different tests which are commonly adapted to measure workability and explain any one test in detail.**

Answer

A. Test for Measure Workability : Following are the test used for measure workability :

i. Slump test.

ii. Compacting factor test.

iii. Vee-Bee test.

B. Concrete Slump Test Procedure :

1. Firstly, the internal surface of the mould is cleaned carefully. Oil can be applied on the surface.
2. The mould is then placed on a base plate.
3. The mould is filled with fresh concrete in three layers. Each layer is tamped 25 times with a steel rod.
4. After filling the mould, excess concrete should be removed and the surface should be leveled.
5. Then the mould is lifted gently in the vertical direction and then unsupported concrete will slump. The decrease in height at the centre point is measured to nearest 5 mm or 0.25 inch and it is known as 'slump'.

Que 4.6. **How do you conduct compacting factor test in laboratory.**

Answer

Compaction Factor Test :

1. The compaction factor test gives the behavior of fresh concrete under the action of external force.
2. In this test, the compaction achieved through a free fall of concrete determines its workability.

Compaction Factor Test Procedure :

1. The concrete sample is placed in the upper hopper.
2. Then the door of hopper is opened. The sample drops into lower hopper filling it to overflowing.
3. The trap door of the lower hopper is then opened and the sample falls into the cylinder which is also filled to overflowing.
4. The surplus concrete is removed from the top of the cylinder with the help of a trowel.
5. The outside surface of cylinder is wiped and cleaned.
6. The cylinder is then weighed and it is recorded as weight of partially compacted concrete.
7. The cylinder is again filled with concrete in layers not exceeding 50 mm in thickness. Each layer is fully compacted with tamping rod.
8. The cylinder is again weighed after wiping and cleaning the outside surface of cylinder. This weight is recorded as the weight of fully compacted concrete.
9. The compacting factor is then calculated from the formula :
   Compacting factor = Weight of partially compacted concrete/Weight of fully compacted concrete.

Que 4.7. Explain the Vee-Bee test of determining workability with neat sketch.

Answer

1. The test is suitable for stiff concrete mixes having low or very low workability.
2. Compared to the slump and compacting factor tests, the Vee-Bee test has the advantage that the concrete in the test receives a treatment similar to what it would in actual practice.
3. The test consists of moulding a fresh concrete cone in a cylindrical container mounted on a vibrating table (Fig. 4.7.1).
4. When the concrete cone is subjected to vibration using a standard vibrator, it starts to occupy the cylindrical container by way of getting remoulded.
5. The remoulding is considered complete when the concrete surface becomes horizontal.
6. The time (in seconds) required for the complete remoulding is considered as a measure of workability and is expressed as the number of Vee-Bee seconds.
7. The end point of the test, when the concrete surface becomes horizontal, has to be ascertained visually.

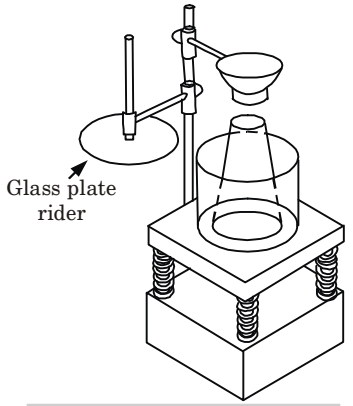


Fig. 4.7.1. Vee-Bee apparatus.

Que 4.8. What is the effect of time and temperature on workability ?

Answer

A. Effect of Time on Workability :

1. Freshly mixed concrete stiffens with the passage of time. This is different from the hardening of the mix.
2. As time passes, water is lost due to absorption by aggregates if they are not already saturated. Some water is lost due to evaporation, especially if the concrete is exposed to hot weather and wind then workability decrease.

B. Effect of Temperature on Workability :

1. When temperature increases, then in the same proportion workability of fresh concrete decreases.
2. The reason that stands behind is "when temperature increases then evaporation rate also increases due to that hydration rate decreases and hence, concrete will gain strength earlier".
3. Due to fast hydration of concrete, a hardening comes in concrete and that decreases the workability of fresh concrete.

PART-2

Segregation and Bleeding in Concrete, Curing of Concrete and Its Method.

CONCEPT OUTLINE : PART-2

Segregation : It is defined as the separating out of ingredients of concrete mix so that the mix is no longer in a homogeneous condition.

Bleeding : Bleeding as concrete is said to occur when unreacted water in the mix tends to rise to the surface of freshly placed concrete due to sedimentation of constituents of concrete.

Curing : The process by which the loss of water from concrete is prevented is known as curing.

Method of Curing : Following are the various method of curing of concrete :

i. Chemical curing.
ii. Steam curing.
iii. Curing of concrete by infrared radiation.
iv. Electrical curing of concrete.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.9. **Write about segregation and its causes. How reduce segregation of concrete ?**

Answer

A. Segregation : It is defined as the separation of the constituents of a homogeneous mixture of concrete. It is caused by the differences in sizes and weights of the constituent particles.

B. Causes of Segregation in Concrete :

1. Transporting concrete mixes for long distances.
2. Poorly proportioned mix, where sufficient matrix is not there to bind the aggregates.
3. Dropping concrete from more than 1m.
4. Vibrating concrete for a long time.

C. Remedial Measures :

i. To reduce segregation, well graded aggregates are used and concrete is placed with enough compaction.
ii. The concrete should not be dropped from a height of more than 1.5 m.

Que 4.10. **Discuss the factors affecting bleeding of concrete.**

Answer

Factors Affecting Bleeding of Concrete : Following are the factors that affecting the bleeding of concrete :

1. Water Content and Water Cement Ratio :

i. Any increase in the amount of water or water-to-cementitious material ratio results in more available water for bleeding.

ii. A one-fifth increase in water content of a normal concrete mixture can increase bleeding rate more than two and a half times.

2. Cement :

i. The type, content and fineness of cement can effect bleeding. As the fineness of the cement increases, the amount of bleeding decreases.

ii. Increases in cement content, reduces the water-cement ratio, and also reduces bleeding.

3. Supplementary Cementing Materials :

i. Fly ash, slag, silica fume, rice husk ash and natural pozzolanas can reduce bleeding by their inherent properties and by increasing the amount of cementitious materials in a mixture.

4. Aggregate :

i. Aggregate that contain a high amount of silt, clay or other material passing the75 μm sieve can have a significant effect in reducing bleeding.

5. Chemical Admixture :

i. Air-entraining agents have been used largely because the air bubbles appear to keep the solid particles in suspension.

ii. Water reducers also reduce the amount of bleeding because they release trapped water in mixture.

Que 4.11. How would you reduce bleeding from concrete ?

Answer

Controlling Measures of Bleeding : Following are the controlling measures of bleeding from concrete :

1. Proper proportioning of concrete.
2. A complete and uniform mixing of concrete.
3. If we can increase the traveling length of water to be bleeded, the bleeding can be reduced considerably. For this purpose we can use finely divided pozzolanic materials
4. An introduction of air-entrainment by using air entraining agent can reduce bleeding.
5. The use of finer cement.
6. By using of a rich mix rather than lean mix.

7. Controlled vibration can reduce bleeding.

Que 4.12. What are the effects of bleeding on concrete properties ?

Answer

Following are the effects of bleeding on concrete properties :

1. Due to bleeding concrete losses its homogeneity.
2. Bleeding is responsible for causing permeability in concrete.
3. This accumulation of water creates a water voids and reduces bond between the aggregate and cement past. So the strength of concrete reduces.
4. Water that accumulates below the reinforcing bars, particularly below the cranked bars, reduces the bond between the reinforcement and concrete.
5. The bleeding water flows at over the unsupported side of pavement which causes collapsing of sides.
6. In pavement construction bleeding water delays surface finishing and application of curing compound.
7. Bleeding causes of 'Laitance in concrete'. Due to the formation of Laitance, structures may lose its wearing capacity and decreases its life.
8. Water while moving from bottom to the top, forms continuous channels. Due to this channel, concrete becomes permeable and allow water to move, which forms water voids in the matrix and reduces the bond between aggregate and the cement paste.

Que 4.13. Describe the curing and importance of curing. Explain the different methods of curing.

Answer

A. Curing : It is a procedure that is adopted to promote the hardening of concrete under conditions of humidity and temperature which are conducive to the progressive and proper setting of the constituent cement.

B. Importance of Curing : Following are the importance of curing of concrete :

1. To maintain moisture content in the mix for complete hydration of concrete.
2. To maintain uniform temperature of the concrete.
3. To preserve the properties of concrete, such as impermeability, durability and strength.
4. To reduce the shrinkage of the concrete.

C. Methods of Curing of Concrete : Following are the methods of curing :

1. **Ponding of Water over the Concrete Surface after it has Set :** This is the most common method of curing the concrete slab or pavements and consists of storing the water to a depth of 50 mm on the surface by constructing small puddle clay bunds all around.
2. **Covering the Concrete with Wet Straw or Damp Earth :** In this method the damp earth or sand in layers of 50 mm height are spread over the surface of concrete pavements. The material is kept moist by periodical sprinkling of water.
3. **Covering the Concrete with Wet Burlap :** The concrete is covered with burlap (coarse jute or hemp) as soon as possible after placing, and the material is kept continuously moist for the curing period.
4. **Sprinkling of Water :**

i. This is a useful method for curing vertical or inclined surfaces of concrete.

ii. The spraying can be done in fine streams through nozzles fixed to a pipe spaced at set intervals.

iii. Flogging is done in the same way except that the flogging nozzles produce a mist-like effect, whereas spraying nozzles shed out fine spray.

5. **Covering the Surface with Waterproof Paper :**

i. Waterproof paper prevents loss of water in concrete and protects the surface from damage.

ii. A good quality paper can be often reused. The paper is usually made of two sheets struck together by rubber latex composition.

6. **Leaving the Shuttering or Formwork :** The thick watertight formwork also prevents the loss of moisture in concrete and helps in curing the sides and the base of the concrete.
7. **Membrane Curing of the Concrete :**

i. The process of applying a membrane forming compound on concrete surface is termed membrane curing.

ii. Often, the term membrane is used not only to refer to liquid membranes but also to a solid sheeting used to cover the concrete surface.

iii. The curing membrane serves as a physical barrier to prevent loss of moisture from the concrete to be cured.

iv. A curing liquid membrane should dry within 3 to 4 hours to form a continuous coherent adhesive film free from pinholes and have no deleterious effect on concrete.

8. **Chemical Curing :**

i. Chemical curing is accomplished by spraying the sodium silicate (water glass) solution on concrete surface.

ii. About 500 g of sodium silicate mixed with water can cover 1 m^2 of surface and from a hard and insoluble calcium silicate film.

iii. It actually acts as a case hardener and curing agent.

Que 4.14. Explain maturity concept of concrete.

Answer

Maturity of Concrete :

1. The strength of concrete depends on both the period of curing (*i.e.* age) and temperature during curing, the strength can be visualized as a function of period and temperature of curing.
2. The maturity of concrete is defined as the summation of product of time and temperature.

$$\text{Maturity} = \Sigma\,(\text{Time} \times \text{Temperature})$$

3. Its units are °C hr or °C days.
4. A sample of concrete cured at 18 °C for 28 days is taken to be fully matured which is equal to

$$M_{28\ \text{days}} = 28 \times 24[18 - (-11)] = 19488\ ^\circ\text{C hr.}$$

5. The temperature is reckoned from – 11 °C as origin in the computation of maturity, since hydration continues to take place up to about this temperature.

Que 4.15. The strength of a sample of fully matured concrete is found to be 40MPa. Find the strength of identical concrete at the age of 7 days when cured at an average temperature during day time at 20 °C and night time at 10 °C. Take $A = 32$, $B = 54$. Use % of strength of concrete at maturity = $A + B \log_{10}\left(\frac{\text{Maturity}}{1000}\right)$.

Answer

Given : Strength of matured concrete = 40 MPa, $A = 32$ and $B = 45$
To Find : Strength of concrete the age of 7 days.

1. Maturity of concrete at the age of 7 days

$$= \Sigma\,(\text{Time} \times \text{Temperature})$$
$$= 7 \times 12 \times [20 - (-11)] + 7 \times 12 \times [10 - (-11)]$$
$$= 7 \times 12 \times 31 + 7 \times 12 \times 21$$
$$= 4368\ ^\circ\text{C-h.}$$

2. The percentage strength of concrete at maturity of 4368 °C-h.

$$= A + B \log_{10} \frac{(\text{Maturity})}{1000} = 32 + 54 \times \log_{10}\left(\frac{4368}{1000}\right) = 66.5\%$$

3. The strength at 7 days $= 40.0 \times \frac{66.5}{100} = 26.5$ MPa.

Que 4.16. **Differentiate between accelerated curing and normal curing.**

Answer

S. No.	Accelerated Curing	Normal Curing
1.	In accelerated curing compressive strength of a concrete mix is determined by curing concrete cubes for about 28 hrs.	In normal curing compressive strength of a concrete mix is determined by curing concrete cubes for 28 days.
2.	In accelerated curing temperature of curing water is raised.	In normal curing temperature of curing water is normal.
3.	Carbonation depth under accelerated curing is higher.	Carbonation depth under normal curing is lower.

PART-3

Determination of Compressive and Flexural Strength as Per BIS.

CONCEPT OUTLINE : PART-3

Test for Determining Compressive and Flexural Strength :

1. Cube test of concrete.
2. Spilt tensile test.
3. Flexure test.
4. Rebound hammer test.
5. Ultrasonic pulse velocity test.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.17. **Explain the various types of tests for compressive strength and tensile strength of concrete.**

Answer

Following are the various test used for determining compressive and tensile strength :

1. Concrete Cube Test :

i. Concrete characteristic is determined by characteristics compressive cube strength test of concrete.

ii. For cube test two types of specimens either cubes of 15 cm × 15 cm × 15 cm or 10 cm × 10 cm × 10 cm depending upon the size of aggregate are used.

iii. For most of the works cubical moulds of size 15 cm × 15 cm × 15 cm are commonly used.

iv. These specimens are tested by compression testing machine after 7 days curing or 28 days curing.

v. Load should be applied gradually at the rate of 140 kg/cm^2 per minute till the specimens fails.

2. Tensile Strength Test :

i. The concrete structures are highly vulnerable to tensile cracking and hence the determination of tensile strength of concrete is very important.

ii. The tensile strength of concrete structures is determined by :

a. Split cylinder test.

b. Flexure test.

3. Core Strength Test :

i. Cylindrical cores are cut from the finished structure with a rotary cutting tool.

ii. The core is soaked, capped and tested in compression to give a measure of the concrete strength in the actual structure.

iii. The ratio of core height to diameter and the location where the core is taken affect the strength.

iv. The strength is lowest at the top surface and increases with depth through the element.

v. A ratio of core height-to-diameter of 2 gives a standard cylinder test.

Que 4.18. Describe the flexure test and split tensile test of concrete.

Answer

A. Flexure Test :

1. The guidelines for performing the flexure test is as per BIS 1881: Part 118 : 1983.

2. Here a concrete beam specimen of dimension 15 × 15 × 75 cm is loaded.

3. The span of the beam specimen must be three times the depth.

4. As shown in the Fig. 4.18.1 equal load application is done at one third distance from the end supports. The reactions are equal at the support.

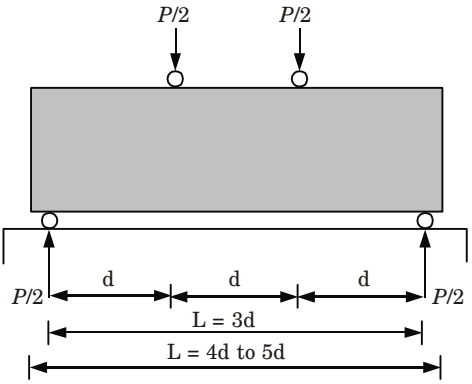


Fig. 4.18.1. Experimental arrangement for flexural strength test.

5. The bottom beam fibre experiences increase in stress with the increase in load application.
6. The increase of stress is at a rate of 0.02 MPa and 0.10 MPa.
7. For low strength concrete we make use of low rate and for high strength we use high rate.
8. The theoretical maximum tensile stress at the bottom face at failure is calculated. This is termed the modulus of rupture. It is about 1.5 times the tensile stress determined by the splitting test.
9. Modulus of rupture is given by,

$$f_{bt} = \frac{PL}{bd^2}$$

B. Split Cylinder Test :

1. Here, the tensile strength is determined indirectly. The test is performed based on BIS: 5816-1970.

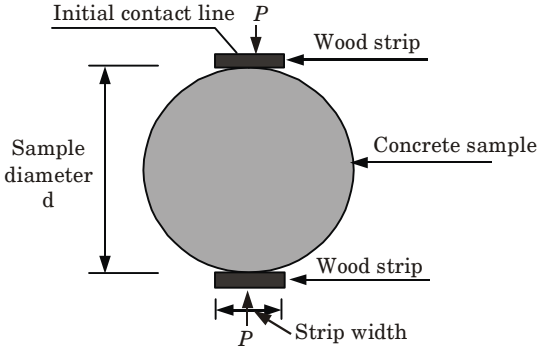


Fig. 4.18.2. Arrangement for split tensile strength.

2. The test specimen employed is 30 cm × 15 cm which is placed over a compression testing machine.
3. The load is applied over the specimen diametrically and uniformly through the cylinder length till the cylinder undergoes failure.
4. The failure of the cylinder will be along the diameter in vertical direction.
5. Between the specimen and the loading plates, plywood strips are placed to avoid direct stress due to direct point of application.
6. The tensile stress formed with the progress of load will split the cylinder into two halves. The splitting takes place along the vertical plane. This is caused due to the indirect tensile stress.
7. Split tensile strength is given by,

$$f_t = \frac{2P}{\pi DL}$$

where, f_t = Tensile strength.
P = Compressive load.
D = Diameter of cylinder.
L = Length of cylinder.

Que 4.19. Explain the various steps involved in evaluation of compressive strength of concrete from preparation to testing of sample.

Answer

Following are the step for cube testing :

1. Cube Casting :

i. Measure the dry proportion of ingredients (cement, sand and coarse aggregate) as per the design requirements. The ingredients should be sufficient enough to cast test cubes.

ii. Thoroughly mix the dry ingredients to obtain the uniform mixture.

iii. Add design quantity of water to the dry proportion (water-cement ratio) and mix well to obtain uniform texture.

iv. Fill the concrete to the mould with the help of vibrator for thorough compaction.

v. Finish the top of the concrete by trowel and tapped well till the cement slurry comes to the top of the cubes.

2. Curing :

i. After some time the mould should be covered with red gunny bag and put undisturbed for 24 hours at a temperature of (21 ± 2) °C.

ii. After 24 hours remove the specimen from the mould.

iii. Keep the specimen submerged under fresh water at 27 °C. The specimen should be kept for 7 or 28 days. Every 7 days the water should be renewed.

iv. The specimen should be removed from the water 30 minutes prior to the testing.

v. The specimen should be in dry condition before conducting the testing.

vi. The cube weight should not be less than 8.1 kg.

3. Testing :

i. Now place the concrete cubes into the testing machine (centrally).

ii. The cubes should be placed correctly on the machine plate (check the circle marks on the machine). Carefully align the specimen with the spherically seated plate.

iii. The load will be applied to the specimen axially.

iv. Now slowly apply the load at the rate of 140 kg/cm^2 per minute till the cube collapse.

v. The maximum load at which the specimen breaks is taken as a compressive load.

4. Calculation : Compressive Strength of concrete = Maximum compressive load / Cross sectional area.

Que 4.20. Describe the non destructive testing of hardened concrete.

Answer

Non-Destructive Tests on Concrete : The main non-destructive tests for strength on hardened concrete are as follows :

1. Rebound Hammer (Hardness) Test :

i. The Schmidt hammer is used in the rebound hardness test in which a metal hammer held against the concrete is struck by another spring-driven metal mass and rebounds.

ii. The amount of rebound is recorded on a scale and this gives an indication of the concrete strength.

iii. The larger the rebound number is, the higher is the concrete strength.

2. Ultrasonic Pulse Velocity Test :

i. In the ultrasonic pulse velocity test the velocity of ultrasonic pulses that pass through a concrete section from a transmitter to a receiver is measured.

ii. The pulse velocity is correlated against strength.

iii. The higher the velocity is, the stronger is the concrete.

3. Pull Out Test :

i. The pull out test will determine the force that is required to pull out a steel rod specially shaped from hardened concrete to which the steel was cast.

ii. Pulling out of steel is done with a cone of concrete that have a slope of 45°.

iii. The force required to pull the concrete out is related with the compressive strength of the concrete.

4. Penetration Resistance Test :

i. Penetration resistance tests on concrete offers a means of determining relative strengths of concrete in the same structure or relative strength of different structures.

ii. Because of nature of equipments, it cannot be expected to yield absolute values of strength.

