

# **ESE 2027**

# **Main Examination**

UPSC ENGINEERING SERVICES EXAMINATION

Topicwise

## **Conventional Practice Book**

## **Civil Engineering**

**PAPER-I**





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**ESE Main Examination • Conventional Practice Book :  
Civil Engineering PAPER-I**

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ESE 2027 Main Examination

# Conventional Practice Book

## Civil Engineering

## PAPER-I

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## 1. Cement

### Level-1

**1.1** Write short notes on the following:

- (a) Hydraulic cement and Non Hydraulic cement.
- (b) Flash set and false set of cement.

[10 Marks]

**Sol:**

**(a) Hydraulic Cement :** It sets and Hardness extremely fast in the presence of water and results in water resistant product which is stable. This allows setting in wet condition or under water and further protects the hardened material from chemical attack e.g. - Portland cement.

**Non Hydraulic Cement:** These are derived from calcination of gypsum or limestone because their products of hydration are not resistant to water. However the addition of pozzolanic materials can render gypsum and lime cement hydraulic. Thus it will not set in wet conditions or under water, rather it sets as it dries and reacts with carbondioxide in the air. Eg. - Plaster of Paris.

**(b) Flash set :** It is defined as the rapid development of permanent rigidity of the portland cement paste, mortar or concrete along with high heat evolution. This rigidity cannot be dispelled and plasticity can not be regained by further mixing without addition of water.

**False set :** It is rapid development of rigidity (Premature stiffening or hardening) in freshly mixed portland cement paste, mortar or concrete with no appreciable evolution of heat. Remixing (large amount of heat is produced in this process) the cement paste without addition of water restores the plasticity of the paste.

**1.2** Describe the various factors on which the hydration of cement depends and also show the relationship between rate of hydration of Bogue compounds.

[10 Marks]

**Sol:**

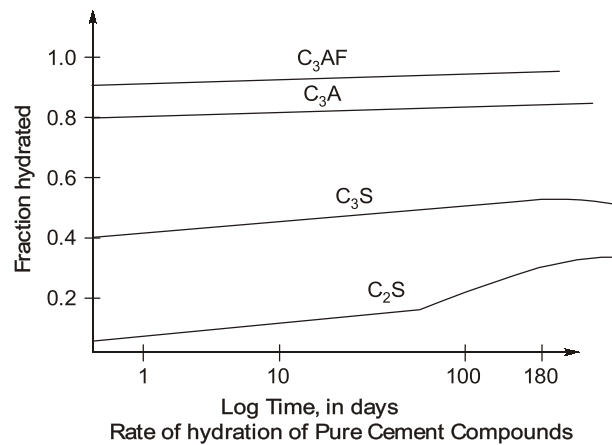
Hydration of cement depends on following factors :

- (i) **Temperature at which hydration takes place :** It is for this reason that in cold weather, sometimes the aggregates are heated before they are used for making concrete.
- (ii) **Fineness of cement :** Finer the cement, rapid is the hydration because finer cements have larger surface areas. However a very fine ground cement is susceptible to air set and deteriorates earlier.
- (iii) **The ingredients of cement :** The reaction can be made rapid or slow by changing the proportions of the ingredients of the cement.

**Rate of hydration of Bogue compounds :**

Bogue compounds of cement are  $C_3S$ ,  $C_2S$ ,  $C_3A$  and  $C_4AF$ . The rate of hydration is increased by an

increase in fineness of cement however, total heat evolved is same. The rate of hydration of the bogue compounds is shown in figure and will be in the following descending order.



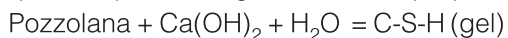
### 1.3 Explain Pozzolanic action.

[5 Marks]

Sol:

#### Pozzolanic action

Pozzolana is a siliceous or siliceous and aluminous material which as such does not have cementitious properties. It reacts with calcium hydroxide in the presence of water at room temperature through a reaction called pozzolanic reaction to form insoluble calcium silicate hydrate and calcium aluminate hydrate compounds possessing cementitious properties. The reaction can be written as



It is firstly slow and hence heat of hydration and strength development will be accordingly slow. The reduction of  $\text{Ca(OH)}_2$  improves the durability of cement paste by making the paste dense and impervious. It also reduces the expansion caused by alkali-aggregate reaction in concrete.