Que 4.21. What are the requirements of non destructive testing of concrete ? Also give their advantages and disadvantages.

Answer

A. Requirement of Non Destructive Test : Following are the requirement of NDT :

1. Assessment of existing structures in the absence of drawings.
2. Quick assessment of the structure.
3. Quality control of construction, in situ.
4. Determining position of reinforcement.
5. Location of cracks/joints/honeycombing.
6. In some cases, it required to assess of concrete damaged due to fire or any other natural calamity due judge the condition of structure.

B. Advantages : Following are the advantages of non destructive testing :

1. Access to hidden items - “see through walls”.
2. Better investigations with NDT.
3. Rapid and on site accumulation of data.
4. Generally less expensive than destructive testing.
5. Gives result without structural damage.

C. Disadvantages : Following are the disadvantages of non destructive testing :

1. More than one test method may be required.
2. Environmental conditions may affect or distort results.
3. Construction details and building components may affect results.
4. Some conditions cannot be determined with a reasonable degree of accuracy without destructive testing.

Que 4.22. What is modulus of elasticity of concrete ? With the help of stress-strain curve, describe the various types of modulus of elasticity ?

Answer

A. Modulus of Elasticity of Concrete : It is defined as the slope of the line drawn from a stress of zero to a compressive stress of 0.45 f_c.

B. Types of Modulus of Elasticity :

1. **Initial Tangent Modulus :** It is given by the slope of a line drawn tangent to the stress-strain curve at the origin. It is used to characterize concrete deflection at very low stresses.

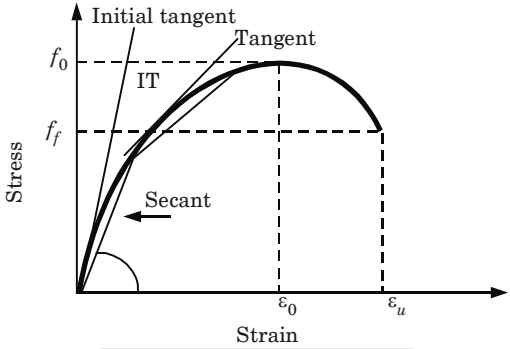


Fig. 4.22.1. Stress-strain plot.

2. **Tangent Modulus :** It is given by the slope of a line drawn tangent to the stress-strain curve at any point on the curve. It is used to simulate the structure to loading or unloading at different unloading stages.

3. **Secant Modulus :** It is given by the slope of a line drawn from the origin to a point on the curve corresponding to a 40 % stress of the failure stress. It is used to simulate the structure during its initial loading stage when permanent load prevail.

PART-4

Mechanical Properties of Concrete : Elastic Modulus, Poisson's Ratio, Creep, Shrinkage and Durability of Concrete.

CONCEPT OUTLINE : PART-4

Mechanical Properties of Concrete : Following are the mechanical properties of concrete :

1. Modulus of elasticity.
2. Creep.
3. Shrinkage.
4. Poisson's ratio.
5. Durability.

Modulus of Elasticity : It is the ratio of the applied stress to the corresponding strain with in elastic limit.

$$E = 5000\sqrt{f_{ck}}$$

Types of Modulus of Elasticity :

1. Initial tangent modulus of elasticity.
2. Tangent modulus of elasticity.
3. Secant modulus of elasticity.

Creep : It can be defined as the elastic and long term deformation of concrete under a continuous load.

Shrinkage of Concrete : The volumetric change of concrete structure due to loss of moisture by evaporation is known as shrinkage of concrete. It is a time dependent deformation which reduces the volume of concrete without the impact of external forces.

Types of Shrinkage :

1. Drying shrinkage.
2. Plastic shrinkage.
3. Carbonation shrinkage.
4. Autogenous shrinkage.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 4.23. What are the affecting factors of modulus of elasticity of concrete ?

Answer

Following are the factor affecting the modulus of elasticity of concrete :

1. **Coarse Aggregate Properties :** Coarse aggregate properties like elastic modulus of aggregate, type of aggregate (crushed or natural), petrology and mineralogy, and quantity of aggregate. The higher the volume of aggregate in the mix, the higher the elastic modulus.
2. **Mix Design :** Mix design includes total cementitious content and w/c ratio. Less paste is good for higher elastic modulus.
3. **Curing Conditions :** Moist cured specimen showed better results than that of dry cured, due to shrinkage and associated cracks.
4. **Loading Rate :** High loading rate will result in higher compressive strength and higher elastic modulus.
5. **Chemical Admixture :** It does not have much influence on elastic modulus. But some type of admixture can produce higher cement

dispersion and thus will result in higher compressive strength and elastic modulus.

6. **Mineral Admixture :** Mineral admixture as they affect the strength of concrete, they affect the elastic modulus too.

Que 4.24. Discuss the relationship between modulus of elasticity and strength concrete.

Answer

Relation between Modulus of Elasticity and Strength of Concrete :

1. Modulus of elasticity of concrete is a key factor for estimating the deformation of structural elements, as well as a fundamental factor for determining modular ratio, n, which is used for the design of structural members subjected to flexure.
2. The modulus of elasticity of concrete is directly proportional to the square root of characteristic compressive strength in the range of normal concrete strength,
3. The IS 456 : 2000 gives the modulus of elasticity of concrete as :

$$E_c = 5000\sqrt{f_{ck}}$$

where, E = Modulus of elasticity.

f_{ck} = Characteristic strength of concrete.

Que 4.25. Explain the procedure for determining the dynamic modulus of elasticity using ultrasonic pulse velocity equipment.

Answer

Test for Determining Dynamic Modulus of Elasticity :

1. In this method pulses of compression waves are generated by an electro-acoustical transducer that is held in contact with one surface of the prismatic or cylindrical concrete specimen.
2. After traversing through the concrete, the pulses are received and converted into electrical energy by a second transducer located at a distance L from the transmitting transducer.
3. The pulse velocity $V = L/T$ is related to the physical properties of a solid by the eq. (4.25.1)

$$V^2 = (K)\frac{E_d}{\rho} \text{ or } E_d = \frac{\rho V^2}{K} \quad ...(4.25.1)$$

where, L = Distance between transducers, m

T = Transit time, seconds

E_d = Dynamic modulus of elasticity, Pa (N/m^2)

V = Pulse velocity, m/sec
ρ = Mass density, kg/m^3
K = 1 (for a cylindrical specimen).

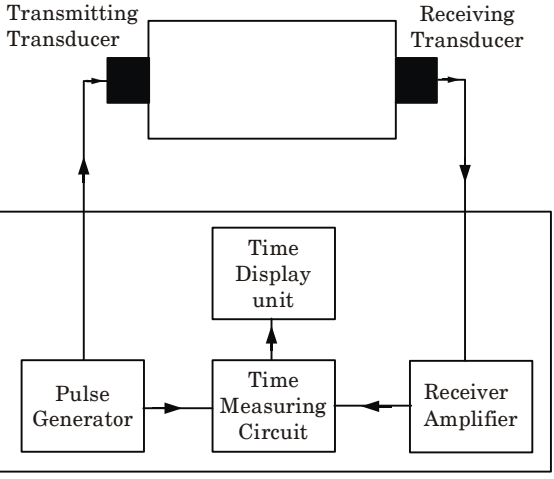


Fig. 4.25.1. Schematic of pulse velocity circuit

Que 4.26. What is creep ? What are the factors influencing creep of concrete ?

Answer

Creep :

1. When concrete is subjected to compressive loading it deforms instantaneously. This immediate deformation is called instantaneous strain. Now, if the load is maintained for a considerable period of time, concrete undergoes additional deformations even without any increase in the load. This time-dependent strain is termed as creep.

Factor Affecting Creep : Following are the factors affecting creep of concrete :

1. Concrete Mix Proportion :

i. Creep increases with increase in water/cement ratio.

ii. A poorer paste structure undergoes higher creep.

iii. The amount of paste content and its quality is one of the most important factors influencing creep.

iv. Creep is inversely proportional to the strength of concrete.

2. Aggregate Properties :

i. Light weight aggregate shows substantially higher creep than normal weight aggregate.

ii. The higher the modulus of elasticity the less is the creep.

iii. Aggregates influence creep of concrete through a restraining effect on the magnitude of creep.

3. Age at Loading :

i. Age at which a concrete member is loaded will have a predominant effect on the magnitude of creep.

ii. The moisture content of the concrete being different at different age also influences the magnitude of creep.

4. Curing Condition : Larger the curing smaller the creep.

5. Cement Properties :

i. The type of cement effects creep in so far as it influences the strength of the concrete at the time of application of load.

ii. Fineness of cement affects the strength development at early ages and thus influences creep.

iii. The finer the cement the higher its gypsum requirement so that re grinding of cement in laboratory without the addition of gypsum produces an improperly retarded cement, which exhibits high creep.

6 Temperature :

i. The rate of creep increases with temperature up to about 70 °C when, for a 1:7 mix and 0.6 w/c ratio. It is approximately 3.5 times higher than at 21 °C.

ii. Between 70 °C and 96 °C it drops off to 1.7 times than at 21 °C.

iii. As far as low temperature is concerned, freezing produces a higher initial rate of creep but it quickly drops to zero.

iv. At temperature between 10 °C and 30 °C, creep is about one half of creep at 21 °C.

7. Stress Level :

i. Higher the stress higher will be the creep.

ii. There is no lower limit of proportionality because concrete undergoes creep even at very low stress.

Que 4.27. What is the effect of creep on concrete structures ?

Answer

Effects of Creep on Concrete Structures :

1. In reinforced concrete beams, creep increases the deflection with time and may be a critical consideration in design.
2. In eccentrically loaded columns, creep increases the deflection and can lead to buckling.
3. Loss of prestress due to creep of concrete in prestressed concrete structure.

4. Creep property of concrete will be useful in all concrete structures to reduce the internal stresses due to non-uniform load or restrained shrinkage.
5. In mass concrete structures such as dams, on account of differential temperature conditions at the interior and surface, creep is harmful and by itself may be a cause of cracking in the interior of dams.

Que 4.28. Explain how creep is measured ?

Answer

Calculating Creep of Concrete :

1. The creep strain-stress relation in concrete is commonly taken to be

$$\in_c = \phi \sigma$$

where ϕ is called the specific creep.

2. The concept of specific creep is useful for comparing the creep of different concrete specimens at different stress levels. A typical value of ϕ is approximately 150 μ /MPa, $\mu = 10^{-6}$.
3. Later the American Concrete Institute (ACI) has developed a simplified creep equation of the form :

$$\frac{\in_c}{\in_e} = \frac{t^{0.6}}{B + t^{0.6}} C_{ult}$$

where, t = Time.

B = Constant that depends on the age of the concrete before loading.

C_{ult} = Ultimate creep coefficient, $C_{ult} = 2.35$.

Que 4.29. What is shrinkage of concrete ? Explain about classification of shrinkage.

Answer

A. Shrinkage :

1. Shrinkage of concrete is the time-dependent strain measured in an unloaded and unrestrained specimen at constant temperature.
2. Shrinkage is shortening of concrete due to drying and is independent of applied loads.

B. Types of Shrinkage : Following are the various types of shrinkage :

1. Plastic Shrinkage :

i. Plastic shrinkage occurs very soon after pouring the concrete in the forms.

ii. The hydration of cement results in a reduction in the volume of concrete due to evaporation from the surface of concrete, which leads to cracking.

2. Drying Shrinkage :

i. The shrinkage that appears after the setting and hardening of the concrete mixture due to loss of capillary water is known as drying shrinkage.

ii. Drying shrinkage generally occurs in the first few months and decreases with time.

3. Carbonation Shrinkage :

i. Carbonation shrinkage occurs due to the reaction of carbon dioxide (CO_2) with the hydrated cement minerals, carbonating $Ca(OH)_2$ to $CaCO_3$.

ii. The carbonation slowly penetrates the outer surface of the concrete.

iii. This type of shrinkage mainly occurs at medium humidity and results increased strength and reduced permeability.

4. Autogenous Shrinkage :

i. Autogenous shrinkage occurs due to no moisture movement from concrete paste under constant temperature.

ii. It is a minor problem of concrete and can be ignored.

Que 4.30. What are the different factors affecting of shrinkage.

Answer

Affecting Factors of Shrinkage :

1. Drying Conditions :

i. The most important factor is the drying condition or the humidity in the atmosphere.

ii. No shrinkage will occur if the concrete is placed in one hundred percent relative humidity.

2. Time :

i. The shrinkage rate will decrease rapidly with time.

ii. It has been documented that 14 to 34 % of the 20 year shrinkage will occur within two weeks of it being poured.

iii. Within one year of the concrete being poured, shrinkage will be about 66 to 85 % of the 20 year shrinkage.

3. Water Cement Ratio :

i. The water to cement ratio will influence the amount of shrinkage that occurs.

ii. The concrete's richness also affects the shrinkage.

iii. The process of swelling and then drying affects the concrete's integrity and the shrinkage.

Que 4.31. What are the effect of shrinkage on concrete and how is it reduces ?

Answer

Effects of Shrinkage : Following are the effects of shrinkage on concrete :

1. Shrinkage of concrete between movement joints causes joints to open or makes it wider. Therefore joints must be designed to accommodate the widening caused by shrinkage.
2. Where other materials, such as ceramic tiles, are fixed on top of concrete surface, shrinkage of the concrete causes relative movement between the different materials. The resulting stresses can cause failure at the interface.
3. If shrinkage is restrained, the concrete is put into tension and when tensile stress becomes equal to tensile strength, the concrete cracks.
4. Shrinkage of the concrete causes the concrete to grip reinforcing bars more tightly. This increases friction between concrete and steel and so improves bond strength, especially for plain bars
5. The deflection of flexural members is increased by shrinkage. This is because the lightly reinforced compression zone is free to shrink more than heavily reinforced tension zone.
6. Shrinkage causes a reduction in pre stressing force.

Prevention of Shrinkage : Following are the measures to be taken to reduced shrinkage :

1. Provide sun shades in case of slab construction to control the surface temperature.
2. Dampen the subgrade of concrete before placement it is liable to water absorption but should not over damp.
3. Try to start the curing soon after finishing.
4. Use chemical admixtures to accelerate the setting time of concrete.

Que 4.32. What do you mean by Poisson's ratio of concrete.

Answer

Poisson's ratio :

1. It is determined as the ratio of lateral to longitudinal strain in compression test and may vary from 0.13 to 0.21.
2. The Poisson's ratio can also be determined from the fundamental resonant frequency of longitudinal vibration of concrete specimen using ultrasonic pulse velocity method.
3. The Poisson's ratio μ can be determined from

$$\left(\frac{v^2}{2nL}\right) = \frac{(1-\mu)}{(1-2\mu)(1+\mu)}$$

where, v = Pulse velocity, mm/sec

n = Resonant frequency of longitudinal vibration in Hz

L = Distance between transducers, mm

4. The value of Poisson's ratio as determined by dynamic tests is slightly higher and ranges from 0.20 to 0.25.

Que 4.33. Define durability of concrete. Discuss the factor affecting concrete durability.

Answer

Durability :

1. The durability of concrete is defined as its ability to resist weathering action, chemical attack, abrasion, or any other process of deterioration.
2. Durable concrete will retain its original form, quality, and serviceability when exposed to environment.

Factors Affecting Durability : Following are the factors affecting the durability of concrete :

1. Physical Factors :

i. Temperature :

a. Unfavourable temperature conditions can lead to shrinkage cracks and volume changes.

b. Variation in temperature changes cause secondary stresses in structures.

ii. Moisture :

a. Moisture induces corrosion in steel. Moisture also acts as a carrier of chemicals inside the body of concrete.

b. Moisture can also cause efflorescence on structural surfaces.

c. Seepage / Leakages cause inconvenience to occupants and deteriorates structures due to permeable concrete.

iii. Freezing and Thawing : Leads to expansion of concrete and cracking.

2. Chemical Factors :

i. When we are dealing with durability, chemical attack which results in volume change, cracking and consequent deterioration of concrete become a major cause of concern.

ii. Ice-melting salts cause erosion of concrete.

3. Cement Content and w/c Ratio of Concrete : Volume change result in cracks and cracks are responsible for disintegration of concrete.

4. Workmanship : Batching, mixing, transportation, placing, compaction and curing require proper workmanship for a durable concrete.

5. Cover to Embedded Steel : (As per IS 456:2000)

i. For main reinforcement up to 12 mm dia bar for mild exposures, the nominal cover may be reduced by 5 mm

ii. Unless specified otherwise, actual concrete cover should not deviate from the required nominal cover by +10 mm.

6. Mineral Oil : usually effects only fresh concrete in their hardening process (petrol, petroleum distillates etc)

7. Organic acid has corrosive effect.

8. Vegetable and animal oils and fats cause deterioration of concrete surfaces due to their corrosive action.

9. Action of sugar has retarding effect on fresh concrete and has gradual corrosive effect on hardened concrete.

10. Action of Sewage : Concrete sewers running full remain unaffected; but in partially filled sewers where hydrogen sulphide gas is evolved and sulphuric acid is formed, concrete above sewage level gets affected due to corrosive action of such acids.

☺☺☺

5
UNIT

Specific Concretes

PART-1

Study and Uses of High Strength Concrete, Self Compacting Concrete.

CONCEPT OUTLINE : PART-1

High Strength Concrete : It has compressive strength of upto 100 MPa as against conventional concrete which has compressive strength of less than 50 MPa. Concrete having compressive strength greater than 200 MPa is classified as ultrahigh strength concrete.

Advantages of High Strength Concrete :

i. Superior durability and long term performance.
ii. Reduced maintenance cost.

Self Compacting Concrete : Fresh concrete can be made to flow without any external effort. Such a flowing concrete which compacts itself due to its own flowability is known as self compacting concrete.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.1. What do you understand by high strength concrete ? Write down its advantages and disadvantages.

Answer

A. High Strength Concrete : For mixtures made with normal-weight aggregates, high-strength concretes are considered to be those which have compressive strengths in excess of 40 MPa.

B. Advantages of HSC :

1. High compressive strength.
2. Increases rental space.
3. Reduces space occupied by columns.
4. Reduces dead load.
5. Reduces amount of steel.
6. High rise buildings can be build by reduced columns.
7. To use the concrete service at early age, e.g., pavement in 3 days

C. Disadvantages of HSC :

1. Must be expertise in selection of ingredients.
2. Damaged at high temperature *i.e.,* less resistance to fire.

Que 5.2. Discuss the guidelines to selection of materials for HSC.

Answer

1. For the higher target compressive strength of concrete, the maximum size of concrete selected should be small, so that the concrete can become more dense and compact and less void ratio.
2. Up to 70 MPa compressive strength can be produced with a good coarse aggregate of a maximum size ranging from 20 to 28 mm.
3. To produce 100 MPa compressive strength aggregate with a maximum size of 10 to 20 mm should be used.
4. Concretes with compressive strengths of over 125 MPa have been produced with 10 to 14 mm maximum size coarse aggregate.
5. Using supplementary cementitious materials, such as blast-furnace slag, fly ash and natural pozzolanas, not only reduces the production cost of concrete, but also addresses the slump loss problem.
6. The optimum substitution level is often determined by the loss in 12 or 24 hour strength that is considered acceptable, given climatic conditions or the minimum strength required.
7. While silica fume is usually not really necessary for compressive strengths under 70 MPa, most concrete mixtures contain it when higher strengths are specified.

Que 5.3. What are the various methods to achieve high strength in concrete ? Also discuss their applications.

Answer

A. Methods to Achieve High Strength in Concrete : Following are the special methods to achieve high strength in concrete :

1. **Seeding :** This involves adding a small percentage of finely ground, fully hydrated Portland cement to the fresh concrete mix. This method may not hold much promise.
2. **Revibration :** Controlled revibration removes all the defects like bleeding, water accumulates, plastic shrinkage, continuous capillary channels and increases the strength of concrete.
3. **High Speed Slurry Mixing :** This process involves the advance preparation of cement - water mixture which is then blended with aggregate to produce concrete.
4. **Use of Admixtures :** Use of water reducing agents are known to produce increased compressive strength.
5. **Sulphur Impregnation :** Satisfactory high strength concrete have been produced by impregnating low strength porous concrete by sulphur. The sulphur infiltrated concrete has given strength up to 58 MPa.

6. **Inhibition of Cracks :** If the propagation of cracks is inhibited, the strength will be higher. Concrete cubes made this way have yielded strength up to 105MPa.

B. Applications of High Strength Concrete :

1. High strength concrete is required in engineering projects that have concrete components that must resist high compressive loads.
2. High strength concrete is typically used in the erection of high-rise structures.
3. It has been used in components such as columns (especially on lower floors where the loads will be greatest), shear walls, and foundations.
4. High strengths are also occasionally used in bridge applications as well.
5. High strength concrete is occasionally used in the construction of highway bridges.
6. Use of HSC in column section decreases the column size.
7. Use of HSC in column decreases amount of steel required for same column.
8. In high rise building, use of HSC increases the floor area for rental purpose.
9. In bridges, use of HSC reduces the number of beams supporting the slab.

Que 5.4. What is self compacting concrete ? What are the properties, advantages and disadvantages of self compacting concrete ?

Answer

A. Self Compacting Concrete : It is defined as "a concrete that is able to flow under its own weight and completely fill the formwork, while maintaining homogeneity even in the presence of congested reinforcement, and then consolidate without the need for vibrating compaction".

B. Properties of SCC : In fresh state, SCC have the following properties :

1. **Filling Ability :** Flows easily at certain speed into formwork.
2. **Passing Ability :** Passes through reinforcement without blocking.
3. **Segregation Resistance :** The distribution of aggregate particles remains homogeneous in both vertical and horizontal direction.

C. Advantages of SCC : Following are the advantages of SCC :

1. A faster rate of placing, without vibration.
2. Improved pumpability.
3. Improved consolidation around reinforcement.
4. Reduced permeability.

5. Reduced wear and tear on forms from vibration.
6. Improves the quality, durability, and reliability of concrete structures due to better compaction and homogeneity of concrete.
7. Ease of placement results in cost savings through reduced equipment and labour requirement.
8. Less noise from vibrators and reduced danger from hand-arm vibration syndrome (HAVS).
9. Improves working conditions and productivity in construction industry.
10. Reduced construction period.
11. Elimination of problems associated with vibration.

D. Disadvantages of SCC : Following are the disadvantages of SCC :

1. More stringent requirements on the selection of materials.
2. Lack of globally accepted test standards and mix designs.
3. Costlier than conventional concrete based on concrete material cost (exception to placement cost).
4. Requires more trial batches at laboratory as well as at ready-mixed concrete plants.
5. More precise measurement and monitoring of the constituent materials.

Que 5.5. Explain the materials used for self compacting concrete. Also give its applications.

Answer

A. Material Required for SCC : Following are the various material required for making SCC :

1. Cement : Ordinary Portland cement of 43 or 53 grade can be used.

2. Aggregates : Well graded cubical or rounded aggregates are desirable.

3. Water Quality : Maintained same as reinforced concrete.

4. Chemical Admixtures : Super plasticizers particularly poly-carboxylated ethers are used in SCC.

5. Mineral Admixtures : Following are the mineral admixtures used is SCC :

i. **Fly Ash :** It improves the quality and durability of concrete.

ii. **GGBFS :** It improves rheological properties (semi-solid and liquid state).

iii. **Silica Fume :** It improves mechanical properties.

iv. **Stone Powder :** Finely crushed limestone, dolomite, granite may be added to increase powder content.

B. Application of SCC : Self compacting concrete is ideal to be used in the following applications :

1. It has been used in bridges and even on pre-cast sections.
2. Drilled shafts.
3. Column.
4. Earth retaining systems.
5. Areas with high concentration of rebar and pipes / conduits, etc.

Que 5.6. Compare the hardened properties of normal concrete and self compacting concrete.

Answer

Following are the comparison of properties between normal concrete and self compacting concrete :

1. **Compressive Strength :** The compressive strength of SCC when compared with normal concrete made for a particular strength is almost the same. The self-compacting property of SCC has very little effect on the strength of concrete.
2. **Tensile Strength :** A comparison between cylinders made of SCC and normal concrete of the same grade shows that there is no major difference between them.
3. **Bond Strength :** The pull-out test carried out to determine the bond strength of SCC indicates superior bond strength of SCC.
4. **Modulus of Elasticity :** The modulus of elasticity for SCC and for normal concrete is the same.
5. **Freeze-thaw Resistance :** The low-strength of SCC has less resistance to freeze and thaw conditions as compared with low-strength normal concrete.
6. **Creep :** SCC normally is more pasty as compared with normal concrete. So its creep is slightly higher.
7. **Durability :** Durability is slightly higher in SCC because of the elimination of errors which may occur during placing and compaction of normal concrete. SCC is likely to have less voids.
8. **Exposure to Fire :** SCC has a more compact microstructure. This can lead to high vapour pressure. So SCC has a higher risk of spalling when exposed to fire.

Que 5.7. Explain the tests used for flow properties of self compacting concrete.

Answer

Following are the various test that carried out on self compacting concrete is fresh state :

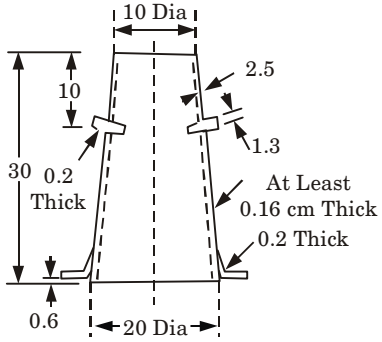
1. Slump Flow and T50 Test :

i. Slump flow test is used to find the filling ability of the SCC.

ii. The SCC sample is poured in to the slump cone then the slump flow diameter is measured.

iii. The flow time is measured and is known as T50 slump time.

iv. The higher the slump flow value, the greater its ability to fill formwork under its own weight.



(All dimension in cm)

Fig. 5.7.1.

2. L-Box Test :

i. The L-box test is used to find the passing ability of SCC.

ii. The SCC sample is poured in to the L-box apparatus, now the plate is removed to allow flow.

iii. The L-box ratio is calculated as H_2 / H_1.

iv. When the ratio of H_2 to H_1 is larger than 0.8, self compacting concrete has good passing ability.

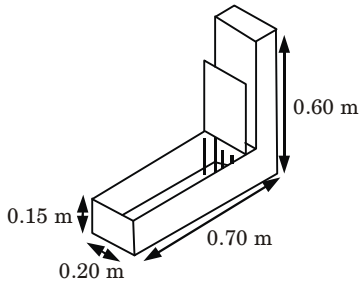


Fig. 5.7.2.

3. V-Funnel Test and V-Funnel Test at T-5 Minutes :

i. The V-funnel test is used to find the segregation resistance of SCC.

ii. The SCC sample is poured in to the V-funnel apparatus, now it's allowed to flow by its weight.

iii. The emptying time of V-funnel is noted.

iv. This test measured the ease of flow of the concrete, shorter flow times indicate greater flow ability. After 5 minutes of setting, segregation of concrete will show a less continuous flow with an increase in flow time

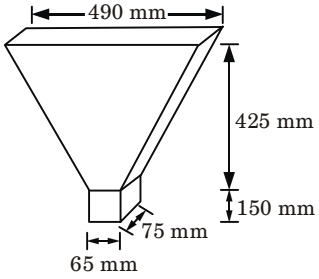


Fig. 5.7.3.

PART-2

Study and Uses of Fiber Reinforced Concrete, Ferro Cement.

CONCEPT OUTLINE : PART-2

Fiber Reinforced Concrete : They have improved tensile strength and toughness compared to conventional concrete. They also have improved energy absorption capacity. Advanced composites offer high tensile strength, durability, ductility, and preferred energy absorption capacity.

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

Material Used in Ferro Cement :

i. Cement mortar mix.
ii. Skeletal steel.
iii. Steel mesh reinforced.
iv. Fiber-reinforced polymeric meshes.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.8. What is the necessity fibre reinforced concrete and explain briefly the factors affecting properties of fibre reinforced concrete.

Answer

Necessity of Fiber Reinforced Concrete :

1. It increases the tensile strength of the concrete.
2. It reduces the air voids and water voids the inherent porosity of gel.
3. It increases the durability of the concrete.
4. Fibers such as graphite and glass have excellent resistance to creep, while the same is not true for most resins.
5. The differential deformations of concrete and the reinforcement are minimized.
6. It has been recognized that the addition of small, closely spaced and uniformly dispersed fibers to concrete would act as crack arrestor and would substantially improve its static and dynamic properties.

Factors Affecting the Properties of FRC : Following are the factors affecting the properties of fibre reinforced concrete :

1. Volume of Fiber :

i. Low volume fraction (< 1%) : Used in slab and pavement that have large exposed surface leading to high shrinkage cracking.

ii. Moderate volume fraction (between 1 and 2 %) : Used in construction method such as shotcrete and in structures which requires improved capacity against delamination, spalling and fatigue.

iii. High volume fraction (> 2 %) : Used in making high performance fiber reinforced composites.

2. Aspect Ratio of Fiber :

i. It is defined as ratio of length of fiber to its diameter (L/d).

ii. Increase in the aspect ratio upto 75, there is increase in relative strength and toughness.

iii. Beyond 75 of aspect ratio, there is decrease in strength and toughness.

3. Orientation of Fibers : Fibers aligned parallel to applied load offered more tensile strength and toughness than randomly distributed or perpendicular fibers.

4. Relative Fiber Matrix :

i. Modulus of elasticity of matrix must be less than of fibers for efficient stress transfer.

ii. Low modulus fibers like Nylons and Polypropylene imparts more energy absorption while high modulus fibers (Steel, Glass, and Carbon) imparts strength and stiffness.

5. **Workability and Compaction of Concrete :** Incorporation of steel fiber decreases the workability considerably. This situation adversely affects the consolidation of fresh mix. Even prolonged external vibration fails to compact the concrete.
6. **Size of Coarse Aggregate :** Fibers also act as aggregate maximum size of the coarse aggregate should be restricted to 10 mm, to avoid appreciable reduction in strength of the composite.
7. **Mixing :** Mixing of fiber reinforced concrete needs careful conditions to avoid balling of fibers, segregation and in general the difficulty of mixing the materials uniformly.

Que 5.9. Explain the various types of fiber used in fiber reinforcement concrete.

Answer

Types of Fiber : Following are the various types of fibers used in fiber reinforced concrete :

1. Steel Fiber :

i. Steel fiber is one of the most commonly used fiber. They are generally round. The diameter may vary from 0.25 mm to 0.75 mm.

ii. The steel fiber is likely to get rusted and lose some of its strength.

iii. Use of steel fiber makes significant improvements in flexural impact and fatigue strength of concrete.

iv. Steel fibers have been extensively used in overlays or roads pavements, air fields, bridge decks, thin shells and floorings subjected to wear and tear and chemical attack.

2. Glass Fiber :

i. These are produced in three basic forms :
   a. Rovings.
   b. Strands.
   c. Woven or chopped strand mat.

ii. Major problems in their use are breakage of fiber and the surface degradation of glass by high alkalinity of the hydrated cement paste.

iii. Glass fiber reinforced concrete (GFRC) is mostly used for decorative application rather than structural purposes.

iv. With the addition of just 5 % glass fibers, an improvement in the impact strength of up to 1500 % can be obtained as compared to plain concrete.

v. With the addition of 2 % fibers the flexural strength is almost doubled.

3. Plastic Fiber :

i. Fibers such as polypropylene, nylon, acrylic, aramid and polyethylene have high tensile strength thus inhibiting reinforcing effect.

ii. Polypropylene and nylon fibers are found to be suitable to increase the impact strength.

iii. Their addition to concrete has shown better distribute cracking and reduced crack size.

4. Carbon Fiber :

i. Carbon fibers possess high tensile strength and high young's modulus.

ii. The use of carbon fiber in concrete is promising but is costly and availability of carbon fiber in India is limited.

5. Asbestos Fiber :

i. Asbestos is a mineral fiber and has proved to be most successful fiber, which can be mixed with OPC.

ii. The maximum length of asbestos fiber is 10 mm but generally fibers are shorter than this

Que 5.10. What are the advantages and disadvantages of using fiber reinforced concrete ?

Answer

Advantages of FRC : Following are the advantages of FRC :

1. FRC possesses enough plasticity to go under large deformation once the peak load has been reached.
2. Structure can be made into thin sheets or irregular shapes.
3. Higher flexural strength, depending on addition rate.
4. Greater retained toughness in conventional concrete mixes.
5. Easily placed, cast, sprayed and less labour intensive than placing rebar.
6. Ideal aspect ratio which makes them excellent for early-age performance.
7. Does not rust nor corrode and requires no minimum cover.
8. High modulus of elasticity for effective long term reinforcement, even in the hardened concrete.

Disadvantages of FRC : Following are the disadvantages of FRC :

1. High cost of materials.
2. Greater reduction of workability.
3. Generally fibers do not increase the flexural strength of concrete, and so cannot replace moment resisting or structural steel reinforcement.

Que 5.11. Explain the mechanical properties of FRC as compared to reinforced concrete and structural behaviour of FRC.

Answer

A. Mechanical Properties of FRC : Following are the mechanical properties of FRC :

1. **Flexure :** The flexural strength was reported to be increased by 2.5 times using 4 percent fibers.
2. **Modulus of Elasticity :** Modulus of elasticity of FRC increases slightly with an increase in the fibers content. It was found that for each 1 percent increase in fiber content by volume, there is an increase of 3 percent in the modulus of elasticity.
3. **Compressive Strength :** The presence of fibers may alter the failure mode of cylinders, but the fiber effect will be minor on the improvement of compressive strength values (0 to 15 percent).
4. **Impact Resistance :** The impact strength for fibrous concrete is generally 5 to 10 times that of plain concrete depending on the volume of fiber.
5. **Fatigue Strength :** The addition of fibers increases fatigue strength of about 90 percent.
6. **Toughness :** For FRC, toughness is about 10 to 40 times that of plain concrete.
7. **Splitting Tensile Strength :** The presence of 3 percent fiber by volume was reported to increase the splitting tensile strength of mortar about 2.5 times that of the unreinforced one.

B. Structural behaviour of FRC : Fibres plays an important role to improving the structural behaviour of concrete. Following are the structural behaviour of FRC :

1. **High Strength Concrete :** Fibers increases the ductility of high strength concrete. Fiber addition will help in controlling cracks and deflections.
2. **Torsion :**

i. The use of fibers eliminates the sudden failure characteristic of plain concrete beams.

ii. It increases stiffness, torsional strength, ductility, rotational capacity, and the number of cracks with less crack width.

3. **Flexure :**

i. The use of fibers in reinforced concrete flexure members increases ductility, tensile strength, moment capacity, and stiffness.

ii. The fibers improve crack control and preserve post cracking structural integrity of members.

4. **Cracking and Deflection :**

i. Fiber reinforcement effectively controls cracking and deflection, in addition to strength improvement.

ii. In conventionally reinforced concrete beams, fiber addition increases stiffness, and reduces deflection.

5. **Column :**

i. The increase of fiber content slightly increases the ductility of axially loaded specimen.

ii. The use of fibers helps in reducing the explosive type failure for columns.

6. Shear :

i. Addition of fibers increases shear capacity of reinforced concrete beams up to 100 percent.

ii. Addition of randomly distributed fibers increases shear-friction strength and ultimate strength

Que 5.12. Explain the use of fiber reinforced concrete.

Answer

Following are the uses of fiber reinforced concrete :

1. Runway, Aircraft Parking, and Pavements :

i. For the same wheel load FRC slabs could be about one half the thickness of plain concrete slab.

ii. FRC pavements offer good resistance even in severe and mild environments.

iii. It can be used in runways, taxiways, aprons, seawalls, dock areas, parking and loading ramps.

2. Tunnel Lining and Slope Stabilization :

i. Steel fiber reinforced concrete is used to line underground openings and rock slope stabilization.

ii. It eliminates the need for mesh reinforcement and scaffolding.

3. Dams and Hydraulic Structure : FRC is being used for the construction and repair of dams and other hydraulic structures to provide resistance to cavitation and severe erosion caused by the impact of large debris.

4. Thin Shell, Walls, Pipes, and Manholes :

i. Fibrous concrete permits the use of thinner flat and curved structural elements.

ii. Steel fibrous shotcrete is used in the construction of hemispherical domes.

5. Agriculture: It is used in animal storage structures, walls, silos, paving, etc.

6. Precast Concrete and Products : It is used in architectural panels, tilt-up construction, walls, fencing, septic tanks, grease trap structures, vaults and sculptures.

7. Commercial : It is used for exterior and interior floors, slabs and parking areas, roadways, etc.

8. Warehouse / Industrial : It is used in light to heavy duty loaded floors.

9. Residential : It includes application in driveways, sidewalks, pool construction, basements, colored concrete, foundations, drainage, etc.

Que 5.13. **Define ferro cement. What are the advantages and disadvantages of ferro cement ?**

Answer

Ferro Cement : It is a type of thin wall reinforced concrete commonly constructed of hydraulic cement mortar reinforced with closely spaced layers of continuous and relatively small size wire mesh.

Advantages of Ferro-Cement :

1. Low maintenance costs.
2. Good impermeability.
3. Good fire resistance.
4. Very appropriate for developing countries; labour intensive.
5. Flexibility in cutting, drilling and jointing.
6. Suitability for pre-casting.
7. 20 % savings on materials and cost.
8. It is highly versatile and can be formed into almost any shape for a wide range of uses.
9. Thin elements and light structures, reduction in self weight and its simple techniques require a minimum of skilled labor.
10. Reduction in expensive form work so economy and speed can be achieved.
11. Only a few simple hand tools are needed to build any structures.
12. Structures are highly waterproof and higher strength to weight ratio than R.C.C.

Disadvantages of Ferro-Cement :

1. Tying rods and mesh together is especially tedious and time consuming.
2. Large number of labours required.
3. It is difficult to fasten to ferro cement with bolt, screw, welding and nail etc.
4. Corrosion of the reinforcing material due to the incomplete coverage of metal by mortar.
5. It can be punctured by collision with pointed objects.
6. Susceptibility to stress rupture failure.
7. Low ductility.
8. Low shear strength.

Que 5.14. **Explain in detail the materials which are required to make ferro cement concrete.**

Answer

Following are the materials required for making ferro cement :

1. Cement Mortar Mix :

i. Its components are Portland cement, fine aggregates, water, and admixtures.

ii. Material should satisfy all requisite standards similar to reinforced concrete.

ii. Additives such as superplasticizers, silica fumes, and fly ash can also be used.

2. Skeletal steel :

i. To from the skeleton of the structures, steel is often used in ferro-cement in the form of welded wires or a simple gird of steel wires, rods, or strands.

ii. Mesh layers are attached around this skeleton steel. The steel also acts as a spacer, leading to savings is the mesh layer.

iii. It helps in resisting tensile and punching shear.

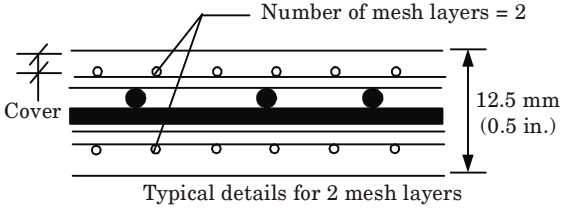


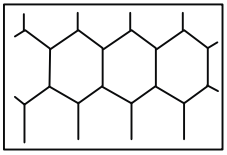
Fig. 5.14.1. Skeletal steel.

3. Steel Mesh Reinforcement :

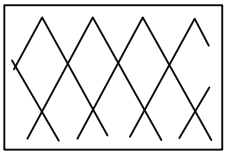
i. Steel meshes are the primary reinforcement for ferro cement.

ii. The meshes can be square woven or welded, or chicken wire meshes of hexagonal shape and sheet

iii. In most steel meshes, whether woven or welded, the properties in the longitudinal and transverse directions are different. This is also applicable for hexagonal and expanded meshes.



Chicken or hexagonal wire mesh
(a)



Expanded metal mesh
(b)

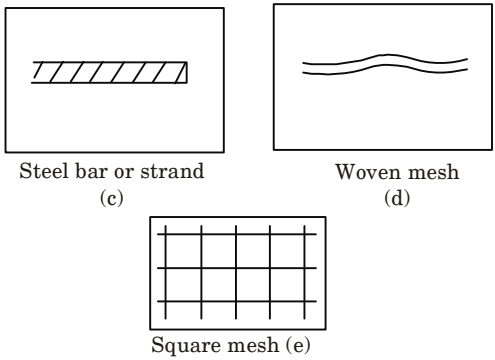


Fig. 5.14.2. Steel meshed used in ferro cement.

4. Fiber Reinforced Polymeric Meshes :

i. Steel reinforcement has poor durability and is susceptible to corrosion. Fiber reinforced polymer is the best alternative to steel meshes.

ii. FRP reinforcements made from carbon, glass, aramid, or other high-performance materials embedded in polymeric matrices in the form of bars, tendons, and strands are being produced and used these days.

Que 5.15. Explain the various methods of manufacturing of ferro cement with their merits and demerits.

Answer

Method of Ferro Cement : Following are the various construction methods of ferro cement :

1. Skeletal Method :

i. In this method a framework of reinforcing bars (skeletal steel) is constructed, to which a layer of meshes is applied Fig. 5.15.1.

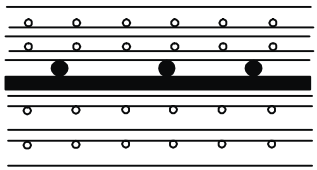


Fig. 5.15.1. Skeletal armature method.

ii. Next, mortar is applied on one side and forced through the mesh until a slight excess appears on the other side.