### 1.4 Describe briefly the air permeability method and Wagner turbidimeter test to check the fineness of cement.

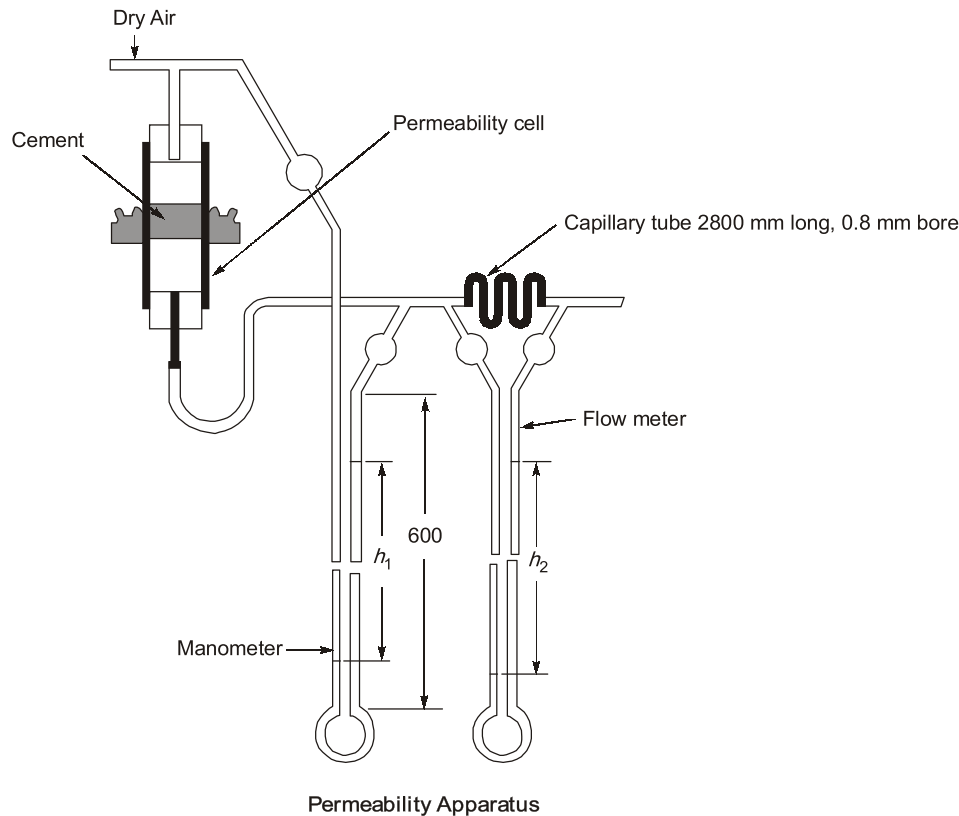
[10 Marks]

Sol:

**Air Permeability Method :** The fineness of cement is represented by specific surface, i.e. total surface area in  $\text{cm}^2$  per gram or  $\text{m}^2$  per kilogram of cement and is measured by Lea and Nurse apparatus or by Wagner turbidimeter.

The Lea and Nurse apparatus shown in figure essentially consists of a permeability test cell - where cement is placed and air pressure is applied, flow meter - to determine the quantity of air passing per second through its capillary tube per unit difference of pressure and manometer - to measure the air pressure.

**Wagner Turbidimeter Method :** L.A. Wagner developed a turbidimeter to estimate the surface area of one gram of cement. The cement is dispersed uniformly in a rectangular glass tank filled with kerosene. Then, parallel light rays are passed through the solution which strike the sensitivity plate of photoelectric cell. The turbidity of the solution at a given instant is measured by taking readings of the current generated by the cell. By recording the readings at regular intervals while the particles are falling in the solution, it is possible to secure information regarding the grading in surface area and in size of particle. Readings are expressed in sq. cm per gram.



## Level-2

**1.5** Name the four important constituents of cement and state the role of each in achieving its properties.

[15 Marks]

**Sol:**

The four important constituents of cement are:

- |                                                     |                                                         |
|-----------------------------------------------------|---------------------------------------------------------|
| (i) Lime ( $\text{CaO}$ ) – 60 to 67%               | (ii) Silica ( $\text{SiO}_2$ ) – 17 to 25%              |
| (iii) Alumina ( $\text{Al}_2\text{O}_3$ ) – 3 to 8% | (iv) Iron oxide ( $\text{Fe}_2\text{O}_3$ ) – 0.5 to 6% |

All these oxides interact with one another in the kiln at high temperature to form more complex compounds. The relative proportions of these oxides compositions are responsible for influencing the various properties of cement in addition to rate of cooling and fineness of grinding. The complex compounds which are formed due to the combination of these oxides are called **Bogue's compounds** and four of them are usually regarded as major compounds. They are tricalcium silicate ( $\text{C}_3\text{S}$ ), dicalcium silicate ( $\text{C}_2\text{S}$ ), tricalcium aluminate ( $\text{C}_3\text{A}$ ) and tetra calcium aluminoferrite ( $\text{C}_4\text{AF}$ ).

The two silicates namely  $\text{C}_3\text{S}$  and  $\text{C}_2\text{S}$  which together constitute about 70 to 80 per cent of the cement control the most of the strength giving properties. Upon hydration, both  $\text{C}_3\text{S}$  and  $\text{C}_2\text{S}$  give the same product called calcium silicate hydrate ( $\text{C}_3\text{S}_2\text{H}_3$ ) and calcium hydroxide.  $\text{C}_3\text{S}$  giving a faster rate of reaction accompanied by a greater heat evolution develops early strength. On the other hand,  $\text{C}_2\text{S}$  hydrates and hardens slowly and provides the ultimate strength. But the hydration of  $\text{C}_3\text{S}$  liberates nearly three times as much calcium hydroxide as compared to  $\text{C}_2\text{S}$ . That's why  $\text{C}_2\text{S}$  provides more resistance to chemical attack.