Advantages : Following are the advantages of the skeletal armature method :

i. No elaborate form material required.

ii. Easy to patch up (repair) the whole area from both sides.

iii. Good penetration.

iv. Easy to repair when damaged.

Disadvantages : Following are the disadvantages of the skeletal armature method:

i. Application of mortar from one side may be difficult for a thick mesh system

ii. Galvanic corrosion may develop between the mesh and skeletal steel

iii. Embedment of skeletal reinforcement near the centre of the section leads to reduced performance in bending

2. Closed Mould Method :

i. In this method, several mesh or mesh-and-rod combination are held together in position against the surface of a mould (Fig. 5.15.2).

ii. Mortar is then applied from the open side. The mould either remains a permanent part of the structure or can be removed and reused.

iii. In this method, a thin layer of mortar is placed first and allowed to settle, over which the mesh is placed and the second layer of mortar poured. This procedure is repeated until the required number of layer are placed.

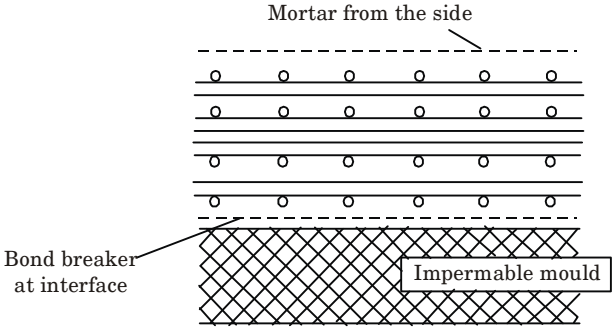


Fig. 5.15.2. Closed mould method.

Advantages : Following are the advantages of the closed mould method :

i. Ideal for factory production since the reuse of moulds is permitted.

ii. Skeletal reinforcement not required.

iii. Suitable for patented lay-up method.

Disadvantages : Following are the disadvantages of the closed mould method :

i. Difficult to avoid internal voids, especially below reinforcement mesh.

ii. Complete penetration of mortar from one side may not be possible.

3. Integral Mould Method :

i. This method involves a semi-rigid framework, Fig. 5.15.3. An integral mould may be formed using foam material such as polystyrene or polyurethane as the core.

ii. Mortar is poured from both sides of the mould. The mould is left inside the ferro cement itself. This method is ideal for field operation.

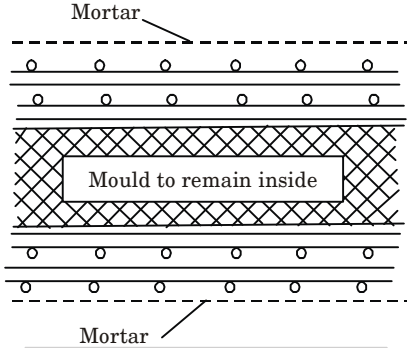


Fig. 5.15.3. Integral mould method.

Advantages : Following are the advantages of the integral mould method :

i. Provides good rigidity.

ii. Provides good water-tightness.

iii. Provides thermal insulation.

Disadvantages : Following are the disadvantages of the integral mould method :

i. Special detailing is required for adequate shear connections between rigid ferro cement layers, especially across insulating cores.

ii. Both the sides need to be finished.

4. Open Mould Method :

i. The open mould method is a traditional method used for boat building.

ii. The open mould is made of lattice wood or some other suitable material and stiffened by ribs.

iii. The mortar is applied through one side only.

iv. To facilitate mould removal, the mould is covered with a release agent or entirely covered with polyethylene sheets. Fig. 5.15.4 illustrated the open mould method.

Advantages : Following are the advantages of the open mould method :

i. No skeletal reinforcement is required.

ii. Better control of finishes than the closed mould method.

iii. Moulds can be reused.

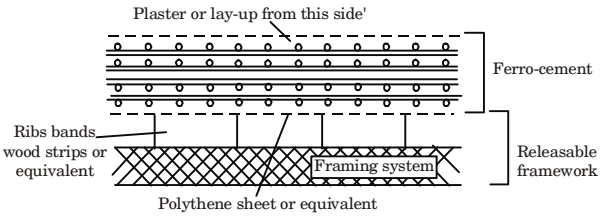


Fig. 5.15.4. Open mould method.

Disadvantages : Following are the disadvantages of the open mould method :

i. Framing and shoring system is costly.

ii. Complete penetration from one side is not guaranteed.

iii. Amenable for any shape.

Que 5.16. Explain the behaviour of ferro cement under tension.

Answer

Behaviour of Ferro Cement in Tension :

1. The typical load elongation curve for reinforced concrete prism and ferro cement prism is shown in Fig. 5.16.1 (a) and (b), respectively.

2. The behaviour is mainly divided into three main stages :

i. Stage I : Corresponds to the ascending linear elastic portion of the curve (OA).

ii. Stage II : Corresponds to the unstable portion (AB) where cracking starts and stabilizes.

iii. Stage III : Where is load elongation is almost linear elastic and the crack width increase with an increase in applied load because of cracking. This stage exists until the reinforcing steel yields. There will be only a few wide cracks across the steel.

3. From Fig. 5.16.1, the main difference lies in unstable stage II (AB).

4. Slowly adapts to the increasing load by increasing its extensibility. Many fine cracks form. When cracks form, the increase in crack width is small compared to reinforced concrete.

5. Crack width in ferro cement can be one to two orders of magnitude smaller than that of reinforced concrete. However, there are a number of fine cracks.

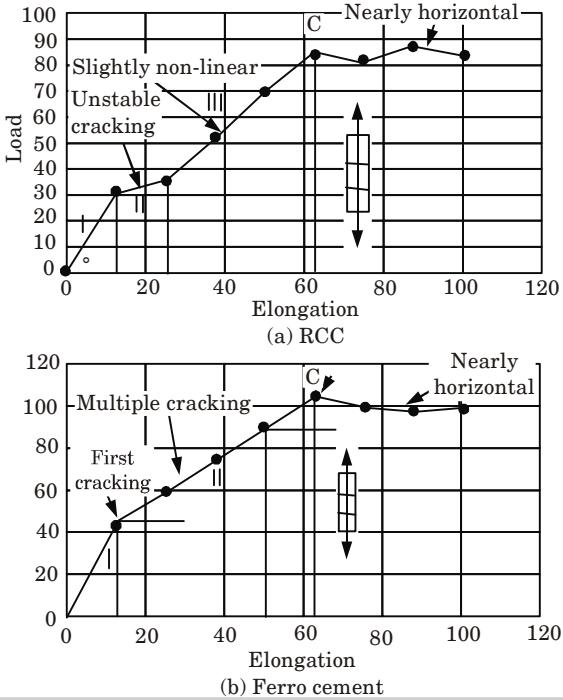


Fig. 5.16.1. Behaviour of (a) RCC compared with that of (b) ferro cement.

Que 5.17. Explain the various application of ferro cement.

Answer

Following are the various applications of ferro cement :

1. Marine Applications :

i. Ferro cement is used for making boats, fishing vessels, barges, cargo tugs, flotation buoys.

ii. Key criteria for marine applications: light weight, impact resistance, thickness and water tightness.

2. Water Supply and Sanitation : Water tanks, sedimentation tanks, swimming pool linings, well casings, septic tanks etc.

3. Agricultural : Grain storage bins, silos, canal linings, pipes, shells for fish and poultry farms.

4. Residential Buildings : Houses, community centers, precast housing elements, corrugated roofing sheets, wall panels etc.

5. **Rural Energy :** Biogas digesters, biogas holders, incinerators, panels for solar energy collectors etc.
6. **Miscellaneous Uses :** Silos and bins, Wind tunnel , Kiosks , Mobile homes, Precast ferro cement structures, soil stabilization ,pedestrian bridges , Bus shelters etc.

Que 5.18. What are the major differences between ferro cement and reinforced concrete ?

Answer

Following are the properties of ferro cement over reinforced concrete :

1. Reinforcement distribution is uniform throughout.
2. Reinforcement is provided in both directions.
3. Thinner section compared to RCC.
4. Ferro cement can have homogeneous, isotropic properties in two directions.
5. Ferro cement generally has high tensile strength and a high modulus of rupture. Its tensile strength can be of the same order as its compressive strength.
6. Ferro cement generally has a high reinforcement ratio in both tension and compression and in both directions.
7. Ferro cement has a large specific surface of reinforcement, which is one to two orders of magnitude that of reinforced concrete.
8. Extensibility of ferro cement is large in comparison of reinforced concrete.
9. The crack widths are generally very small. It shows good durability under various kinds of environmental exposure.
10. Ferro cement has better resistance towards punching shear as well as resistance to impact compared to reinforced concrete.

PART-3

Study and Uses of Ready Mix Concrete, Recycled Aggregate Concrete and Status in India.

CONCEPT OUTLINE : PART-3

Ready Mixed Concrete (RMC) : It is a specialized material in which cement, aggregate, and other ingredients are weigh batched at a plant in a central or truck mixer before delivery to the construction site.

Recycled Aggregate Concrete : The reuse of broken concrete pieces as coarse aggregate is a proven technology. Old concrete can be crushed and used in fresh concrete as partial replacement for conventional natural aggregates. The old concrete can be from demolition waste or left over concrete at a construction site.

Questions-Answers

Long Answer Type and Medium Answer Type Questions

Que 5.19. Define ready mix concrete. What are the advantages and disadvantages of using ready mixed concrete instead of site mixed concrete ?

Answer

1. **Ready Mix Concrete :** Ready mixed concrete is defined as concrete mixed in a stationary mixer in a central batching and mixing plant or in a truck mixer and supplied in a fresh condition to the purchaser either at site or into purchaser's vehicle.

2. **Advantages of RMC :** Following are the advantages of ready mix concrete :

i. Better quality concrete is produced.
ii. Elimination of storage space for basic materials at site.
iii. Elimination of hiring plant and machinery.
iv. Wastage of basic materials is avoided.
v. Labour associated with production of concrete is eliminated.
vi. Time required is greatly reduced.
vii. Noise and dust pollution at site is reduced.
viii. No wastage on site.
ix. Environment friendly.

2. **Disadvantages of RMC :** Following are the disadvantages of RMC :

i. Need huge initial investment.
ii. Not affordable for small projects (small quantity of concrete).
iii. Needs effective transportation system from RMC to project site.
iv. Traffic jam or failure of the vehicle creates a problem if the proper dose of admixture is not given.
v. Concrete's limited time span between mixing and going-off means that ready-mix should be placed within 90 minutes of batching at the plant.

Que 5.20. Explain the components of RMC plant in brief.

Answer

Components of RMC Plant : Following are the components of RMC plants :

1. Batching Plant:

i. Inline Bins : Raw materials like fine and coarse aggregates are stored in bins known as "Inlines bins" where the trucks carrying fine and coarse aggregate can dump the material easily.

ii. Silos : Cement and fly ash are stored in an airtight container called as "silos". The required quantity of cement and fly ash is extracted by the silos.

iii. Screw Conveyer Belt :

i. Cement and fly ash are fed to holding hopper with the help of a screw conveyer.

ii. A heavy duty cement screw conveyor is fixed in an inclined position to convey the cement from manual feeding hopper to cement hopper.

2. Transit Mixers :

i. Transit mixers are made to transport and mix concrete up to the construction site.

ii. The discharge of concrete is done from rear side of the transit mixer.

3. Concrete Pumps : A concrete pump is a machine used for transferring liquid concrete by pumping.

4. Vibrator : A vibrator is a mechanical device to generate vibrations to remove the air voids in concrete and for proper compaction of concrete.

Que 5.21. What are the applications of ready mixed concrete ?

Answer

Following are the applications of RMC :

1. Ready mix concrete is a modern technique of production of concrete in large quantities away from the actual site of placing.
2. RMC is very useful in cities where demand of concrete is very high and construction sites are in congested areas, where mixing on site is not possible.
3. The supervisory and labour costs associated with production of RMC is less, and the quality of concrete is high.
4. RMC is suitable for huge industrial and residential projects where time plays a vital role.

5. RMC is used for civil engineering works and structures such as bridge, tunnel covered trenches, concrete for retainment, shotcrete, etc.
6. RMC is used for building projects such as walls, piles, columns, girders etc.
7. RMC is used for road and systems development such as extruded concrete, concrete trenches, exposed aggregate concrete, linked sintered concrete.

Que 5.22. **Describe the comparison of ready mix concrete and normal site mixing concrete.**

Answer

Comparison between Ready Mix Concrete & Site Mix Concrete :

S. No.	Ready Mix Concrete	Site Mix Concrete
1.	Quality is consistent because concrete is made in high tech batching plants in a computerized environment.	Quality is inconsistent because concrete is hand mixed.
2.	Construction in double quick time.	Manual mixing is time consuming. Projects take longer time to finish.
3.	There's no worry about to stock materials and watch over them.	Risk of stealing of raw materials is high.
4.	Large quantities of concrete can be ordered in less time.	It more time, due to large manual works.
5.	No wastage of raw materials at site.	High wastage of raw materials due to manual mixing.
6.	No hassle of managing labour on site.	Management of labour means more time, efforts and money.
7.	Safe work practices - no disruption in the schedule.	Unskilled and untrained labourers may work carelessly resulting in dangerous working condition

Que 5.23. **Explain recycled aggregate concrete. Describe the various properties of recycled aggregate concrete.**

Answer

Recycled Aggregate Concrete :

1. Recycled aggregate concrete is simply the old aggregate concrete that has been removed from buildings foundations pavements and others structures, and crushed to the specified size.
2. The reuse of broken concrete pieces as coarse aggregate is a proven technology. Old concrete can be crushed and used in fresh concrete as partial replacement for conventional natural aggregates.
3. The old concrete can be from demolition waste (recycled concrete aggregate) or leftover concrete at a construction site (leftover concrete aggregate).
4. The fresh concrete leftover at a site can also be washed free of cement paste and the aggregates recovered to be used subsequently (recovered concrete aggregate).
5. Waste materials from other industries (e.g. broken glass pieces) can be used as secondary aggregates.

Properties of Recycled Aggregate Concrete :

1. The concrete produced with recycled aggregate losses its workability more rapidly than the conventional concrete.
2. If both fine and coarse aggregates are recycled aggregates, around 15 per cent more free water is required.
3. An air entraining and water reducing admixture shall be incorporated into fresh recycled aggregate concrete mix.
4. The air content of recycled aggregate concrete may be slightly higher than that of conventional aggregate concretes, it shall be between 3 and 6 per cent.
5. The slump of recycled coarse aggregate concrete shall not exceed 200 mm.
6. Water-cement ratio shall not exceed 0.65. Cement content shall not be less than 260 kg/m^3.
7. To achieve comparable strength, recycled aggregate concretes requires approximately 8 to 15 per cent higher cement contents.
8. The compressive strength of recycled segregate concrete is in the range of about 75 per cent, and the modulus of elasticity about 65 per cent of conventional concrete with natural aggregates.
9. The tensile and flexural strengths are approximately 10 per cent lower.
10. The damping capacity, expressed in terms of logarithmic decrement, has been reported to be between 15 to 20 per cent higher.
11. The creep and drying shrinkage are 30 to 60 per cent higher.
12. The abrasion resistance for concrete has been found to reduce as compared to original concrete.

Que 5.24. What are the advantages and disadvantages of recycled aggregate concrete ?

Answer

Advantages of Recycled Aggregate Concrete :

1. Using recycled concrete as the base material for roadways reduces the pollution involved in trucking material.
2. Using recycled material as gravel reduces the need for gravel mining.
3. Keeping concrete debris out of landfills saves landfill space.
4. Produce specification sized recycled aggregates at own location.
5. Avoid haul-off costs and landfill disposal fees.
6. Eliminate the expense of aggregate material imports and exports.
7. Increase project efficiency and improve job cost - recycled concrete aggregates yield more volume by weight (up to 15 %).

Disadvantages of Recycled Aggregate Concrete :

1. Decrease in strength and elastic modulus.
2. Lower bulk specific gravity.
3. Reduced workability due to higher water absorption capacity.
4. Higher absorption capacity range from 3 % - 9 %.
5. Greater moisture shrinkage potential.

Que 5.25. How recycled aggregate produced ? Also give its applications.

Answer

Production of Recycled Aggregate :

1. The basic method of the recycling is one of crushing the debris to produce a granular product of given particle size and then reprocessing and screening, the degree of which depends on the level of contamination and the application of which recycled aggregate is produced.
2. Recycled aggregates normally have more angular shape and more coarser surface and exhibit more or less similar particle size distribution as that for natural aggregate.

Applications of Recycled Aggregate : The applications of recycled aggregate in construction areas are as follows :

1. Aggregate Base Course, or the untreated aggregates used as foundation for roadway pavement, is the underlying layer which forms a structural foundation for paving.
2. It is used for residential slab and foundation; walk and curb residential street; commercial slab and foundation and concrete paving per aggregate approval.

3. **Pipe Bedding :** Recycled concrete can serve as a stable bed or firm foundation in which to lay underground utilities.
4. **Paving Blocks :** Recycled aggregate have been used as paving blocks in some countries.
5. **Building Blocks :** Recycled aggregate has been used as building blocks.
6. **Landscape Materials :** Recycled concrete can be used in various landscape settings. Sized concrete rubble can serve as landscape feature.
7. Recycled aggregate has been used as boulder/stacked rock walls, underpass abutment structures, erosion structures, water features, retaining walls.
8. It can be used for constructing gutters, pavements etc.
9. Large pieces of crushed aggregate can be used for building revetments which in turn is very useful in controlling soil erosion.
10. Recycled concrete rubbles can be used as coarse aggregate in concrete.
11. Production of recycled aggregate also results in generation of many by-products having many uses such as a ground improvement material, a concrete addition, an asphalt filler etc.

Que 5.26. Write shorts notes on status of recycled aggregate concrete in India.

Answer

Recycled Aggregate Use in India :

1. Currently India has a severe shortage of infrastructural facilities. Nonetheless India is constructing its foundation at a very fast rate.
2. In this process of construction and reconstruction it has become the second largest producer of cement in the world only after China.
3. Though it is not even in top ten when it comes to production of recycled aggregate concrete.
4. Now as the government is gearing up for development of new cities, buildings, roads etc., the gates are wide open for production of more recycled aggregate.
5. Not only the problem of hundreds of thousands of tons of construction debris can be solved by recycling and reusing the building wastes, but also the issue of shortage of natural aggregates can be addressed.
6. Recycled aggregate concrete have several reliable applications. However, countries like India need to take some serious urgent measures to unleash the scope of recycled aggregate and if done so, concrete recycling will become one of the most important elements for construction sustainability.

1
UNIT

Cement Production and Aggregates (2 Marks Questions)

1.1. What do you understand by cement ?

Ans. Cement is an extremely ground material having adhesive and cohesive properties, which provide a binding medium for the discrete ingredients.

1.2. Give the chemical composition of ordinary portland cement.

Ans.

Oxide	Percentage	Average
Lime, CaO	60–65	63
Silica, SiO_2	17–25	20
Alumina, Al_2O_3	3.5–9	6.3
Iron oxide, FeO_3	0.5–6	3.3
Magnesia, MgO	0.5–4	2.4
Sulphur trioxide, SO_3	1–2	1.5
Alkalis, *i.e.*, soda or potash, Na_2O, K_2O	0.5–1.3	1.0

1.3. Enlist the Bogue's composition of cement.

Ans. The composition of portland cement is basically consist of four main compounds :

i. Tricalcium silicate $C_3S \rightarrow 3\ CaO\ .\ SiO_2$ (Alite)
ii. Dicalcium silicate $C_2S \rightarrow 2CaO\ .\ SiO_2$ (Belite)
iii. Tricalcium aluminate $C_3A \rightarrow 3\ CaO\ .\ Al_2O_3$ (Aluminate)
iv. Tetracalcium alumino ferrite $C_4AF \rightarrow 4CaO\ .\ Al_2O_3\ .\ Fe_2O_3$ (Ferrite)

1.4. What do you mean by hydration of cement ?

Ans. The chemical reactions that take place between cement and water is referred as hydration of cement.

1.5. Define heat of hydration.

Ans. When reaction takes place between cement and water, the reaction liberate a considerable quantity of heat. This liberation of heat is called heat of hydration.

1.6. Give the various types of cement.

Ans. Following are the various types of cement :

i. Ordinary Portland cement. ii. Rapid hardening cement.
iii. Sulphate resisting cement. iv. Quick setting cement.
v. Low heat cement. vi. High alumina cement.
vii. Air entraining cement.

1.7. Where are rapid hardening cement used ?

Ans. Rapid hardening cement is recommended in the following situation :
i. In pre-fabricated concrete construction.
ii. Road repair works.
iii. In cold weather concrete construction.