The compound tricalcium aluminate ( $\text{C}_3\text{A}$ ) is characteristically fast reacting with water and may lead to an immediate stiffening of paste, and this process is termed as **flash set**. The role of gypsum added in the manufacture of cement is to prevent such a fast reaction. The hydrated aluminates do not contribute

anything to the strength of concrete. On the other hand, their presence is harmful to the durability of concrete particularly where the concrete is likely to be attacked by sulphates. As it hydrates fast it may contribute a little to the early strength.

On hydration,  $C_4AF$  is believed to form a system of the form  $CaO-Fe_2O_3-H_2O$ . A hydrated calcium ferrite of the form  $C_3FH_6$  is comparatively more stable. This hydrated product also does not contribute anything to the strength. The hydrates of  $C_4AF$  show a comparatively higher resistance to the attack of sulphates than the hydrates of calcium aluminate.

- The raw materials used for the manufacture of cement consist mainly of lime, silica, alumina and iron oxide.
- These oxides when subjected to high clinkering temperature combine with each other to form complex compounds.
- The identification of major complex compounds is based on R.H. Bogue's work and hence these are called Bogue's compound.

There are 4 Bogue's compounds:

#### 1. Tricalcium Silicate ( $C_3S$ )

Chemical formula :  $3CaOSiO_2$

Percentage : 30 - 50%

- It undergoes hydration within a week and is responsible for development of early strength in cement.
- It is the best cementing material and is well burnt.
- Increases resistance to freezing and thawing.
- Renders the clinker easier to grind.
- Its proportion can be increased where early gain of strength is required.

*Example* : Emergency repair work, cold weather concreting, prefabricated construction, etc.

#### 2. Dicalcium silicate ( $C_2S$ )

Chemical formula :  $2CaOSiO_2$

Percentage : 20-45%

- It hydrates and hardens slowly and takes long time to add to strength (1 year or more).
- Imparts resistance to chemical attack.
- Proportion is increased when early strength is not required and higher heat of hydration should not be there.

*Example* : Dam or Bridge construction.

#### 3. Tricalcium Aluminate ( $C_3A$ )

Chemical formula :  $3CaOAl_2O_3$

Percentage : 8-12%

- Responsible for flash set of cement as it undergoes hydration within 24 hours after water addition.
- Highest heat of hydration and tendency to volume changes causing cracking.
- If present in higher amount, resistance to sulphate attack decreases.

#### 4. Tetra calcium Alumino Ferrite ( $C_4AF$ )

Chemical formula :  $4CaOAl_2O_3Fe_2O_3$

Percentage : 6-10%

- Responsible for flash set but generates less heat.
- Poorest cementing value.
- Raising its content reduces the strength slightly.

**1.6** Write short notes on the following :

- (i) High Alumina Cement
- (ii) Quick Setting Portland Cement
- (iii) Portland Slay Cement
- (iv) Low Heat Portland Cement

[20 Marks]

**Sol:**

**(i) High Alumina Cement :**

- The raw material used for its manufacture consists of 40% bauxite, 40% lime and 15% iron oxide with a little percentage of ferric oxide and silica, magnesia etc. ground finely at a very high temperature.
- Since  $C_3A$  is not present, the cement has good resistance against attack by sulphate and some dilute acids and is particularly suitable for sea and under water work.
- High Alumina Cement has very high early compressive strength and has high heat of hydration in comparison to OPC 43 grade.
- High Alumina Cement has initial setting time of about 3.5 - 4 hours and final settling time of 5 - 5.5 hours.
- It should not be used in places where temperature exceeds  $18^\circ\text{C}$  and it is extremely resistant to action of fire, chemical attack, sea water, acidic water and sulphates.
- It is preferred for use in cold region due to high heat of hydration.

**(ii) Quick Setting Portland Cement :**

- In the manufacture of this cement, gypsum content is reduced to get the quick setting property. Also small amount of aluminium sulphate is added.
- It is ground much finer than OPC.
- It sets quickly but does not hardens quickly.
- Initial setting time = 5 minutes.
- Final setting time = 30 minutes.
- It is used when concrete is to be laid under water or in running water.

**(iii) Portland Slay Cement :**

- It is made by intergrinding portland cement clinker ( $\neq 35\%$ ) and granulated blast furnace slag (which is a waste product in the manufacture of pig iron) and gypsum.
- Properties of these slag cements are similar to those of OPC but they have a lower lime and higher silica and alumina content.
- Blast furnace slag cement is less reactive than OPC and gain strength a little more slowly during the first 28 days. It has high percentage of  $C_3S$ .
- It has high sulphate resistance rendering it suitable for use in environments exposed to sulphate.
- Due to low heat of hydration, it can also be used for mass concreting e.g. dams, foundations etc.