1.8. Under what situations, we use sulphate resisting cement.

Ans. Following are the conditions in which sulphate resisting cement used :
i. Concrete to be used in marine condition.
ii. Concrete to be used in foundation and basement, where soil is infested with sulphates.
iii. Concrete to be used in the construction of sewage treatment works.

1.9. What are the advantages of Portland slag cement ?

Ans. Following are the advantages of Portland slag cement :
i. It reduces heat of hydration.
ii. It refines the porous structure.
iii. It reduces permeability.
iv. It increases resistance to chemical attack.

1.10. Give the use of Portland pozzolana cement.

Ans. Following are the uses of Portland pozzolana cement :
i. For hydraulic structure.
ii. For mass concrete structure like dam, bridge pier and raft foundations.
iii. For marine structure.
iv. For sewers and sewage disposal work, etc.

1.11. What are the pozzolanic materials ?

Ans. 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.

1.12. Enlist the various types of pozzolanic materials.

Ans. Following are the various types of pozzolanic materials :
1. Natural Pozzolanas :
i. Clay and shales. ii. Diatomaceous earth.
iii. Volcanic tuffs and Pumicites.
2. Artificial Pozzolanas :
i. Fly ash. ii. Blast furnace slag. iii. Silica fume.
iv. Rice husk ash. v. Metakaolin. vi. Surkhi.

1.13. Define fly ash.

Ans. It is finely divided residue resulting from the combustion of powdered coal and transported by the flue gases and collected by electrostatic precipitator.

1.14. Discuss silica fume.

Ans. Silica fume is very fine pozzolanic material composed of ultrafine, amorphous glassy sphere of silicon dioxide produced during the manufacturing of silica or ferro-silicon by electric arc furnace at temperature of over 2000 °C.

1.15. What do you understand by surkhi ?

Ans. Surkhi is an artificial pozzolana made by powdering bricks or burnt clay balls.

1.16. What are the properties of aggregate that affects the concrete properties ?

Ans. Following are the important properties of aggregate which affect the properties of concrete :

i. Particle shape.
ii. Surface texture.
iii. Specific gravity.
iv. Bulk density.
v. Bulking of sand.
vi. Soundness of aggregate.
vii. Alkali aggregate reaction etc.

1.17. What are the deleterious substances in aggregates ?

Ans. Following are the deleterious substances in aggregates :

i. Organic impurities, which interfere the hydration of concrete.
ii. Salt when aggregate is obtained from sea-shore.
iii. Weak or unsound particles.

1.18. Discuss alkali-aggregate reaction between aggregate and cement.

Ans. When active silica constituents of aggregate react with the alkalies in cement, alkali-silicate gel is formed. This reaction is known as alkali-aggregate reaction.

1.19. What are the effects of alkali-aggregate reaction on concrete ?

Ans. Due to this reaction, alkali-silicate gel is formed which swells and exerts internal pressure leading to expansion, cracking and disruption of cement paste.

1.20. Enumerate the controlling measure of alkali-aggregate reaction.

Ans. Following are the controlling measures of alkali-aggregate reaction :

i. Selection of non-reactive aggregate.
ii. By the use of low alkali cement.
iii. By controlling moisture, void space and temperature of concrete.
iv. By the addition of reactive silica in finely powdered form.

1.21. What do you understand by term 'all in aggregate' ?

Ans. Sometimes combined aggregates are available in nature comprising different fractions of fine and coarse aggregates which are known as all-in-aggregates.

1.22. What do you mean by single size aggregates ?

Ans. Aggregates comprising particles falling essentially within a narrow limit of size fractions are called single-size aggregates.

1.23. Describe the soundness of aggregate.

Ans. The soundness indicates the ability of the aggregate to resist excessive changes in the volume due to change in environment conditions. E.g., freezing and thawing, thermal changes and alternating wetting and drying.

1.24. Enlist the thermal properties of aggregates.

Ans. Following are the thermal properties of aggregate :

i. Coefficient of thermal expansion.
ii. Specific heat.
iii. Thermal conductivity.

1.25. Explain the gap grading of aggregates.

Ans. Gap grading is defined as a grading in which one or more intermediate size fractions are absent.

1.26. Give the features of gap graded aggregates.

Ans. Following are the features of gap graded aggregates :

i. Gap-graded aggregate does not affect compressive or tensile strength.
ii. Gap-graded aggregate requires lesser cement and lower water-cement ratio.
iii. The drying shrinkage is reduced in the concrete using gap graded aggregate.
iv. Specific surface area of gap graded aggregate is lower because of higher percentage of coarse aggregate.

1.27. Enlist the various tests which are performed on the aggregate.

Ans. Following are the various test performed on the aggregates :

i. Aggregate crushing value test.
ii. Aggregate impact value test.
iii. Aggregate abrasion value test.
iv. Bulk density test, etc.

1.28. What are the effects of impurities in water on properties of concrete ?

Ans. Following are the effects of impurities in water on properties of concrete.

1. The strength and durability of concrete is reduced due to the presence of impurities in the mixing water.
2. Water containing large quantities of chlorides tends to cause persistent dampness, surface efflorescence and increases the corrosion of the reinforcing steel.

2 UNIT

Chemical and Mineral Admixtures (2 Marks Questions)

2.1. Classify the admixtures used in concrete production.

Ans. Following are the different types of admixtures :

i. Plasticizers.
ii. Superplasticizers.
iii. Retarders.
iv. Accelerators.
v. Air entraining admixtures.
vi. Pozzolanic or mineral admixtures.
vii. Water proofing admixtures, etc.

2.2. What are accelerators ?

Ans. These are substance which when added to concrete, mortar or grout, increase the rate of hydration of a hydraulic cement, shorten the time of set or increase the rate of hardening or strength development.

2.3. Give the examples of accelerating admixtures.

Ans. Calcium chloride, soluble carbonates, silicates, fluosilicates, etc.

2.4. Describe the application of accelerator in concrete.

Ans. Accelerators are used in cold weather and under water construction.

2.5. Discuss retarders.

Ans. These are the substances which retard the setting rate of concrete.

2.6. Enlist the some retarding admixtures.

Ans. Sugar, carbohydrates derivatives, soluble zinc salt, etc., are used as retarders.

2.7. Where are retarding admixtures used ?

Ans. These are particularly used in hot weather or for ready mixed concrete where it is required to delay the setting of cement.

2.8. Define plasticizers.

Ans. These are the substance which when added to concrete, increase workability without increasing the water content *i.e.*, the concrete made using these admixtures is a flowing concrete.

2.9. In what situation, plasticizers are used in concrete.

Ans. Following are the situation where plasticizers used :

i. It is particularly useful for very heavily reinforced sections or where rapid placing of concrete is desired.
ii. It is used for reducing water cement ratio in extremely high strength concrete.

2.10. Enumerate the new generation superplasticizers.

Ans. Following are the new generation superplasticizers :

i. Acrylic polymer based.
ii. Copolymer of carboxylic acrylic ester.
iii. Cross linked acrylic polymer.
iv. Polycarboxylate ester.
v. Multicarboxylate ethers, etc.

2.11. Write down the advantages of accelerators.

Ans. Following are the advantages of accelerators :

i. Permit earlier removal of form work.
ii. Reduce the required period of curing.
iii. Advance the time that a structure can be placed in concrete.
iv. In the emergency repair work.

2.12. What do you understand by air-entraining agents ?

Ans. These are the admixtures which cause air to be incorporated in the form of minute bubbles in concrete during mixing to increase the workability and resistance to freezing and thawing and disruptive action of de-icing salts.

2.13. Enlist the air entrainment agents used in concrete production.

Ans. Visol resin, natural wood resin, animal/vegetable fats etc, are the substance to be used as an air entraining agents.

2.14. Write down the effect of air entrainment on the properties of concrete.

Ans. Following are the effect of air entrainment on properties of concrete :

1. Increased resistance to freezing and thawing.
2. Improvement in workability.
3. Reduction in strength.
4. Reduces the alkali aggregate reaction.
5. Permits reduction in water content.

2.15. Write down the application of pozzolonas.

Ans.

i. Pozzolona used for reduction in the heat of hydration.
ii. It is used for improvement in the workability.

2.16. Give the advantages and disadvantages of air-entraining admixtures.

Ans. **Advantages :**

i. Increase resistance of concrete towards thawing and freezing.
ii. Increase workability of concrete.
iii. Reduce bleeding and segregation of concrete mixtures.

Disadvantages :

i. Reduce strength in high cement content concretes.

2.17. What are the advantages and disadvantages of water reducing admixtures ?

Ans. **Advantages :**

i. Increase workability of concrete.
ii. High strength can be obtained with the same cement content.
iii. Save up cement upto 10 %

Disadvantages :

i. Aggravate the rate of slump loss with time.

2.18. Describe the merits and demerits of plasticizers.

Ans. **Merits :**

i. Enhance concrete early strength.
ii. Produce flowing concrete to use in heavy reinforced structure with inaccessible areas.

Demerits :

i. Loss of workability as a result of rapid slump loss.
ii. Incompatibility of cement and plasticizers.

2.19. Enumerate the advantages and disadvantages of accelerating admixtures.

Ans. **Advantages :**

i. Shorten the setting time of cement.
ii. Reduce segregation and increase density and compressive strength.
iii. Reduce water requirements.

Disadvantages :

i. Might cause discoloration.
ii. Potential corrosion of reinforcement.
iii. Increase in drying shrinkage.

3 UNIT

Mix Design and Rheology of Concrete (2 Marks Questions)

3.1. What do you understand by the term 'proportioning of mix' ?

Ans. Proportioning a concrete mix for a given purpose is thus the art of obtaining a suitable ratio of the various ingredients of concrete with the required properties at the lowest cost.

3.2. Discuss the principles of mix proportioning.

Ans. Following are the data required for proportioning a concrete mix :

i. The environmental exposure conditions.
ii. Grades of concrete.
iii. Types of cement.
iv. Types and size of aggregates.
v. Maximum and minimum cement content.
vi. The maximum free water-cement ratio.
vii. Degree of workability.
viii. Type of admixture used.
ix. Density of concrete.
x. Type of mixing and curing.

3.3. Write down the environment exposer conditions for concrete.

Ans. Following are the environment exposers conditions :

i. Mild.
ii. Modulate.
iii. Sever.
iv. Very sever.
v. Extreme.

3.4. What are the properties of concrete related to mix design ?

Ans. Following are the properties of concrete related to mix design :

i. Durability.
ii. Workability.
iii. Strength.

3.5. Define harshness of mix.

Ans. It is defined as the inability of concrete to have a smooth finish even after trowelling. This happens when the cement mortar is insufficient to fill all the voids and when too many particles are large or have the same size.

3.6. What the various methods of proportioning concrete mixes.

Ans. Following are the various methods of proportioning concrete mixes :

i. Trial mixes.
ii. Nominal mixes.
iii. America concrete institute method.
iv. BIS method.
v. Minimum voids method.
vi. Maximum density method.

3.7. Write down the factors that affects the workability.

Ans. Following are the factors affecting the workability of concrete :

i. Types of aggregate rounded, angular, flaky, etc
ii. Grading of fine and coarse aggregates *i.e.*, poorly and well graded.
iii. Quantity of cement paste in the mix.
iv. Consistency of the paste.

3.8. Write down the compressive strength formula according to Abram's law.

Ans. Compressive strength is expressed as :

$$F = \frac{A_1}{B_1^x}$$

$$\log F = \log A_1 - x \log B_1$$

where, F = Compressive strength.

A_1 and B_1 = Constants.

x = Water-cement ratio.

3.9. What is mean strength ?

Ans. This is the average strength $\bar{x}$ obtained by dividing the sum of individual strength (x) of all the cubes by the number of cubes (n).

Mean strength, $\bar{x} = \frac{\Sigma x}{n}$

3.10. Define variance.

Ans. This is the measure of variability of difference between any single observed data from the mean strength.

3.11. Define characteristic strength of concrete.

Ans. It is defined as that value below which not more than 5 % of the test results are expected to fall.

3.12. Give the statement of Abram's law.

Ans. According to Abram's law, "the strength of fully compacted hardened concrete is approximately inversely proportional to the water content per cubic metre of cement *i.e.*, water-cement ratio".

3.13. What is rheology and rheological models of concrete ?

Ans. Rheology is the science of flow of material. Rhelogical models of fresh concrete give us information about the ability of fresh concrete mix to flow under its own weight and fill the moulds without voids.

3.14. Write down the rheological characteristics of fresh concrete.

Ans. Following are the characteristic of fresh concrete :

i. Workability.
ii. Compactability.
iii. Flowability.
iv. Pumpability.
v. Flow under its own weight.
vi. Fillability.
vii. Stability.
viii. Finishability.

3.15. Classify the flow of fresh concrete.

Ans.

i. **Confined Flow :** Concrete flow under its own weight through an orifice.
ii. **Free Flow :** Concrete flows freely under its own weight or is poked and inserted by rod or a plunger by only gravitational force.
iii. **Vibration Flow :** Concrete flows under the influence of vibrations.

3.16. What are the factors which affects the rheological properties of concrete ?

Ans. Following are the factors affecting the rheological properties of concrete :

i. Mixing of concrete.
ii. Effect of cohesion.
iii. Effect of water and super plasticizers.
iv. Heat of hydration and air entrained.

4 UNIT

Concrete Production, Properties and Testing (2 Marks Questions)

4.1. What are the step in concreting process ?

Ans. The concreting process involves the following five steps :

i. Batching or measurement of materials.
ii. Mixing of concrete.
iii. Transportation.
iv. Placing, compacting and finishing of concrete.
v. Curing.

4.2. Write down the factors affecting the batching process.

Ans. Following are the affecting factor of batching process :

i. Size of job.
ii. Required production rate, and
iii. Required standard of batching performance.

4.3. Classify the batching process of concrete.

Ans. Following are the batching process of concrete :

i. Manual batching.
ii. Semi automated batching.
iii. Automated batching.

4.4. Classify the mixers, which are used in mixing of concrete.

Ans. Following are the various types of mixer commonly employed :

1. Horizontal or inclined (B drum) mixer :
   i. Tilting drum.
   ii. Non-tilting drum.
   iii. Reversing drum.
2. Vertical (Pan) mixer.

4.5. Enumerate the various equipments which are used for transporting of concrete.

Ans. Following equipments are used for transporting concrete :

i. Barrows.
ii. Dumpers and trucks.
iii. Elevating tower and hoists.

iv. Cranes and cableways.
v. Belt conveyor.

4.6. Define curing of concrete.

Ans. Curing refers to maintaining satisfactory moisture content and temperature in fresh concrete in order to achieve the desired strength and hardness.

4.7. What are the advantages of curing in concrete ?

Ans. Following are the advantages of curing in concrete :
i. Favorably cured concrete has better strength.
ii. Drying shrinkage and cracking are reduced.
iii. Concrete of better durability.

4.8. What are the different methods of curing ?

Ans. Following are the various methods of curing :
i. Covering concrete surface with hessian or gunny bags.
ii. Sprinkling of water.
iii. Ponding method.
iv. Membrane curing.
v. Steam curing.
vi. Electrical curing.

4.9. What are the limitations of slump cone test of concrete ?

Ans. Slump cone test does not give good results in case of stiff or harsh concrete.

4.10. Define compacting factor.

Ans. Compacting factor is a ratio of weight of partially compacted concrete to weight of fully compacted concrete.

4.11. In which conditions compacting factor test is not suitable.

Ans. It is not suitable for concrete of very low workability of 0.7 or below.

4.12. Discuss Abram's law.

Ans. "For plastic mixtures using neat and clean aggregate the strength of concrete under specified conditions is governed by the net quantity of water mixed per bag of cement".

4.13. What is gel space ratio ?

Ans. Gel-space ratio is defined as the ratio of volume of hydrates cement paste to the sum of the volume of the hydrated cement and that of the capillary pores.

$$S = 240\, x^3$$

4.14. Write the factor affecting the strength of concrete ?

Ans. Following are the factors affecting the strength of concrete :

i. Size of test specimen.
ii. Size of specimen relative to maximum size of aggregate.
iii. Moisture condition of specimen.
iv. Air voids.
v. Rate of loading.
vi. Age and types of cement, etc.

4.15. What is maturity of concrete and how it is calculated ?

Ans. It is defined as the summation of product of time and temperature.

$$\text{Maturity} = \Sigma(\text{Time} \times \text{Temperature})$$

4.16. What is creep ?

Ans. It may be defined as increase of strain in concrete with time sustained load. This is also known as plastic flow or time field.

4.17. What do you mean by shrinkage ? How is it determine ?

Ans. Contraction of concrete in the absence of load is known as shrinkage.

Shrinkage can be estimated by,

$$E_s = 0.00125(0.90 - h)$$

where, h = Relative humidity.

4.18. Define plastic shrinkage.

Ans. Shrinkage of concrete due to absorption of water by aggregate, rapid evaporation of water and bleeding.

4.19. Describe drying shrinkage.

Ans. The shrinkage taking place due to capillary water, absorbed water, or interlayer water after the concrete has set and hardened.

4.20. Give the remedial measures to overcome the effect of creep.

Ans. The effect of creep can be reduced by,

i. Using high strength concrete.
ii. Delaying the application of finishes, partition wall, etc
iii. Adding reinforcement.
iv. Steam curing under pressure.

4.21. Write down the various types of test performed for determining the compressive and flexural strength.

Ans. Following are the various test performed for determining the compressive and flexural strength of concrete :

A. Destructive Test :

i. Cube test.
ii. Tensile strength test :
   a. Split tensile test.
   b. Flexure test.

iii. Concrete core test.

B. Non-Destructive Test :

i. Rebound hammer test.
ii. Ultrasonic pulse velocity test.
iii. Pull out test.
iv. Penetration resistance test.

4.22. What is creep coefficient ?

Ans. It is the ratio of the ultimate creep strain to the elastic strain at the age of loading.

Age of Loading	Creep Coefficient
7 days	2.2
28 days	1.6
1 year	1.1

4.23. Define initial tangent modulus of concrete.

Ans. It is a slope of the curve from origin.

4.24. What are the advantages of ultrasonic pulse velocity test ?

Ans. **Advantages :**

i. High penetrating power.
ii. High sensitivity.
iii. Greater accuracy.
iv. Some capability in estimating the size, shape, nature of the flows.
v. Portability.

4.25. Give the disadvantages of ultrasonic pulse velocity test.

Ans. **Disadvantages :**

i. Skilled person are required.
ii. Difficulty in inspecting the parts which are irregular.
iii. Requirement of the couplants.
iv. Test objects should be water resistant.

4.26. What is the relation between cohesiveness and segregation ?

Ans.

1. Cohesive means bonding force and segregation means separation, when boding is increased between ingredients of concrete then segregation will be less.
2. Hence cohesiveness and segregation are inversely related.

5 UNIT

Specific Concretes (2 Marks Questions)

5.1. What is the self compacting concrete ?

Ans. Self compacting concrete is a concrete that can be compacted into every corner of a formwork purely by means of its own weight, without using any external vibrators.

5.2. Discuss the material required for self compacting concrete.

Ans. Following are the material required for self compacting concrete :

i. Cement. ii. Fine aggregate.
iii. Coarse aggregate. iv. Water.
v. Chemical admixture such as superplasticizers, viscosity modifying agents, air-entraining agents.
vi. Mineral admixtures such as fly ash, GBFS, silica fume.

5.3. What are the advantages of self compacting concrete ?

Ans. Following are the advantages of self compacting concrete :

i. Improves the quality, durability and reliability of concrete structures due to better compaction and homogeneity of concrete.
ii. Reduced permeability.
iii. Ease of placement result in cost savings.

5.4. What do you understand by fiber reinforced concrete ?

Ans. **Fiber Reinforced Concrete :** Concrete containing cement, water, aggregate, and discontinuous, uniformly dispersed or discrete fibers is called fiber reinforced concrete.

5.5. What are the affecting factors of properties of fiber reinforced concrete ?

Ans. Following are the factors affecting properties of fiber reinforced concrete :

i. Mixing.
ii. Workability and compaction of concrete.
iii. Size of coarse aggregate.
iv. Orientation of fibres.
v. Aspect ratio of fibres.
vi. Volume of fibres.

5.6. Give the advantages of fiber reinforced concrete.

Ans. **Advantages of Fiber Reinforced Concrete :**

i. Lower permeability of concrete.
ii. Better toughness.
iii. Enhancement of fatigue strength and endurance limit.
iv. Improvement in bond strength.
v. Reduction in shrinkage and cracking.

5.7. Discuss the application of fiber reinforced concrete.

Ans. **Application of Fiber Reinforced Concrete :**

i. Repairs and rehabilitation works.
ii. Wearing surface to exiting bridges/ culverts.
iii. Precast products.
iv. Blast resistance structures.
v. Water retaining structures.
vi. Pavements and floors.