**(iv) Low Heat Portland Cement :**

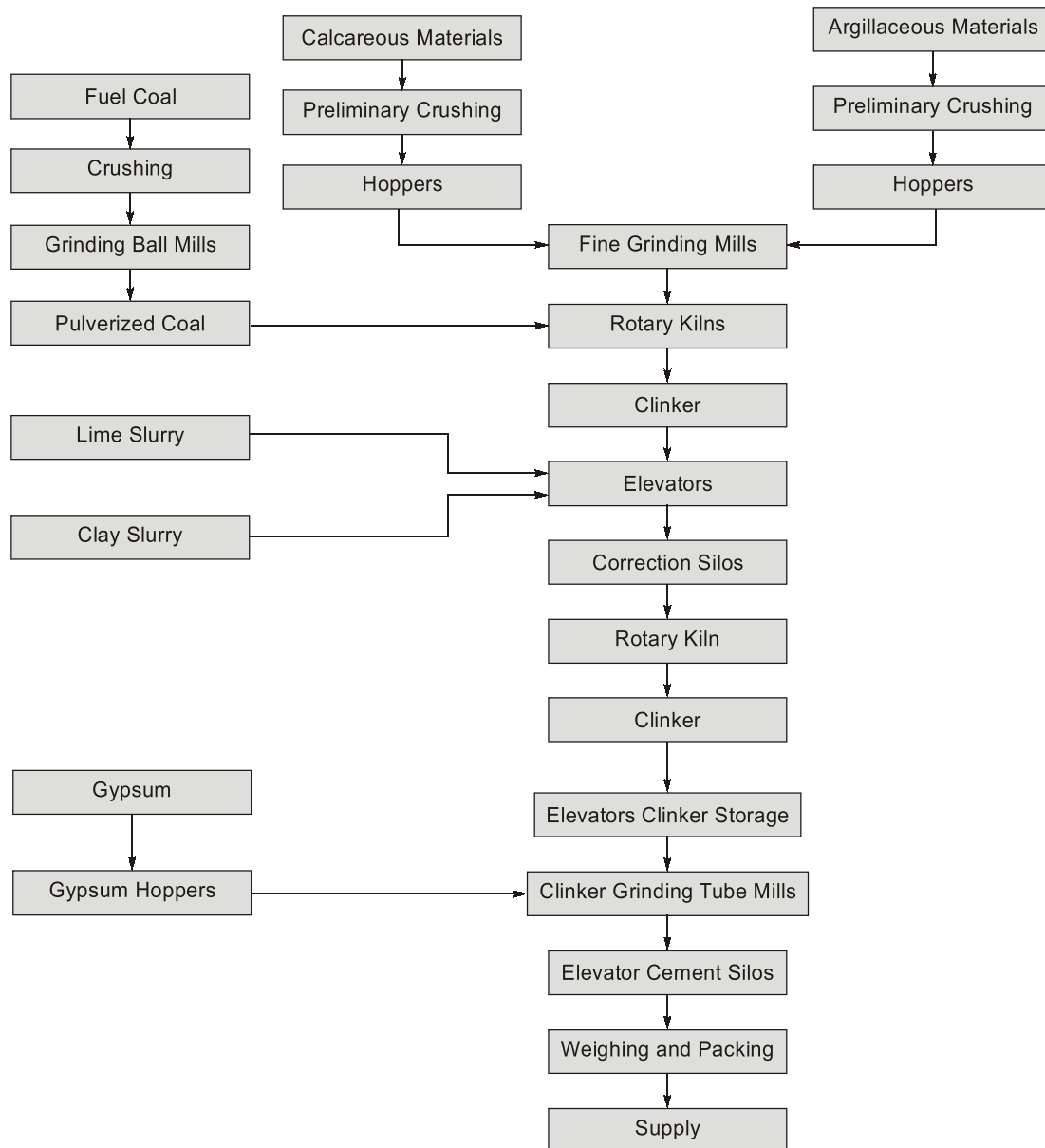
- It is a Portland cement with relatively lower contents of the more hydrating compounds  $C_3S$  and  $C_3A$  and more content of  $C_2S$ .
- This is desirable in mass concreting of gravity dams.
- It is helpful in preventing shrinkage at higher temperature.
- Rate of development of strength is slow but the ultimate strength is same as that of OPC.