5.8. Write down the comparison of FRC and NRC.

Ans.

S. No.	FRC (Fiber Reinforced Concrete)	NRC (Normal Reinforced Concrete)
1.	High durability.	Lower durability.
2.	Protect steel from corrosion.	Steel potential to corrosion.
3.	Lighter materials.	Heavier material.
4.	More expensive.	Economical.
5.	With the same volume, the strength is greater.	With the same volume, the strength is less.
6.	Less workability.	High workability as compared to FRC.

5.9. What is ferro-cement ?

Ans. It is a type of thinwall reinforced cement commonly constructed of hydraulic cement mortar reinforced with closely spaced layers of continuous and relatively small size wire mesh.

5.10. What are the constituents of ferro-cement ?

Ans. Following are the constituents of ferro-cement :

i. Cement mortar mix.
ii. Skeleton steel.
iii. Steel mesh reinforcement or fibre reinforcement polymeric meshes.

5.11. Enumerate the manufacturing techniques of ferro-cement.

Ans. Following are the manufacturing techniques of ferro-cement :

i. Hand plastering.
ii. Semi-mechanized process.
iii. Centrifuging and guniting.

5.12. Describe properties of ferro-cement.

Ans. Following are the properties of ferro-cement :

i. It is very durable, cheap and versatile material.
ii. High tensile strength and stiffness.
iii. Better impact and punching shear resistance.

5.13. Enumerate the mechanical properties of ferro-cement.

Ans. **Mechanical Properties of Ferro-cement :**

i. Compressive strength – 27.5 to 60 N/mm^2.
ii. Allowable tensile strength – 10.0 N/mm^2.
iii. Ultimate tensile strength – 34.5 N/mm^2.
iv. Steel cover – 1.5 mm to 5 mm.
v. Steel percentage – 5 to 8 %.
vi. Thickness – 10 mm to 60 mm.

5.14. Describe the various application of ferro-cement.

Ans.

1. **Marine Application :** It is used for constructing boats, fishing vessels, barrages, docks, floating buyos. etc.
2. **Rural Energy Application :** Biogas digester, biogas holder, incinerator etc.

5.15. Compare recycled aggregate and natural aggregate.

Ans.

S. No.	Recycled Aggregate	Natural Aggregate
1.	It has rough textured angular elongated particles.	It has smooth and rounded compacted particles.
2.	It is well graded.	It is not well graded.
3.	It has more water absorption.	It has less water absorption.
4.	It has lower dry density.	It has more dry density.

5.16. Write down the applications of recycled aggregate.

Ans. Following are the applications of recycled aggregate :

i. **Embankment Fill Materials :** The embankment site is on the wet subgrade areas. Recycled aggregate can stabilize the base and provide an improved working surface.
ii. **Backfill Materials :** Recycled aggregate can be used as backfill materials in the pipe zone along trenches after having testing in laboratory.

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B.Tech.
(SEM. V) ODD SEMESTER THEORY EXAMINATION, 2018-19
CONCRETE TECHNOLOGY

Time : 3 Hours **Max. Marks : 70**

Note : Attempt **all** sections. If any missing data required, then choose suitably.

Section – A

1. Attempt **all** questions in brief. **(2 × 7 = 14)**

a. What is bulking of sand ?

b. What are the thermal properties of aggregate ?

c. Define Plastic concrete.

d. What is the impact of W/C ratio on durability ?

e. Write the concept of mix design.

f. Define standard deviation.

g. What is the Rheological representation of creep ?

Section-B

2. Attempt any **three** of the following : **(7 × 3 = 21)**

a. What are the roles of various ingredients of cement ? What are the harmful compounds likely to be present in cements ?

b. Describe the mechanism of action of plasticizers with neat sketch. Mention any three super plasticizers.

c. Design a concrete mix of M 30 grade. Take standard deviation 5 MPa. The specific gravities of coarse aggregate and fine aggregate are 2.75 and 2.62 respectively. The bulk density of coarse aggregate is 1610 kg/m^3 and fineness modulus of aggregate is 2.70. A slump of 60 mm is necessary. The water absorption of coarse aggregate is 1 % and free moisture in fine aggregate is 2 %. Design the concrete mix using IS code method. Assume any missing data.

d. What is the relation between creep and time ? What is the effect of creep on concrete ?

e. Explain the following :
A. Light weight aggregate concrete.
B. SIFCON.
C. Types of polymer concrete.

Section-C

3. Attempt any **one** part of the following : **(7 × 1 = 7)**

a. What are the sources of aggregate ? And also classify the particles on the basis of aggregate in tabular form.

b. How is water used in making concrete and what is its role in the foundation and properties of concrete ?

4. Attempt any **one** part of the following : **(7 × 1 = 7)**

a. Describe gas forming agents ? Give an example of a material in powder form used as a gas forming agent.

b. Write a note on workability agents. Give examples.

5. Attempt any **one** part of the following : **(7 × 1 = 7)**

a. Explain how you would determine the various elastic moduli for concrete.

b. What do you understand by carbonation of concrete ? How is it tested ?

6. Attempt any **one** part of the following : **(7 × 1 = 7)**

a. Write a brief note on flexure strength of concrete.

b. Discuss the influence of mix proportions of concrete on shrinkage.

7. Attempt any **one** part of the following : **(7 × 1 = 7)**

a. What is the need to study fiber reinforced concrete and explain briefly the factors effecting properties of fiber reinforced concrete ?

b. Difference between high performance concrete and high density concrete.

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SOLUTION OF PAPER (2018-19)

Note : Attempt **all** sections. If any missing data required, then choose suitably.

Section – A

1. Attempt **all** questions in brief. **(2 × 7 = 14)**

a. What is bulking of sand ?

Ans. **Bulking of Fine Aggregate :**

1. The increase in the volume of a given mass of fine aggregate caused by the presence of water is known as bulking.
2. The bulking of fine aggregate is caused by the films of water which push the particles apart.
3. The extent of bulking depends upon the percentage of moisture present in the sand and its fineness.
4. It is seen that bulking increases gradually with moisture content up to a certain point and then begins to decrease with further addition of water due to the merging of films, until when the sand is inundated.
5. With ordinary sands the bulking usually varies between 15-30 %.
6. In extremely fine sand the bulking may be of the order of 40 % at a moisture content of 10 % but such sand is unsuitable for concrete.

b. What are the thermal properties of aggregate ?

Ans. Following are the thermal properties of aggregate :

i. Coefficient of thermal expansion.
ii. Specific heat.
iii. Thermal conductivity.

c. Define Plastic concrete.

Ans. If recycled waste plastic were mixed with cement concrete, then it is called as plastic concrete.

d. What is the impact of W/C ratio on durability ?

Ans. **Cement Content and w/c Ratio of Concrete :** Volume change result in cracks and cracks are responsible for disintegration of concrete.

e. Write the concept of mix design.

Ans. **Principles of Mix Proportions :** According to IS 456 : 2000 and IS 1343 – 1980 the design of concrete mix should be based on following principles :

i. Grade designation.
ii. Type and grade of cement.

iii. Minimum nominal size of aggregate.
iv. Grading of combined aggregate.
v. Water cement ratio.
vi. Workability.
vii. Durability.
viii. Quality control.

f. Define standard deviation.

Ans. **Standard Deviation :**

i. This is the root mean square deviation of all the results, is denoted by s or σ. Numerically it can be explained as,

$$\sigma = \sqrt{\frac{\Sigma(x - \bar{x})^2}{n - 1}}$$

where, σ = Standard deviation.
n = Number of observations.
x = Particular value of observations.
$\bar{x}$ = Arithmetic mean.

ii. Standard deviation increases with increasing variability.
iii. The characteristics of the normal distribution curve are fixed by the average value and the standard deviation.

g. What is the Rheological representation of creep ?

Ans. Rheological representation of creep is rheological models consisting of springs and dashpots that represent the time-dependent behaviour of materials like concrete and masonry.

Section-B

2. Attempt any **three** of the following : **(7 × 3 = 21)**

a. What are the roles of various ingredients of cement ? What are the harmful compounds likely to be present in cements ?

Ans.

A. Roles of Various Ingredients of Cement : Following are the roles of various ingredients of cement :

1. Lime (CaO) :

i. Lime forms nearly two-third (2/3) of the cement.
ii. Sufficient quantity of lime forms di-calcium silicate ($C_2Si\ O_2$) and tri-calcium silicate in the manufacturing of cement.
iii. Lime in excess, causes the cement to expand and disintegrate.

2. Silica (SiO_2) :

i. The quantity of silica should be enough to form di-calcium silicate (C_2SiO_2) and tri-calcium silicate in the manufacturing of cement.
ii. Silica gives strength to the cement.
iii. Silica in excess causes the cement to set slowly.

3. Alumina (Al_2O_3) :

i. Alumina supports to set quickly to the cement.
ii. It also lowers the clinkering temperature.
iii. Alumina in excess reduces the strength of the cement.

4. Iron Oxide (Fe_2O_3) : Iron oxide gives colour to the cement.

5. Magnesia (MgO) :

i. It also helps in giving colour to the cement.
ii. Magnesium in excess makes the cement unsound.

6. Calcium Sulphate (or) Gypsum ($CaSO_4$) : At the final stage of manufacturing, gypsum is added to increase the setting of cement.

B. Harmful Compounds : The presence of the following two oxides adversely affects the quality of cement :

1. Alkali oxides K_2O and Na_2O.
2. Magnesium oxide MgO.

b. Describe the mechanism of action of plasticizers with neat sketch. Mention any three super plasticizers.

Ans.

A. Mechanism of Action of Plasticizers : The action of plasticizers is mainly to fluidify the mix and improve the workability of concrete, mortar or grout. The mechanisms involved are :

1. Dispersion :

i. Portland cement being in fine state will have a tendency to flocculate in wet concrete, these flocculation entraps certain amount of water used in the mix.
ii. When plasticizers are used, they get adsorbed on the cement particles, creates particle to particle repulsive forces which overcome the attractive forces.
iii. This repulsive force is called Zeta Potential, which depends on the base, solid content, quantity of plasticizer used.
iv. When cement particles are deflocculated, the water trapped inside the flocs gets released and is now available to fluidify the mix.

2. Lubricating : The agents are organic by nature, thus they lubricate the mix reducing the friction and increasing the workability.

3. Retarding Effect :

i. Plasticizers get adsorbed on the surface of the cement particles and form a thin sheath.
ii. This sheath inhibits the surface hydration reaction between water and cement as long as sufficient plasticizers molecules are available.
iii. Quantity of plasticizers will decrease as the polymers become entrapped in hydration products.

The following mechanisms may take place simultaneously :

a. Reduction in the surface tension of water.
b. Induced electrostatic repulsion between particles of cement.
c. Lubricating film between cement particles.
d. Dispersion of cement grains, releasing water trapped within cement flocs.

e. Inhibition of the surface hydration reaction of the hydration cement particles, leaving more water to fluidify the mix.

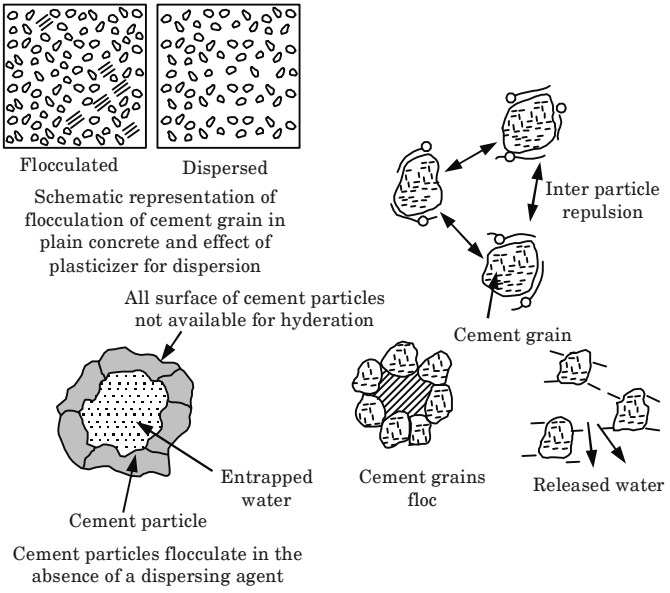

Fig. 1. Mechanism of action of plasticizers.

B. Super Plasticizers :

Types of Superplasticizers : Different types of superplasticizers are as follows :

1. **Lignosulphonates :** These are derived from neutralization, precipitation, and fermentation processes of the waste liquor obtained during production of paper-making pulp from wood
2. **Sulphonated Melamine Formaldehyde (SMF) :** It is manufactured by normal resinification of melamine - formaldehyde.
3. **Sulphonated Napthalene Formaldehyde (SNF) :** Produced from naphthalene by oleum or SO_3 sulphonation; subsequent reaction with formaldehyde leads to polymerization and the sulphonic acid is neutralized with sodium hydroxide or lime.

c. Design a concrete mix of M 30 grade. Take standard deviation 5 MPa. The specific gravities of coarse aggregate and fine aggregate are 2.75 and 2.62 respectively. The bulk density of coarse aggregate is 1610 kg/m^3 and fineness modulus of aggregate is 2.70. A slump of 60 mm is necessary. The water absorption of coarse aggregate is 1 % and free moisture in

fine aggregate is 2 %. Design the concrete mix using IS code method. Assume any missing data.

Ans.

Given : Standard deviation, σ = 5 MPa, Specific gravity of CA = 2.75, Specific gravity of FA = 2.62, Bulk density of CA = 1610 kg/m^3, Fineness modulus of aggregate = 2.70, Slump value = 60 mm, Water absorption of CA = 1 %, Free moisture in FA = 2 %.

To Find : Design mix M30 grade concrete.

1. Assuming 5 percent of results are allowed to fall below specified design strength. The mean strength,
$$f_m = f_{min} + k\sigma$$
$$= 30 + 1.64 \times 5 = 38.2 \text{ MPa}$$
2. Assume estimated w/c ratio is 0.47.

i. This w/c ratio from strength point of view is to be checked against maximum w/c ratio given for special exposure condition given in IS 456 : 2000 and minimum of the two is to be adopted.

ii. From IS 456 : 2000 the maximum w/c ratio is 0.60.
Therefore, adopt w/c ratio of 0.47.

3. From IS 456 : 2000, for a slump of 60 mm, 20 mm maximum size of aggregate, for non-air-entrained concrete, the mixing water content is 185 kg/m^3 of concrete. Also the approximate entrapped air content is 2 %.
The required cement content = 185 / 0.47 ≃ 394 kg/m^3
4. From IS 456 : 2000, for 20 mm coarse aggregate, for fineness modulus of 2.60, the dry rodded bulk volume of coarse aggregate is 0.62 per unit volume of concrete.
5. Therefore the weight of coarse aggregate = 0.62 × 1610 = 998.2 kg/m^3.
6. From IS code, the first estimate of density of fresh concrete for 20 mm maximum size of aggregate and for non-air-entrained concrete = 2355 kg/m^3.
7. The weight of all the known ingredient of concrete are :
Weight of water = 185 kg/m^3
Weight of cement = 394 kg/m^3
Weight of CA = 998.2 kg/m^3
Weight of FA = 2355 – (185 + 394 + 998.2) = 777.8 kg/m^3
8. Alternatively the weight of FA can also be found out by absolute volume method which is more accurate, as follows :

Item Number	Ingredients	Weight kg/m^3	Absolute Volume cm^3
1.	Cement	394	$\frac{394}{3.15} \times 10^3 = 125 \times 10^3$
2.	Water	185	$\frac{185}{1} \times 10^3 = 185 \times 10^3$
3.	Coarse aggregate	998.2	$\frac{998.2}{2.75} \times 10^3 \simeq 363 \times 10^3$
4.	Air		$\frac{2}{100} \times 10^6 = 20 \times 10^3$

Total absolute volume = 693×10^3 cm^3

Henceabsolute volume of FA = $(1000 - 693) \times 10^3 = 307 \times 10^3$ cm^3

Weight of FA = $307 \times 2.62 \simeq 804.34$ kg/m^3

9. Estimated quantities of materials per cubic meter of concrete are :

Cement = 394 kg

FA = 804.34 kg

CA = 998.2 kg

Water = 185 kg

Density of fresh concrete = 2381.54 kg/m^3.

10. Proportions :

Cement	Fine Aggregate	Coarse Aggregate	Water
394	804.34	998.2	185
1	2.04	2.52	0.47

Weight of materials for one bag mix in kg = 50 : 102 : 126.5 : 23.5

The above quantity is on the basis that both FA and CA are in saturated and surface dry condition.

11. The proportions are required to be adjusted for the field conditions. FA has moisture of 2 per cent.

i. Total free surface moisture in FA = (2/100) × 804.34 = 16.08 kg/m^3

ii. Weight of FA in field condition

= 804.34 +16.08 = 820.42 kg/m^3 ≈ 821 kg/m^3

iii. CA absorbs 1 % water

Quantity of water absorbed by CA = (1/100) × 998.2 = 9.981 kg/m^3

iv. Weight of CA in field condition

= 998.2 – 9.982 = 989.2 kg/m^3

v. With regard to water, 16.08 kg of water is contributed by FA and 9.982 kg of water is absorbed by CA.

Therefore 16.08 – 9.982 = 6.1 kg of extra water is contributed by aggregates. This quantity of water is deducted from total water

185.00 – 6.1 = 178.9 kg/m^3 ≈ 179 kg/m^3

12. Quantities of materials to be used in the field duly corrected for free surface moisture in FA and absorption characteristic of CA

Cement = 394 kg/m^3
FA = 821 kg/m^3
CA = 989 kg/m^3
Water = 179 kg/m^3

Field density of fresh concrete = 2388 kg/m^3

d. What is the relation between creep and time ? What is the effect of creep on concrete ?

Ans.

A. Relation between Creep and Time :

1. The rate of creep decreases with time and the creep strains at five years are taken as terminal values.
2. Creep increases rapidly with the stress, loading at an early age of concrete, broken ballast, soft and porous aggregate, poorly graded and improperly compacted concrete.

B. Effects of creep on concrete structures :

1. In reinforced concrete beams, creep increases the deflection with time and may be a critical consideration in design.
2. In eccentrically loaded columns, creep increases the deflection and can lead to buckling.
3. Loss of prestress due to creep of concrete in prestressed concrete structure.
4. Creep property of concrete will be useful in all concrete structures to reduce the internal stresses due to non-uniform load or restrained shrinkage.
5. In mass concrete structures such as dams, on account of differential temperature conditions at the interior and surface, creep is harmful and by itself may be a cause of cracking in the interior of dams.

e. Explain the following :

A. Light weight aggregate concrete.

B. SIFCON.

C. Types of polymer concrete.

Ans.

A. Light Weight Aggregate Concrete : Concrete of substantially lower density than that made using aggregates of normal density; consists entirely of light weight aggregate or a combination of light weight aggregate and normal-density aggregate; its equilibrium densities are generally between 1120 to 1920 kg/m^3.

B. SIFCON :

1. SIFCON is the slurry infiltrated fiber concrete.
2. It is one such high performance material that possesses excellent mechanical properties coupled with greater energy absorption characteristics.

3. It contains 6-20 % of fibres.
4. The coarse aggregate is omitted.
5. The strength of the concrete is high with the flexural strength and is suitable for earthquake prone areas.
6. It possesses high flow ability and passing ability.
7. It is fabricated by infiltrating a bed of pre-placed fibres with cement slurry.
8. It is unsuitable and uneconomical for hydraulic structures.

C. Types of Polymer Concrete : Following are the various types of polymer concrete :

1. Polymer impregnated concrete (PIC).
2. Polymer cement concrete (PCC).
3. Partially impregnated and surface coated polymer concrete.
4. Polymer concrete (PC).

Section-C

3. Attempt any **one** part of the following : **(7 × 1 = 7)**

a. What are the sources of aggregate ? And also classify the particles on the basis of aggregate in tabular form.

Ans.

A. Source of Aggregate : Following are the sources of aggregate :

1. Natural Aggregate :

i. Almost all natural aggregate materials originate from bed rocks.
ii. There are three kinds of rocks, namely, igneous, sedimentary and metamorphic.
iii. The igneous rocks are formed by the cooling of molten magma or lava at the surface of the crest (trap and basalt) or deep beneath the crest (granite).
iv. The sedimentary rocks are formed originally below the sea bed and subsequently lifted up.
v. Metamorphic rocks are originally either igneous or sedimentary rocks which are subsequently metamorphosed due to extreme heat and pressure.

2. Artificial Aggregates : They are obtained either as a by-product or by a special manufacturing process such as heating. (*e.g.* blast furnace slag, expanded perlite).