1.7 Draw flow diagram of dry process and wet process of manufacturing of cement.

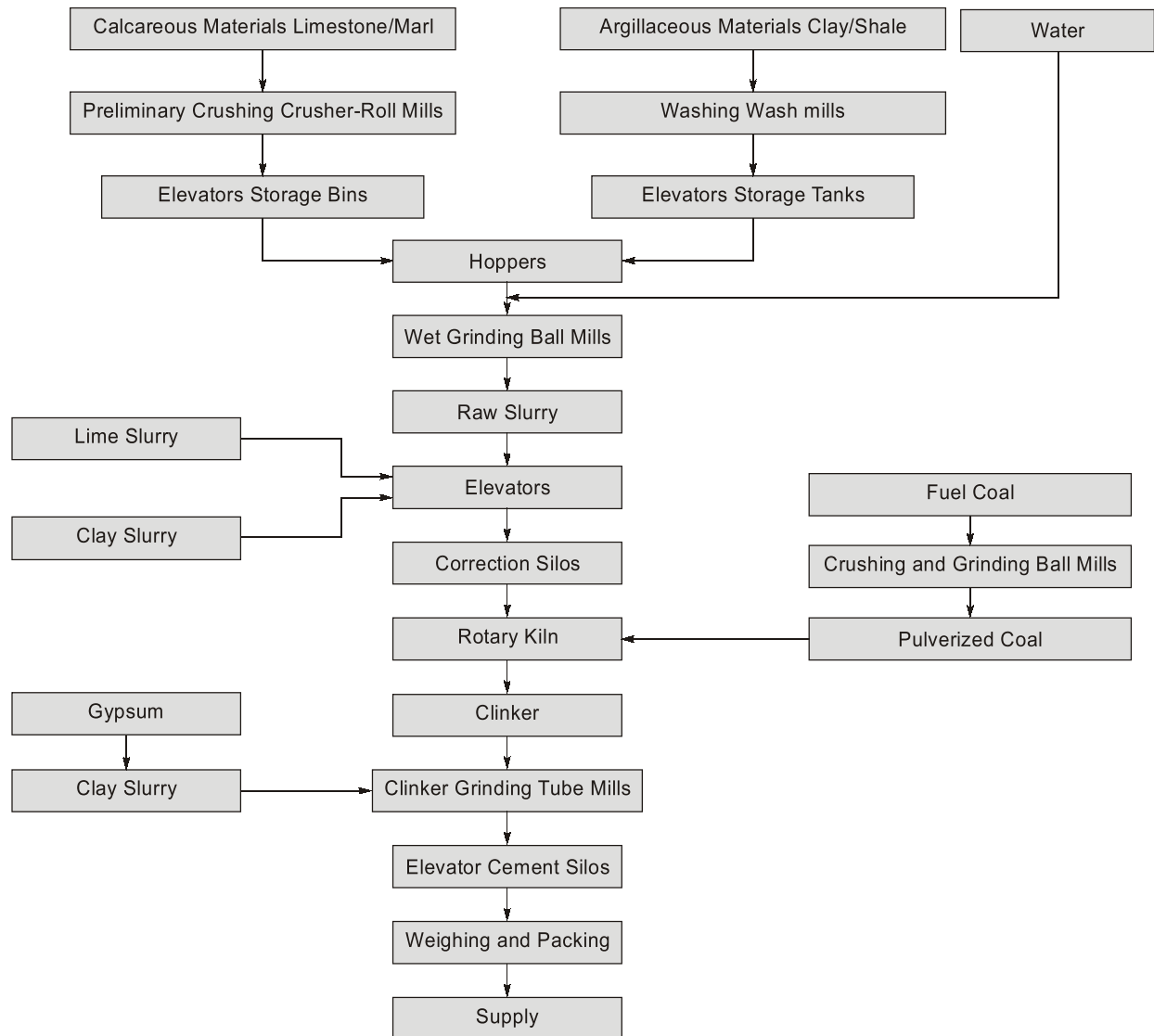
[20 Marks]

Sol:

Dry Process:



Flow Diagram of Cement Manufacture - Dry Process

**Wet Process:**

Flow Diagram of Cement Manufacture - Wet Process

**1.8** List the various laboratory tests for assessing the quality of cement and their importance.

[15 Marks]

**Sol:**

The various tests done to determine the quality of cement are as follows:

**A. Fineness test**

1. The fineness of cement has an important bearing on the rate of hydration and hence on the rate of gain of strength and also on the rate of evolution of heat. Finer cement offers a greater surface area for hydration and hence faster the development of strength.
2. Increase in fineness of cement is also found to increase the drying shrinkage of concrete.
3. Fineness of cement is tested in two ways :
  - (a) **By sieving** : The principle is that, we determine the proportion of cement whose grain size is larger than specified mesh size.

(b) **By determination of specific surface area** (total surface area of all the particles in one gram of cement) by air-permeability apparatus. Expressed as  $\text{cm}^2/\text{gm}$  or  $\text{m}^2/\text{kg}$ . Generally, Blaine Air permeability apparatus is used.

4. Maximum number of particles in a sample of cement should have a size less than about 100 microns. The smallest particle may have a size of about 1.5 microns. By and large an average size of the cement particles may be taken as about 10 micron.

#### **B. Setting Time Test**

1. The significance of initial and final setting times is in the construction industry. There are various time bound factors involved in cement work such as mixing, transportation, laying, compacting and finishing, which will be facilitated only if cement or concrete is in plastic condition. For this purpose the initial setting time of concrete is determined.
2. Simultaneously, it is also very important that once the concrete is compacted and finished, it attains its firmness as soon as possible to avoid damages from external forces, bringing final setting time into the picture.
3. Vicat's apparatus is used to find these parameters.