B. Classification of Particles on the basis of shape of the Aggregate :

Classification	Description	Examples
Rounded	Fully water worn or completely shaped by attrition	River or seashore gravels ; desert, seashore and wind-blown sands
Irregular or partly rounded	Naturally irregular or partly shaped by attrition, having rounded edges	Pit sands and gravels ; land or dug flints ; cuboid rock
Angular	Possessing well-defined edges formed at the intersection of roughly planar faces	Crushed rocks of all types ; talus ; screes
Flaky	Material, usually angular, of which the thickness is small relative to the width and/or length	Laminated rocks

b. How is water used in making concrete and what is its role in the foundation and properties of concrete ?

Ans.

A. Water used in Making Concrete :

1. The water used for the mixing and curing of concrete should be free from injurious amounts of deleterious materials.
2. The unwanted situations, leading to the distress of concrete, have been found to be a result of, among others, the mixing and curing water being of inappropriate quality.
3. Potable water is generally considered satisfactory for mixing concrete.
4. In the case of doubt about the suitability of water, particularly in remote areas or where water is derived from sources not normally utilized for domestic purposes, water should be tested.

   Table gives the typical limits of impurities in water as per IS : 456-2000.

Solids	Permissible limits, max. (mg/L)
Organic	200
Inorganic	3000
Sulphates (as SO_3)	400
Chlorides (as Cl_2) :	
i. For plain concrete	2000
ii. For reinforced concrete	500
Suspended matter	2000

B. Role of Water :

1. Water is the most important and least expensive ingredient of concrete.
2. It plays an important role in mixing, laying, compaction, setting and hardening of concrete.
3. The strength of concrete depends on the quality and quantity of water used in the mix.
4. The functions of water in the concrete mix are given below :
   i. It acts as lubricant for the fine and coarse aggregate and makes the mixture workable.
   ii. It acts chemically with cement to form the binding paste.
   iii. It is employed to damp the aggregate surface in order to prevent them from absorbing water vitally necessary for chemical action.
   iv. It facilitates the spreading of aggregate.
   v. It helps to flux the cementing material over the surface of the aggregate.
   vi. It enables the concrete mix to flow into moulds.

4. Attempt any **one** part of the following : **(7 × 1 = 7)**

a. Describe gas forming agents ? Give an example of a material in powder form used as a gas forming agent.

Ans.

A. Gas Forming Agent :

1. These admixtures when added to mortar or concrete mixture react chemically with hydroxides present in the cement and form minute bubbles of hydrogen gas of size ranging from 0.1 to 1 mm throughout the cement-water matrix.
2. This action, when properly controlled, causes a slight expansion in plastic concrete or mortar and thus reduces or eliminates voids caused by normal settlement that occur during the placement of concrete.
3. Water films around the gas bubbles prevent bleeding.
4. The gas is beneficial in improving the effectiveness of grout for filling joints, in improving the homogeneity of grouted concrete, and in filling block outs and openings in concrete structures.
5. Larger amounts of powder increase the expansion appreciably resulting in a gas-filled lightweight low strength concrete. These are also called foamed concrete or aerated concrete or cellular concrete.

B. Example : Aluminium powder, Hydrogen peroxide, Activated carbon, etc.

b. Write a note on workability agents. Give examples.

Ans.

A. Workability Agents :

1. The workability of concrete is governed by the amount of aggregate in the mix. Where reduction of aggregate (or increase in cement) is impractical, workability is increased by adding a plasticizer.
2. Air-entraining agents, when used, are plasticizers. Other substances include calcium chloride, lime, fly ash, and other pozzolans.
3. Lime increases the cementing properties of cement, as do pozzolans combined with lime.
4. Fly ash is inexpensive compared to cement and is used as a partial replacement (up to as much as 50 percent) of the cement.
5. It changes both the plastic and the hardened properties of concrete.
6. Fly ash improves workability and reduces segregation, bleeding, and the heat of hydration.

B. Example : Bentonite clay, Diatomaceous earth, Fly ash, Finely divided silica, Hydrated lime, etc.

5. Attempt any **one** part of the following : **(7 × 1 = 7)**

a. Explain how you would determine the various elastic moduli for concrete.

Ans. Following are the various elastic modulus for concrete :

A. Static Modulus of Elasticity :

1. Modulus of elasticity of concrete is a key factor for estimating the deformation of structural elements, as well as a fundamental factor for determining modular ratio, n, which is used for the design of structural members subjected to flexure.
2. The modulus of elasticity of concrete is directly proportional to the square root of characteristic compressive strength in the range of normal concrete strength,
3. The IS 456 : 2000 gives the modulus of elasticity of concrete as :

$$E_c = 5000\sqrt{f_{ck}}$$

where, E = Modulus of elasticity.
f_{ck} = Characteristic strength of concrete.

B. Dynamic Modulus of Elasticity :

1. In this method pulses of compression waves are generated by an electro-acoustical transducer that is held in contact with one surface of the prismatic or cylindrical concrete specimen.
2. After traversing through the concrete, the pulses are received and converted into electrical energy by a second transducer located at a distance L from the transmitting transducer.
3. The pulse velocity $V = L/T$ is related to the physical properties of a solid by the eq. (1)

$$V^2 = (K)\frac{E_d}{\rho} \text{ or } E_d = \frac{\rho V^2}{K} \quad ...(1)$$

where, L = Distance between transducers, m
T = Transit time, seconds
E_d = Dynamic modulus of elasticity, Pa (N/m^2)

V = Pulse velocity, m/sec
ρ = Mass density, kg/m^3
K = 1 (for a cylindrical specimen).

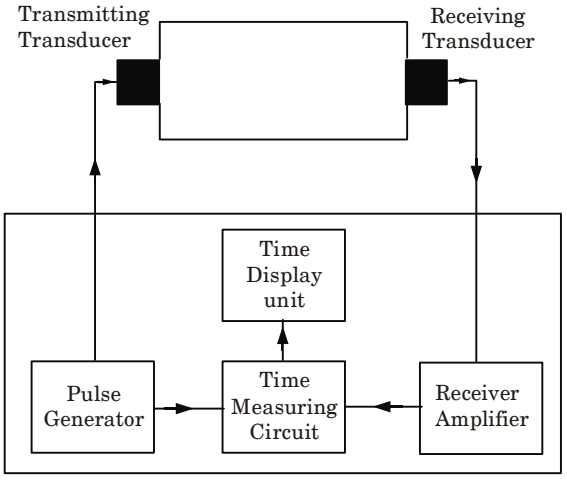

Fig. 2. Schematic of pulse velocity circuit.

b. What do you understand by carbonation of concrete ? How is it tested ?

Ans.

A. Carbonation of Concrete :

1. Carbonation occurs in concrete because the calcium bearing phases present are attacked by carbon dioxide of the air and converted to calcium carbonate.
2. Cement paste contains 25-50 % calcium hydroxide ($Ca(OH)_2$) by weight, which mean that the pH of the fresh cement paste is at least 12.5.
3. The pH of a fully carbonated paste is about 7.
4. The concrete will carbonate if CO_2 from air or from water enters the concrete according to:

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$$

5. When $Ca(OH)_2$ is removed from the paste hydrated CSH will liberate CaO which will also carbonate.
6. The rate of carbonation depends on porosity and moisture content of the concrete.
7. The carbonation process requires the presence of water because CO_2 dissolves in water forming H_2CO_3.
8. If the concrete is too dry (RH < 40 %) CO_2 cannot dissolve and no carbonation occurs.

9. If on the other hand it is too wet (RH > 90 %) CO_2 cannot enter the concrete and the concrete will not carbonate. Optimal conditions for carbonation occur at a RH of 50% (range 40-90 %).

B. Test of Carbonation of Concrete :

1. Carbonation may be recognized in the field by the presence of a discoloured zone in the surface of the concrete.
2. The colour may vary from light gray and difficult to recognize to strong orange and easy to recognize.
3. Carbonation can be visualized by using phenolphthalein.
4. In the optical microscope carbonation is recognized by the presence of calcite crystals and the absence of calcium hydroxide, ettringite and un-hydrated cement grains.

6. Attempt any **one** part of the following : **(7 × 1 = 7)**

a. Write a brief note on flexure strength of concrete.

Ans. **Flexure Strength of Concrete :**

1. The determination of flexural tensile strength is essential to estimate the load at which the concrete members may crack.
2. As it is difficult to determine the tensile strength of concrete by conducting a direct tension test, it is computed by flexure testing.
3. The flexural tensile strength at failure or the modulus of rupture is thus determined and used when necessary.
4. Its knowledge is useful in the design of pavement slabs and airfield runway as flexural tension is critical in these cases.
5. The modulus of rupture is determined by testing standard test specimens of 150 mm × 150 mm × 700 mm over a span of 600 mm or 100 mm × 100 mm × 500 mm over a span of 400 mm, under symmetrical two-point loading.
6. The modulus of rupture is determined from the moment at failures as $f_r = M/Z$.

b. Discuss the influence of mix proportions of concrete on shrinkage.

Ans. Following are the affecting factors of shrinkage :

1. **Type of Coarse Aggregates :** In general, concretes made with high moduli of elasticity non-shrinking aggregates will have low shrinkage.
2. **Shape of Aggregates :** The size and shape of coarse aggregate influence the loss of moisture and it has therefore an indirect effect on the shrinkage of concrete. In general, the smaller the aggregate size, the more surface area, more water is absorbed as a result and, therefore, more shrinkage.
3. **Hardness of Aggregates :** Harder aggregate with higher modulus of elasticity like quartz shrinks much less than softer aggregates such as sandstone.
4. **Effect of Admixtures :** Addition of calcium chloride increases the shrinkage of concrete generally between 10 to 50 % .The plasticizers

which reduce the water-cement ratio of the concrete, their net effect on shrinkage is negligible.

5. **Chemical Composition of Cement :** The chemical composition of cement has been observed as not having any effect on the shrinkage of concrete. However cement deficient in gypsum exhibits a greatly increased shrinkage.
6. **Effect of High Alumina Cement :** The shrinkage of concrete made with high alumina cement is of the same magnitude as that of concrete made with Portland cement, but in case of high alumina cement shrinkage takes place much more rapidly than when Portland cement is used.
7. **Water Content :** The water content affects the water-cement ratio hence higher the amount of water, greater the shrinkage as higher the water-cement ratio.
8. **Properties of Cement :** The properties of cement have little effect on the shrinkage of concrete. Fineness of cement has no influence on the shrinkage of concrete. However it increases the shrinkage of cement paste.
9. **Quality of Cement Paste :** The quality of cement paste influences the magnitude of shrinkage. The quality of cement pate is dependent on the water cement ratio. Higher the w/c ratio, greater the shrinkage,

7. Attempt any **one** part of the following : **(7 × 1 = 7)**

a. What is the need to study fiber reinforced concrete and explain briefly the factors effecting properties of fiber reinforced concrete ?

Ans.

A. Necessity of Fiber Reinforced Concrete :

1. It increases the tensile strength of the concrete.
2. It reduces the air voids and water voids the inherent porosity of gel.
3. It increases the durability of the concrete.
4. Fibers such as graphite and glass have excellent resistance to creep, while the same is not true for most resins.
5. The differential deformations of concrete and the reinforcement are minimized.
6. It has been recognized that the addition of small, closely spaced and uniformly dispersed fibers to concrete would act as crack arrestor and would substantially improve its static and dynamic properties.

B. Factors Affecting the Properties of FRC : Following are the factors affecting the properties of fibre reinforced concrete :

1. Volume of Fiber :

i. Low volume fraction (< 1%) : Used in slab and pavement that have large exposed surface leading to high shrinkage cracking.

ii. Moderate volume fraction (between 1 and 2 %) : Used in construction method such as shotcrete and in structures which requires improved capacity against delamination, spalling and fatigue.

iii. High volume fraction (> 2 %) : Used in making high performance fiber reinforced composites.

2. Aspect Ratio of Fiber :

i. It is defined as ratio of length of fiber to its diameter (L/d).

ii. Increase in the aspect ratio upto 75, there is increase in relative strength and toughness.

iii. Beyond 75 of aspect ratio, there is decrease in strength and toughness.

3. Orientation of Fibers : Fibers aligned parallel to applied load offered more tensile strength and toughness than randomly distributed or perpendicular fibers.

4. Relative Fiber Matrix :

i. Modulus of elasticity of matrix must be less than of fibers for efficient stress transfer.

ii. Low modulus fibers like Nylons and Polypropylene imparts more energy absorption while high modulus fibers (Steel, Glass, and Carbon) imparts strength and stiffness.

5. Workability and Compaction of Concrete : Incorporation of steel fiber decreases the workability considerably. This situation adversely affects the consolidation of fresh mix. Even prolonged external vibration fails to compact the concrete.

6. Size of Coarse Aggregate : Fibers also act as aggregate maximum size of the coarse aggregate should be restricted to 10 mm, to avoid appreciable reduction in strength of the composite.

7. Mixing : Mixing of fiber reinforced concrete needs careful conditions to avoid balling of fibers, segregation and in general the difficulty of mixing the materials uniformly.

b. Difference between high performance concrete and high density concrete.

Ans.

A. High Performance Concrete :

1. High performance concrete is a concrete mixture, which possess high durability and high strength when compared to conventional concrete.
2. This concrete contains one or more of cementitious materials such as fly ash, silica fume or ground granulated blast furnace slag and usually a super plasticizer.
3. High performance concrete has high strength and low permeability.
4. High performance concrete is not a special type of concrete. It comprises of the same materials as that of the conventional cement concrete.
5. The use of some mineral and chemical admixtures like silica fume and super plasticizer enhance the strength, durability and workability qualities to a very high extent.
6. It is used in high rise building column, off shore platforms and heavy-duty floors.

B. High Density Concrete :

1. Concrete having unit weight of 30 kN/m^3 to 64 kN/m^3 is called high density or heavy weight concrete.
2. Thus unit weight of high density concrete is more than about 25 percent higher than that of conventional concrete which is the range of 24 kN/m^3.
3. High density concrete can be produced by using different types of heavy weight aggregates.
4. High density concrete is used for construction of nuclear radiation shields walls, ballast blocks, counterweights, sea walls and other applications where high density is important.

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B.Tech.
(SEM. V) ODD SEMESTER THEORY EXAMINATION, 2019-20
CONCRETE TECHNOLOGY

Time : 3 Hours **Max. Marks : 70**

Note : Attempt **all** sections. If require any missing data; then choose suitably.

Section-A

1. Attempt **all** questions in brief. **(2 × 7 = 14)**

a. Write wet process of cement.

b. What are supplementary cementitious materials ?

c. Define creep of concrete ?

d. Write short note on cellular concrete.

e. What is durability of concrete ?

f. What are the statical methods of mix design ?

g. Define mix concrete.

Section-B

2. Attempt any **three** of the following : **(7 × 3 = 21)**

a. Write down the names of important compounds of cement and explain the influence of each on the properties of cement.

b. Differentiate between the controlled concrete and ordinary concrete.

c. Write the factors to be considered for a mix design.

d. Why it is necessary to add gypsum in the manufacturing of cement ?

e. Write the basic principle of ready mix concrete placement methods.

Section-C

3. Attempt any **one** part of the following : **(7 × 1 = 7)**

a. Classify the types of cement and explain air entraining cement.

b. Describe the sieve analysis to determine the fineness modulus of the aggregates.

4. Attempt any **one** part of the following : **(7 × 1 = 7)**

a. Write the advantages of addition of pozzolana as admixtures.

b. Describe characteristic of metakaolin on concrete properties.

5. Attempt any **one** part of the following : **(7 × 1 = 7)**

a. What data required for mix proportioning and explain target mean strength.

b. What are the role of water in concrete ? Explain what are the sources of aggregates ?

6. Attempt any **one** part of the following : **(7 × 1 = 7)**

a. Describe in detail Vee-Bee consistometer test to determine workability of concrete.

b. Define light weight concrete and explain in detail the classification of light weight concrete.

7. Attempt any **one** part of the following : **(7 × 1 = 7)**

a. Describe recycled aggregate concrete status in India.

b. What do you mean by fiber reinforced concrete and also explain factors affecting the properties of FRC.

SOLUTION OF PAPER (2019-20)

Note : Attempt **all** sections. If require any missing data; then choose suitably.

Section-A

1. Attempt **all** questions in brief. **(2 × 7 = 14)**

a. Write wet process of cement.

Ans. **Wet Process :**

i. In this process, the raw materials are changed to powdered form in the presence of water.
ii. In this process, raw materials are pulverized by using a ball mill, which is a rotary steel cylinder with hardened steel balls.
iii. When the mill rotates, steel balls pulverize the raw materials which form slurry (liquid mixture).
iv. The slurry is then passed into storage tanks, where correct proportioning is done.
v. Proper composition of raw materials can be ensured by using wet process than dry process.
vi. This process is generally used when raw materials are soft because complete mixing is not possible unless water is added.
vii. Corrected slurry is then fed into rotary kiln for burning.

The actual purpose of both processes is to change the raw materials to fine powder.

b. What are supplementary cementitious materials ?

Ans. **Supplementary Cementing Materials :** Supplementary cementing materials, also called mineral additives, contribute to the properties of hardened concrete through hydraulic or pozzolanic activity.Pozzolanic material can be divided into two groups :

1. Natural Pozzolana :

i. Clay and shales.
ii. Diatomaceous earth.
iii. Volcanic tuffs and pumicites.

2. Artificial Pozzolana :

i. Fly ash.
ii. Blast furnace slag.
iii. Silica fume.
iv. Rice husk ash.
v. Metakaoline.
vi. Surkhi.

c. Define creep of concrete ?

Ans. It may be defined as increase of strain in concrete with time sustained load. This is also known as plastic flow or time field.

d. Write short note on cellular concrete.

Ans. Cellular concrete is a lightweight cement-based material, containing many gas bubbles evenly distributed in the volume, produced by blending and maturing of a mixture of cement, filler, water, agent generating cells.

e. What is durability of concrete ?

Ans. **Durability :**

1. The durability of concrete is defined as its ability to resist weathering action, chemical attack, abrasion, or any other process of deterioration.
2. Durable concrete will retain its original form, quality, and serviceability when exposed to environment.

f. What are the statical methods of mix design ?

Ans. **Concrete Mix Design :** Mix Design is the science of determining the relative proportions of the ingredients of concrete to achieve the desired properties in the most economical way.

Methods of Mix Design : Following are the methods of mix design :

1. Nominal mixes.
2. Standard mixes.
3. Design mixes.

g. Define mix concrete.

Ans. **Concrete Mix Design :** It is a process of selecting suitable ingredients for concrete and determining their proportions which would produce, as economically as possible, *i.e.*, concrete having a certain minimum compressive strength, workability and durability.

Section-B

2. Attempt any **three** of the following : **(7 × 3 = 21)**

a. Write down the names of important compounds of cement and explain the influence of each on the properties of cement.

Ans.

A. Bogue's Compound of Cement : Following are the various Bogue's compound of cement :

1. Alite or $3CaO.SiO_2$ or C_3S :

i. It is responsible for early strength.
ii. First 7 days strength is due to C_3S.
iii. It produces more heat of hydration.
iv. A cement with more C_3S content is better for cold weather concreting.

2. Belite or $2CaO.SiO_2$ or C_2S :

i. The hydration of C_2S starts after 7 days. Hence it gives strength after 7 days.
ii. C_2S hydrates and hardens slowly and provides much of the ultimate strength.
iii. It is responsible for the later strength of the concrete.
iv. It produces less heat of hydration.

3. Celite or $3CaO.Al_2O_3$ or C_3A :

i. The reaction of C_3A with water is very fast.
ii. It may lead to an immediate stiffening of paste, and it is called flash set.
iii. To prevent this flash set, 2-3 % gypsum is added at a time of grinding cement clinker.
iv. The hydrated C_3A do not contribute to the strength of the concrete.
v. Low C_3A for sulfate resistance Cement.

4. Ferrite or $4CaO.Al_2O_3.Fe_2O_3$ or C_4AF :

i. C_4AF hydrates rapidly.
ii. It does not contribute to strength of the concrete.
iii. Controls the color of cement.

b. Differentiate between the controlled concrete and ordinary concrete.

Ans.

S. No.	Controlled Concrete	Ordinary Concrete
1.	A concrete with ingredient proportions fixed by designing the concrete mixes with preliminary test are called controlled concrete.	Ordinary concrete is one where nominal mixes are adopted.
2.	For making controlled concrete guideline are provided in IS 456 : 2000.	No provision about ordinary concrete in IS 456 : 2000.
3.	Controlled concretes have more durability and strength.	It is less durable and has less strength as compared to controlled concrete.
4.	It includes quality control.	There is no quality control.
5.	It includes more than M15 grades concrete.	It includes the M5 and M7.5 grade concrete.
6.	It is used in RCC works and specific purpose.	It is used for lean concrete bases, simple foundation and temporary construction works.

c. Write the factors to be considered for a mix design.