#### **C. Compressive Strength Test**

1. The compressive strength of hardened cement is the most important and most specified of all the properties.
2. Therefore cement is always tested for this strength before employing it for important works.
3. Before starting any project, concrete mix designs are prepared in the lab in accordance with the properties of available materials. For checking the applicability and suitability of these designs, this test is used.
4. It is also employed to check the strength of concrete ready for dispatch from the batching plant.

#### **D. Soundness Test**

1. It is very essential that the cement after setting shall not undergo any appreciable change in volume, because change in volume after setting of cement causes :
  - Cracks
  - Undue expansion which results in disintegration of concrete
  - Adverse effect on durability
2. It can be tested with Le-Chatelier method or by autoclave method.
3. Le-Chatelier method is used in case of unsoundness due to free lime only as it does not indicate the presence and after effects of excess of Magnesia.
4. For magnesia content exceeding 3%, Autoclave test has to be used as it is sensitive to both free lime and magnesia.

#### **E. Heat of Hydration Test**

1. It is estimated that exothermic reaction of cement with water generates about 120 calories of heat for 1 gram of cement.
2. A temperature rise of about  $50^\circ\text{C}$  is observed in the interior of mass concrete dam. This can cause serious expansion of the body of the dam and subsequent cooling will cause shrinkage which can lead to serious cracking of concrete.
3. So test of heat of hydration is essentially required for low heat cements.
4. This is carried out over a few days by vacuum flask methods, or over longer periods in adiabatic calorimeter.

#### **F. Chemical Composition Test**

1. Cement mainly consists of lime, silica, alumina and iron oxide.
2. Their relative proportions greatly influence the various properties of cement.
3. So it is of vital importance to carry out chemical composition tests in laboratory.

## 2. Concrete

### Level-1

**2.1** What is curing? What is its significance ? Describe any one method of curing.

[8 Marks]

**Sol:**

Curing is name given to procedures that are employed for actually, promoting the hydration of cement in a suitable environment during early stages of hardening of concrete.

IS 456 define curing as the process of preventing the loss of moisture from the concrete while maintaining a satisfactorily temperature regime.

**Objectives of curing :**

- (i) To keep capillary pores saturated, to ensure hydration of cement, to increases durability, impermeability of concrete and reduce the shrinkage.
- (ii) It improves wear resisting and weather resisting qualities.
- (iii) To prevent the loss of moisture from concrete due to evaporation or any other reason, supply additional moisture or heat and moisture to accelerate the gain of strength.

**Electrical curing**

Concrete products can be cured by passing alternating current of low voltage and high ampere through electrodes in the form of plates covering the entire area of two opposite faces of concrete. Potential difference between 30 V and 60 V is generally adopted. Evaporation is prevented by using an impermeable rubber membrane on the top surface of the concrete. By electrical curing, concrete can attain the normal 28 days strength in a period of 3 days.

**2.2** Write short notes on the following

- (a) Steam curing
- (b) Maturity of concrete

[8 Marks]

**Sol:**

**(a) Steam curing :**

- For concrete mixes with water-cement ratio ranging from 0.3 to 0.7, the increased rate of strength development can be achieved by resorting to steam curing.
- Concrete members are heated by steam at 93°C either at low pressure or high pressure.
- It reduces shear strength of concrete.
- It results in increased resistance to sulphate action and to freezing and thawing.
- Rate of increase or decrease of temperature should not exceed 10°C to 20°C per hour to avoid thermal shocks.
- Steam curing should be followed by water curing for a period of atleast 7 days.

**(b) Maturity of concrete :**

- The strength of concrete depends on both period of curing (i.e. age) and temperature during curing.
- The product (Period × Temperature) is called the maturity of concrete.
- It is measured in °C hours or °C days.
- The maturity of concrete is defined as the summation of product of time and temperature.
- Maturity =  $\sum (\text{Time} \times \text{Temperature})$

**2.3** Write short notes on the following.

- |                           |                           |
|---------------------------|---------------------------|
| (a) Heavy Weight Concrete | (b) Light Weight Concrete |
| (c) Foam Concrete         | (d) Polymer Concrete      |

[8 Marks]

**Sol:**

- (a) **Heavy weight concrete** : These concretes are made with specially selected heavy weight aggregate to obtain a density higher than  $3000 \text{ Kg/m}^3$ . They can be used for gravity dams, retaining wall and special atomic power plants.
- (b) **Light Weight Concrete** : These concretes are made with artificially produced aggregate to obtain a density less than  $1800 \text{ Kg/m}^3$ . The strength can be as high as 50 MPa.
- (c) **Foam Concrete** : It is also referred to as aerated concrete. It is very light weight concrete consisting of cellular structure with bubbles of gas made with the help of a suitable admixture.
- (d) **Polymer Concrete** : The mechanical properties and durability of concrete can be improved by filling the pores, voids and cracks by using polymers with concrete.
- Polymer concrete composites are obtained by processing polymeric materials with some or all of the ingredients of the cement concrete composition.
  - A polymer concrete can be classified depending on the process by which the polymeric materials are incorporated in concrete.
    - I. Polymer Concrete or Resin concrete
    - II. Polymer Impregnated concrete.
    - III. Latex modified concrete.