Ans. **Factors :** Following are the factors to be considered for a mix design :

1. Grade of Concrete :

i. The grade of concrete gives characteristic compressive strength of concrete.

ii. The grade M20 denotes characteristic compressive strength f_{ck} of 20 N/mm^2.

iii. Depending upon the degree of control available at site, the concrete mix is to be designed for a target mean compressive strength (f_{ck}) applying suitable standard deviation.

2. Type of Cement :

i. The higher the strength of cement used in concrete, lesser will be the cement content.

ii. The use of 43 grade and 53 grade of cement, gives saving in cement consumption as much as 15 % and 25 % respectively, as compared to 33 grade of cement.

3. Maximum Nominal Size of Aggregates :

i. It is designated by the sieve size higher than larger size on which 15 % or more of the aggregate is retained.

ii. The maximum nominal size of aggregate should not be more than one-fourth of minimum thickness of the member.

iii. For heavily reinforced concrete members as in the case of ribs of main beams, the nominal maximum size of the aggregate should usually be restricted to sum less than the minimum clear distance between the main bars or 5 mm less the minimum cover to the reinforcement, whoever is smaller.

4. Grading of Combined Aggregates :

i. The relative proportions of the fine and coarse aggregate in a concrete mix is one of the important factors affecting the strength of concrete.

ii. For dense concrete, it is essential that the fine and coarse aggregate be well graded.

5. Maximum Water/Cement Ratio : The lower the water/cement ratio, the greater is the compressive strength.

6. Workability : Workability of fresh concrete determines the case with which a concrete mixture can be mixed, transported, placed, compacted and finished without harmful segregation and bleeding.

7. Durability :

i. Durability require low water/cement ratio.

ii. It is usually achieved not by increasing the cement content, but by lowering the water demands at given cement content.

iii. Water demand can be lowered by through control of the aggregate grading and by using water reducing admixtures.

d. Why it is necessary to add gypsum in the manufacturing of cement ?

Ans. **Role of Gypsum in Cement :**

1. The main purpose of adding gypsum in the cement is to slow down the hydration process of cement once it is mixed with water.
2. The process involved in hydration of cement is that, when the water is added into cement, it starts reacting with the C_3A and hardens. The time taken in this process is very less, which does not allow time for transporting, mixing and placing.
3. When gypsum is added into the cement and water is added to it, reaction with C_3A particles takes place to form ettringite.
4. This ettringite is initially formed as very fine-grained crystals, which form a coating on the surface of the C_3A particles .These crystals are too small to bridge the gaps between the particles of cement. The cement mix therefore remains plastic and workable.
5. The time allowed for mixing, transporting and placing plays an important role in strength, composition and workability of concrete. As gypsum retards the process of hydration, it is termed as retarding agent of cement.

e. Write the basic principle of ready mix concrete placement methods.

Ans. Following are the basic principle of ready mix concrete placement methods :

1. When arriving to the site, the concrete transport certificate must be checked for desired characteristics of ordered concrete (quantity, class, maximum aggregate size, slump, temperature, type of cement etc.) and time duration of transport.
2. Concrete shall be delivered to the site and discharged from the truck completely and in the forms ready for vibration within 1-1/2 hours after batching
3. Concrete shall be placed in maximum 15 minutes after its arrival to the site, and the finishing of placement will take place before the cement starts setting.
4. Concrete shall be stored / deposited as near as (physically and economically) possible to its final position, in crane hoisted buckets, concrete pumps, chutes etc.
5. The receptacles used for the transport and deposition of concrete shall be cleaned and washed out at the end of each day's work and whenever concreting is interrupted for more than 30 minutes.
6. If the concrete, due to transport, is segregated. It should be mixed again on clean platforms, without adding water.
7. As placing begins the consistency of the delivered concrete should be checked with a slump cone for conformance with specifications and the required number of samples must be taken (1 sample = 3 specimens) according to the volume of concrete placed.
8. Concrete shall be placed to prevent segregation. The concrete shall not be permitted to strike against forms and ricochet on bars and form faces. The free fall of concrete should in no case exceed 1.5 m.

For greater heights, as in walls or columns, metal or rubber hoppers, chutes or flexible hoses must be lowered into the formwork to control the rate of fall of the concrete, if not the concrete will flow rapidly entering the forms invariably resulting separation and honeycombing.

9. When concrete is dumped from a cart or wheelbarrow, there is a tendency for the heavier particles to separate from the mass. To prevent this, the concrete should be discharged against a striking (baffle) board.

Section-C

3. Attempt any **one** part of the following : **(7 × 1 = 7)**

a. Classify the types of cement and explain air entraining cement.

Ans.

A. Types of Cement : Following are the various types of cements :

1. Sulphate Resisting Cement :

i. In this cement, the percentage of tricalcium aluminate C_3A is kept below 5 % and it results in the increase in resisting power against sulphates.

2. Rapid Hardening Cement :

i. The initial and final setting times of this cement are same as those of ordinary cement. But it attains high strength in early days.

ii. It contains high percentage of tricalcium silicate C_3S to the extent of about 56 %.

3. White Cement :

i. White cement is prepared from such raw materials which are practically free from colouring oxides of iron, manganese or chromium.

ii. It is white in colour and is used for floor finish, plaster work, ornament work, etc.

4. Coloured Cement :

i. The cement of desired colour may be obtained by intimately mixing mineral pigments with ordinary cement.

ii. The amount of coloring material may vary from 5 to 10 %.

iii. These types of coloured cement are widely used for finishing of floors, external surfaces, artificial marble, window sill slabs, textured panel faces, stair treads, etc.

S.No.	Pigment	Colour
1.	Chromium Oxide	Green
2.	Cobalt Imparts	Blue
3.	Iron Oxide in different proportion	Brown, Red, Yellow
4.	Manganese Dioxide	Black or Brown

5. Pozzolana Cement :

i. Pozzolana is a volcanic powder.

ii. This type of cement is used to prepare mass concrete of lean mix and for marine structures.

iii. It is also used in sewage works and for laying concrete under water.

6. Hydrophobic Cement :

i. It is manufactured by grinding ordinary portland cement clinker with 0.1 to 0.4 % of oleic acid, stearic acid or pentachlorophenol.

ii. This addition forms water repellent film around each particle by the moisture content of atmosphere.

iii. When concrete is prepared using this cement, the water repellent film breaks out which improves the workability of concrete.

7. Quick Setting Cement :

i. When concrete is to be laid under water, quick setting cement is to be used.

ii. This cement is manufactured by adding small percentage of aluminum sulphate (Al_2SO_4) which accelerates the setting action.

iii. The setting action of such cement starts with in 05 minutes after addition of water and it becomes stone hard in less than half an hour.

8. Low Heat Cement :

i. In this cement the heat of hydration is reduced by tricalcium aluminate (C_3A) content.

ii. It contains less percentage of lime than ordinary portland cement.

iii. It is used for mass concrete works such as dams etc.

9. High Alumina Cement :

i. This cement contains high aluminate percentage usually between 35-55 %.

ii. It gains strength very rapidly within 24 hours. It is also used for construction of dams and other heavy structures.

iii. It has resistance to sulphates and action of frost also.

B. Air Entraining Cement :

1. Air entraining cement is produced by grinding minute air entraining materials with clinker or the materials are also added separately while making concrete.
2. Entrainment of air also improves workability and durability. It is found that entrainment of air or gas bubbles while applying cement, increases resistance to frost action.
3. It is recommended that air contents should be 03-04 % by volume. Natural resins, fats, oils are used as air entraining agents.

b. Describe the sieve analysis to determine the fineness modulus of the aggregates.

Ans. Sieve Analysis :

1. This is the name given to the operation of dividing a sample of aggregate into various fractions each consisting of particles of the same size.
2. The sieve analysis is conducted to determine the particle size distribution in a sample of aggregate, which we call gradation.
3. The aggregates used for making concrete are normally of the maximum size 80 mm, 40 mm, 20 mm, 10 mm, 4.75 mm, 2.36 mm, 600 micron, 300 micron and 150 micron. The aggregate fraction from 80 mm to 4.75 mm is termed as coarse aggregate and the fraction from 4.75 mm to 150 micron is termed as fine aggregate.
4. The FM is an index of the fineness of the aggregate. The higher the FM the coarser the aggregate. FM of fine aggregate is useful in estimating proportions of fine and coarse aggregate in concrete mixtures.
5. The fineness modulus (FM) for both fine and coarse aggregates is obtained by adding the cumulative percentages by mass retained on each of a specified series of sieves and dividing the sum by 100.

$$FM = \frac{\Sigma \text{ (Cumulative \% retained on specified seive)}}{100}$$

Sand	Fineness Modulus
Fine	2.2 – 2.6
Medium	2.6 – 2.9
Coarse	2.9 – 3.2

4. Attempt any **one** part of the following : **(7 × 1 = 7)**

a. Write the advantages of addition of pozzolana as admixtures.

Ans. **Advantages of Pozzolanic Materials :** Following are the advantages of pozzolanic materials :

1. Lower the heat of hydration and thermal shrinkage.
2. Increase the water-tightness.
3. Reduce the alkali-aggregate reaction.
4. Improve resistance to attack by sulphate soils and sea water.
5. Improve extensibility.
6. Lower susceptibility to dissolution and leaching.
7. Improve workability.
8. Lower costs.

b. Describe characteristic of metakaolin on concrete properties.

Ans. **Characteristic of Metakaolin on Concrete Properties :** Following are the effect of metakaolin on concrete properties :

1. **Physical Properties of Cementititous Materials :** Specific gravity of cement is 3.09, whereas specific gravity of metakaolin is 2.50.

2. **Setting Times of Concrete :** Setting time of concrete mixture without metakaolin is 5 hrs 12 min and with 10 % metakaolin is 4 hrs 24 min.
3. **Mechanical Properties of Concrete :**

i. Compressive strength of concrete mixture without metakaolin is 20.9 MPa on 1st day and with 10 % metakaolin is 25.0 MPa on 1st day.
ii. Splitting tensile without metakaolin after 28 days is 2.7 MPa and splitting tensile with 10 and metakaolin after 28 days is 3.1 MPa.
iii. Flexural without metakaolin after 28 days is 6.3 MPa and flexural with 10 % metakaolin after 28 days is 7.4 MPa.

4. **Resistance to Chloride Ion Penetration (RCIP) :** RCIP without metakaolin after 28 days is 3175 coulombs and RCIP with 10 % metakaolin after 28 days is 390 coulombs.
5. **Resistance to Freezing and Thawing Cycles :**

i. Air content of concrete mixture without metakaolin is 6.6% and with 10 % metakaolin is 4.9 %.
ii. Durability factor without metakaolin is 98.3% and with 10 and metakaolin is 100.3 %.
iii. Residual flexural strength without metakaolin is 85 % and with 10 % metakaolin is 89 %.

6. Thus we can see that metakaolin improves most mechanical and durability properties of concrete.

5. Attempt any **one** part of the following : **(7 × 1 = 7)**

a. What data required for mix proportioning and explain target mean strength.

Ans.

1. **Required Data :** Following are the data required for mix proportioning :

i. Grade of concrete.
ii. Maximum size of aggregate.
iii. Minimum cement content.
iv. Maximum w/c ratio.
v. Workability in terms of slump.
vi. Exposure conditions.
vii. Maximum temperature at the pouring point.
viii. Early age strength (if required).
ix. Grading zone of the aggregate.
x. Type of aggregate.
xi. Maximum cement content.
xii. What kind of admixture is used – Brand name.
xiii. Specific gravity of all the materials used and dosage etc.

2. **Target Mean Strength of Concrete :** Target mean strength is denoted by f_t which is obtained by characteristic compressive strength of concrete at 28 days (f_{ck}) and value of standard deviation (σ)

$$f_t = f_{ck} + 1.65 \times \sigma$$

Standard deviation can be taken from below table 2.

Table 2.

Grade of Concrete	Standard Deviation (N/mm^2)
M10	3.5
M15	3.5
M20	4.0
M25	4.0
M30 ..... so on	5.0

b. What are the role of water in concrete ? Explain what are the sources of aggregates ?

Ans.

A. Role of Water in Concrete :

1. Water is the key ingredient, which when mixed with cement, forms a paste that binds the aggregate together.
2. The water causes the hardening of concrete through a process called hydration. Hydration is a chemical reaction in which the major compounds in cement form chemical bonds with water molecules and become hydrates or hydration products.
3. The role of water is important because the water to cement ratio is the most critical factor in the production of "perfect" concrete. Too much water reduces concrete strength, while too little will make the concrete unworkable.
4. Concrete needs to be workable so that it may be consolidated and shaped into different forms (*i.e.*, walls, domes, etc.). Because concrete must be both strong and workable, a careful balance of the cement to water ratio is required when making concrete.

B. Source of Aggregate :

1. Almost all natural aggregate materials from bed rocks.
2. There are three kinds of rocks, namely, igneous, sedimentary and metamorphic.
3. The igneous rocks are formed by the cooling of molten magma or lava at the surface of the crest (trap and basalt) or deep beneath the crest (granite).
4. The sedimentary rocks are formed originally below the sea bed and subsequently lifted up.
5. Metamorphic rocks are originally either igneous or sedimentary rocks which are subsequently metamorphosed due to extreme heat and pressure.

Aggregates from Igneous Rocks :

i. Most igneous rocks make highly satisfactory concrete aggregates because they are normally hard, tough and dense.

ii. The igneous rocks have massive structure, entirely crystalline or wholly glassy or in combination in between, depending upon the rate at which they where cooled during formation.

iii. They may be acidic or basic depending upon the percentage of silica content. They may occur light coloured or dark coloured.

iv. The igneous rocks as a class are the most chemically active concrete aggregate and show a tendency to react with the alkaline in cement.

v. As the igneous rock is one of the widely occurring type of rocks on the face of the earth, bulk of the concrete aggregates, that are derived, are of igneous origin.

Aggregates from Sedimentary Rocks :

i. Igneous rocks or metamorphic rocks are subjected to weathering agencies such as sun, rain and wind.

ii. These weathering agencies decompose, fragmentise, transport and deposit the particles of rock, deep beneath the ocean bed where they are cemented together by some of the cementing materials.

iii. The cementing materials could be carbonaceous, siliceous or argillaceous in nature. At the same time the deposited and cemented material gets subjected to static pressure of water and becomes compact sedimentary rock layer.

Aggregates from Metamorphic Rocks :

i. Both igneous rocks and sedimentary rocks may be subjected to high temperature and pressure which causes metamorphism which changes the structure and texture of rocks.

ii. The thickness of this foliation may vary from a few centimetres to many metres.

iii. If the thickness of this foliation is less, then individual aggregate may exhibit foliation which is not a desirable characteristic in aggregate.

iv. However, many metamorphic rocks particularly quartzite and gneiss have been used for production of good concrete aggregates.

6. Attempt any **one** part of the following : **(7 × 1 = 7)**

a. Describe in detail Vee-Bee consistometer test to determine workability of concrete.

Ans. **Vee-Bee Consistometer Test :**

1. The test is suitable for stiff concrete mixes having low or very low workability.
2. Compared to the slump and compacting factor tests, the Vee-Bee test has the advantage that the concrete in the test receives a treatment similar to what it would in actual practice.
3. The test consists of moulding a fresh concrete cone in a cylindrical container mounted on a vibrating table (Fig. 1).

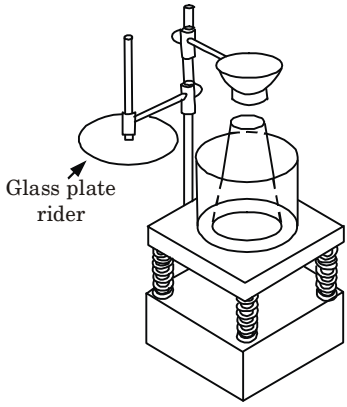

Fig. 1. Vee-Bee apparatus.

4. When the concrete cone is subjected to vibration using a standard vibrator, it starts to occupy the cylindrical container by way of getting remoulded.
5. The remoulding is considered complete when the concrete surface becomes horizontal.
6. The time (in seconds) required for the complete remoulding is considered as a measure of workability and is expressed as the number of Vee-Bee seconds.
7. The end point of the test, when the concrete surface becomes horizontal, has to be ascertained visually.

b. Define light weight concrete and explain in detail the classification of light weight concrete.

Ans.

A. Light Weight Concrete :

1. Light weight concrete mixture is made with a light weight coarse aggregate and sometimes a portion or entire fine aggregates may be light weight instead of normal aggregates.
2. Structural light weight concrete has an in-place density (unit weight) on the order of 1440 to 1840 kg/m^3.
3. Normal weight concrete a density in the range of 2240 to 2400 kg/m^3.
4. Light weight aggregates used in structural light weight 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.
5. There are other classes of non-structural LWC with lower density made with other aggregate materials and higher air voids in the cement paste matrix, such as in cellular concrete.

B. Classification of Light weight concrete : There are three broad classifications of light weight concrete based on the method employed for production.

1. **Light weight Aggregate Concrete :** In this method a porous light weight aggregate of low specific gravity instead of normal aggregate of specific gravity 2.6 is used.
2. **Aerated, Cellular, Foamed or Gas Concrete :** Large voids (Gas bubbles) are introduced into the concrete or mortar to produce a cellular mass.
3. **No-Fines Concrete :** In this method the fine aggregates are not used and only coarse aggregates are used in concrete as a result large voids are left reducing the density of concrete and hence the weight.

7. Attempt any **one** part of the following : **(7 × 1 = 7)**

a. Describe recycled aggregate concrete status in India.

Ans. **Indian Status :**

1. There is severe shortage of infrastructural facilities like houses, hospitals, roads etc. in India and large quantities of construction materials for creating these facilities are needed.
2. The planning commission allocated approximately 50 % of capital outlay for infrastructure development in successive 10th and 11th five year plans.
3. Rapid infrastructural development such as highways, airports etc. and growing demand for housing has led to scarcity and rise in cost of construction materials.
4. Most of waste materials produced by demolished structures disposed off by dumping them as landfill. Dumping of wastes on land is causing shortage of dumping place in urban areas. Therefore, it is necessary to start recycling and reuse of demolition concrete waste to save environment, cost and energy.
5. Central Pollution Control Board has estimated current quantum of solid waste generation in India to the tune of 48 million tons per annum out of which, waste from construction industry only accounts for more than 25 %. Management of such high quantum of waste puts enormous pressure on solid waste management system.
6. In view of significant role of recycled construction material and technology in the development of urban infrastructure.
7. The total quantum of waste from construction industry is estimated to be 12 to 14.7 million tons per annum out of which 7-8 million tons are concrete and brick waste.
8. According to findings of survey, 70 % of the respondent have given the reason for not adopting recycling of waste from construction industry is "Not aware of the recycling techniques" while remaining 30 % have indicated that they are not even aware of recycling possibilities.
9. Further, the user agencies/ industries pointed out that presently, the BIS and other codal provisions do not provide the specifications for use of recycled product in the construction activities.

b. What do you mean by fiber reinforced concrete and also explain factors affecting the properties of FRC.

Ans.

A. Fiber Reinforced Concrete : Concrete containing cement, water, aggregate, and discontinuous, uniformly dispersed or discrete fibers is called fiber reinforced concrete.

B. Factors Affecting the Properties of FRC : Following are the factors affecting the properties of fibre reinforced concrete :

1. Volume of Fiber :

i. Low volume fraction (< 1%) : Used in slab and pavement that have large exposed surface leading to high shrinkage cracking.

ii. Moderate volume fraction (between 1 and 2 %) : Used in construction method such as shotcrete and in structures which requires improved capacity against delamination, spalling and fatigue.

iii. High volume fraction (> 2 %) : Used in making high performance fiber reinforced composites.

2. Aspect Ratio of Fiber :

i. It is defined as ratio of length of fiber to its diameter (L/d).

ii. Increase in the aspect ratio upto 75, there is increase in relative strength and toughness.

iii. Beyond 75 of aspect ratio, there is decrease in strength and toughness.

3. Orientation of Fibers : Fibers aligned parallel to applied load offered more tensile strength and toughness than randomly distributed or perpendicular fibers.

4. Relative Fiber Matrix :

i. Modulus of elasticity of matrix must be less than of fibers for efficient stress transfer.

ii. Low modulus fibers like Nylons and Polypropylene imparts more energy absorption while high modulus fibers (Steel, Glass, and Carbon) imparts strength and stiffness.

5. Workability and Compaction of Concrete : Incorporation of steel fiber decreases the workability considerably. This situation adversely affects the consolidation of fresh mix. Even prolonged external vibration fails to compact the concrete.

6. Size of Coarse Aggregate : Fibers also act as aggregate maximum size of the coarse aggregate should be restricted to 10 mm, to avoid appreciable reduction in strength of the composite.

7. Mixing : Mixing of fiber reinforced concrete needs careful conditions to avoid balling of fibers, segregation and in general the difficulty of mixing the materials uniformly.

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