**2.4** Can sea water be used for making concrete? Elaborate your answer.

[10 marks]

**Sol:**

(i) **Sea water for making concrete**

It is advisable to use clean water which is fit for drinking purpose for making cement concrete. However, at places where sea water is available in abundance and potable water is costly, sea water can be used for making cement concrete. The problem of using sea water for making cement concrete has to be studied from the following two aspects:

- (a) Strength
- (b) Corrosion of reinforcement

(a) **Strength**: Sea water contains about 3.50 per cent of dissolved salts. The approximate percentage of various salts are 78 percent of sodium chloride, 15 percent of magnesium chloride and magnesium sulphate and the rest 7 percent of calcium sulphate, potassium sulphate, etc. Now, all chlorides tend to accelerate the setting of cement and to improve the strength of concrete in early stages. On the other hand, sulphates tend to retard the setting of cement and to discourage the strength of concrete in early stages. It is found that the net effect of these two contradictory actions is the fall in strength of concrete to the tune of about 8 to 20 percent. Hence sea water can be used for making cement concrete for structures where such fall in strength is permissible or where it is possible to correct the same by adjusting water-cement ratio, cement content in concrete, etc.

Sea water tends to develop dampness and efflorescence. Hence, it can be adopted for concrete structures where finishing characteristics are not important or where persistent dampness of surface is permissible.

- (b) **Corrosion of reinforcement:** It is found that sea water does not lead to corrosion of reinforcement, provided concrete is designed for this aspect and there is enough cover to the reinforcement. The minimum cement content for concrete permanently under sea water should be 300 kg per m<sup>3</sup> and the minimum cover to the reinforcement should be 75 mm. However, it is not advisable to take the risk of corrosion of reinforcement for prestressed concrete and hence, sea water should not be used for making prestressed concrete.

**2.5** Explain the five key modification for concrete mix design in IS 10262 : 2009 comparing to IS 10262 : 1982.

[10 Marks]

**Sol:**

(1) **Title of the code :**

**IS 10262 : 1982 :** Recommended guideline for concrete mix design.

**IS 10262 : 2009 :** Concrete mix proportioning guidelines.

(2) **Strength and durability :** The 1982 version considers strength as the governing criteria for durability and so also for the mix design process. But according to the revised one strength may be a factor for acceptance but may not assure durability.

(3) **Air content :** IS 10262 : 1982 considers expected air content of 1% to 3% in the design process depending on the nominal maximum size of aggregates.

**IS 10262 : 2009** eliminates consideration of air content in the mix proportion calculation as its not of much significance.

(4) **Water cement ratio :** The old version suggested that selection of preliminary free water cement ratio may be adopted from established relationship presented in the form of graph as generalized water cement ratio curves for different cement strengths. The selected water cement ratio is to be checked against limiting water cement ratio for durability.

The revised version encourages establishing the relationships for actually used material. Otherwise it suggests to consider it from the specified table 5 of IS 456 for desired exposure condition as preliminary water cement ratio that has to be further checked for limiting value ensuring durability.

(5) **Measure of workability :** **IS 10262 : 1982** considers compaction factor as the measurement of workability, in revised one, slump is considered as the measure of workability.

**2.6** Write a short note on Ultrasonic Pulse Velocity Test. Also discuss its advantage and disadvantage.

[12 Marks]

**Sol:**

- The test is based on the principle that velocity of sound in a solid material is a function of  $\sqrt{\frac{E}{\rho}}$ , where  $E$  is modulus of elasticity and  $\rho$  is density.
- An ultrasonic pulse apparatus consists of a transmitter and a receiver which are held against the faces of concrete.
- The apparatus generates pulse of ultrasonic frequency which are transmitted through concrete by the transmitter. On the other face, the receiver receives the pulse and the apparatus record them.
- The velocity of pulse is found which is correlated to the strength of the concrete.
- Higher the velocity of pulse, greater is the strength of concrete.
- It is only one of the dynamic test that shows the potential concrete strength in-situ.

**Advantages :**

- Can be used for existing structure and those under construction.
- Establishes Uniformity of concrete.

3. Determines modulus of Elasticity.
4. Detection of cracks.

**Disadvantages :**

1. Holes have to be cut in the formwork so that transducers can be in direct contact with the concrete surface.
2. As concrete ages, the rate of increase of pulse velocity slows down much more rapidly than the rate of development of strength.
3. Accuracy depends on the careful calibration as well as on the use of the same concrete mix proportions and aggregate in making the test samples used for calibration as in the structure.

**2.7 (i) What is Gel-space Ratio?**

**(ii) What are problems encountered for concreting in hot climate?**

[6 + 6 marks]

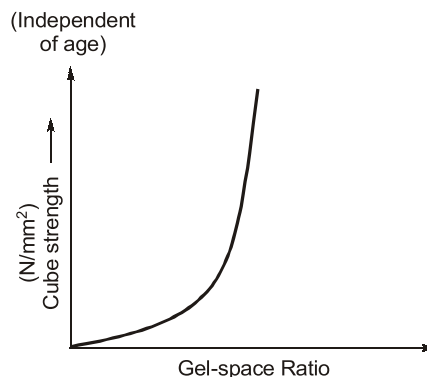
**Sol:**

- (i) **Gel-space Ratio :** Gel-space ratio is defined as the ratio of volume of hydrated cement paste to the sum of the volumes of the hydrated cement and that of the capillary pores. A typical curve relating gel-space ratio and compressive strength of concrete is shown which is given by.

$$S = 240x^3$$

where  $S$  = Strength of concrete  $\text{N/mm}^2$

$x$  = Gel-space ratio



- (ii) **Concreting in hot weather poses some special problems such as,**

- Strength reduction
- Cracking of flat surfaces due to too rapid drying.

Concrete that stiffens before consolidation is caused by too rapid setting of cement and too much absorption and evaporation of mixing water. This leads to difficulty in finishing flat surfaces. Therefore, limitations are imposed on placing concrete during hot weather and on the maximum temperature of the concrete; quality and durability suffer when concrete is mixed, placed and cured at high temperature.

**2.8 State the important properties of concrete which govern the design of concrete mix. Explain them in brief.**

[12 marks]

**Sol:**

**Important properties of concrete governing design of concrete mix:**

- (a) **Grade of Concrete :** The grade M20, M25 etc. connotes the characteristic strength,  $f_{ck}$  of  $20 \text{ N/mm}^2$ ,  $25 \text{ N/mm}^2$  respectively and the corresponding target mean strength is based on degree of control to be exercised at site.

- (b) *Type of cement*: The grade of OPC such as 33, 43 or 53 grade or PPC to relevant specification affects the design mix.
- (c) *Type and size of aggregate* : Natural sand, crushed stone, gravel etc. conforming to IS : 383-1970 quoting source of supply.
- (d) *Nominal maximum size of aggregate*: 40, 20 mm, 10 mm as per **IS : 383-1970**.
- (e) *Type of mixing and curing water* : This is required for durability consideration.
- (f) *Maximum free water/cement ratio by weight* : Whether fresh potable water, seawater, ground water to be used.
- (g) *Degree of workability* : This is dependent on placing and compaction condition.
- (h) *Air content and type of admixture* : This is inclusive of entrained air.
- (i) *Maximum/minimum density of concrete* : These are considered in design of concrete mix.
- (j) Maximum/minimum temperature of fresh concrete.

## Level-2

**2.9** Discuss in brief the various operations involved in production of concrete.

[12 marks]

**Sol:**

The various operations in production of concrete include:

- **Storing of materials** : In general, cement should be stored in such a way that it does not come in contact with moisture. All aggregates must be clean and free from dust, dirt, mud, silt, clay etc. There should not be presence of vegetable matter and animal refuse. These impurities do not allow the proper bond between cement paste and aggregates, consequently the strength of concrete gets reduced. The aggregate should be stored on hard and dry base or on platforms of planks, GI sheets etc. Different size of aggregates should be piled separately by constructing different compartments. Water for concrete mixing at site should be stored in masonry built tanks or other clean containers. The tanks should be always thoroughly and regularly cleaned and water should not be stored over a longer period but stored a day in advance only.
- **Batching or measurement of materials** : A proper and accurate measurement of all the materials used in the production of concrete is essential to ensure uniformity of proportions and aggregate grading in successive batches. For most of the large and important jobs the batching of materials is usually done by weighing. In weigh batching, the weight of surface water carried by the wet aggregates must be taken into account. The factors affecting the choice of proper batching system are: (i) size of job, (ii) required production rate, and (iii) required standards of batching performance. The batching equipment falls into three general categories, namely, manual, semi-automatic and fully automatic systems.
- **Mixing of concrete materials** : The object of mixing is to coat the surface of all aggregate particles with cement paste and to blend all the ingredients of concrete into a uniform mass. The mixing action of concrete thus involves two operations : (i) a general blending of different particle sizes of the ingredients to be uniformly distributed throughout the concrete mass, and (ii) a vigorous rubbing action of cement paste on to the surface of the inert aggregate particles. Concrete mixing is normally done by mechanical means called mixer, but sometimes the mixing of concrete is done by hand. Machine mixing is more efficient and economical as compared to hand mixing.
- **Transportation of concrete** : Concrete from the mixer should be transported to the point where it has to be placed as rapidly as possible by a method which prevents segregation or loss of ingredients. The concrete has to be placed before setting has commenced. Attempts have been made to limit the time