POSTAL BOOK PACKAGE 2025

CIVIL ENGINEERING

CONVENTIONAL Practice Sets

CONTENTS

CONSTRUCTION MATERIALS

1 CHAPTER

Cement

Q.1 Name the four important constituents of cement and state the role of each in achieving its properties.

Solution:

The four important constituents of cement are:

(i) Lime (CaO) – 60 to 67%
(ii) Silica (SiO_2) – 17 to 25%
(iii) Alumina (Al_2O_3) – 3 to 8%
(iv) Iron oxide (Fe_2O_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 oxide 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 (C_3S), dicalcium silicate (C_2S), tricalcium aluminate (C_3A) and tetra calcium aluminoferrite (C_4AF).

The two silicates namely C_3S and C_2S which together constitute about 70 to 80 per cent of the cement constituents control the most of the strength giving properties. Upon hydration, both C_3S and C_2S give the same product called calcium silicate hydrate ($C_3S_2H_3$) and calcium hydroxide [$Ca(OH)_2$]. C_3S gives a faster rate of reaction accompanied by a greater heat evolution thereby giving early strength. On the other hand, C_2S hydrates and hardens slowly and responsible for the ultimate strength. But the hydration of C_3S liberates nearly three times more calcium hydroxide as compared to C_2S. That's why C_2S provides more resistance to chemical attack.

The compound tricalcium aluminate (C_3A) 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 during 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 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.

Q.2 Explain pozzolanic action.

Solution:

A pozzolana is a finely ground siliceous material which as such does not possess cementitious property in itself but reacts in the presence of water with calcium hydroxide at normal temperature to form compounds of low solubility having cementitious properties. The action is known as pozzolanic action.

The reaction can be shown as

$$\text{Pozzolana} + Ca(OH)_2 + H_2O \rightarrow \underset{\text{(gel)}}{\text{C-S-H}}$$

This reaction is called pozzolanic reaction. The characteristic feature of pozzolanic reaction is initially slow, with the result that heat of hydration and strength development will accordingly be slow. The reaction involves

the consumption of $Ca(OH)_2$ and not production of $Ca(OH)_2$. It may be noted that on hydration of C_3S and C_2S present in cement, $Ca(OH)_2$ is formed as one of the products of hydration. This compound has no cementitious value and it is soluble in water and may be leached out by the percolating water. It is pointed out that $Ca(OH)_2$, otherwise, a water soluble material is converted into insoluble cementitious material by reaction of pozzolanic materials.

The reduction of $Ca(OH)_2$ also improves the durability of cement paste by making the paste dense and impervious. Pozzolanic materials can be natural or artificial. Clay and shales, opaline cherts, diatomaceous earth and volcanic tuffs are natural pozzolanic materials. Fly ash, blast furnace slag, silica fume, rice husk ash are artificial pozzolanic materials.

The pozzolanic action also reduce the expansion caused by the alkali-aggregate reaction in concrete. Excessive expansion causes pattern cracking of concrete. This expansion can usually be controlled by using of pozzolana ranging from 2 to 35% by mass of cement depending upon the type of aggregate and alkali content of cement.

Q.3 **Differentiate between flash set and false set.**

Solution:

Flash set : When portland Clinker is ground alone and mixed with water, the aluminate (C_3A) phase initially reacts rapidly and if C_3A level is appreciable, then flash set or quick set is likely to happen.

- Since plasticity of mix is not restored after flash setting, it is deteterious to concrete production.
- In order to prevent flash set, gypsum is added to cement to ensure smooth set regulation prior to normal setting.

False set : False set is sometimes also known as early stiffening or premature stiffening or gum set. It refers to cement which when gauged with water and mixed for short while, stiffens up and appears to set. Remixing breaks up this stiffening and cement proceeds to the normal sets.

Q.4 **Explain the difference between various grades of OPC.**

Solution:

The commonly used portland cement in India is branded as **33-grade** (IS:269-1989), **43-grade** (IS:8112-1989) and **53 grade** (IS:12269-1987) having 28 days mean compressive strengths exceeding 33 MPa, 43 MPa and 53 MPa respectively. All the three grades are produced from same materials. The higher strengths are achieved by increasing C_3S content and also by finely grinding the clinker. The fineness of 53-grade OPC obtained by Blaine's air permeability test is specified to be of the order of 350000 mm^2/g. The initial and final setting times are same for all the three grades. The 33-grade cement has virtually disappeared and has been replaced by high strength 43-grade cement. The minimum compressive strengths of the 43-grade cement are 23 MPa and 33 MPa at the end of 3 and 7 days respectively. At higher water cement ratio, the concrete produced with high strength cement has about 80% higher strength and at lower water cement ratio, it has 40% higher strength than that of concrete using 33-grade cement. Greater fineness of 43 and 53 grade cements increase workability due to reduction of friction between aggregates. Moreover, due to shorter setting time and faster development of strength, the stripping time is shorter. Although cements of grade 43 and 53 are desirable for economical design of high grade concretes but they can also be used for lower grade concretes.

Q.5 **List the various laboratory tests for assessing the quality of cement and their importance.**

Solution:

The following tests are usually conducted in laboratory to assess the quality of cement:

(i) **Fineness test:** The fineness of cement affects the rate of hydration and hence the rate of gain of strength and also the rate of evolution of heat. Fineness of cement can be tested in two ways viz. by sieving and

by determination of specific surface using air permeability apparatus.

(ii) **Setting time test:** In actual construction dealing with cement paste, mortar or concrete, certain time is required for mixing, transporting, placing, compacting and finishing. During this time cement paste, mortar or concrete should be in plastic condition. This time is known as initial setting time. Once the concrete is placed in the final position, compacted and finished, it should lose its plasticity in the earliest possible time so that it is least vulnerable to damages from external destructive agencies. This time is known as final setting time. Setting time test is carried out with the help of Vicat apparatus.

(iii) **Compressive strength test:** The compressive strength of hardened cement is the most important of all the properties. Therefore, it is not surprising that the cement is always tested for its strength in laboratory before the cement is used in important works.

(iv) **Soundness test:** It is very important that the cement after setting shall not undergo any appreciable change of volume. The testing of soundness of cement, to ensure that the cement does not show any appreciable subsequent expansion is of prime importance. Unsoundness in cement is due to excess of lime, excess of magnesia or excessive proportions of sulphates. Unsoundness due to lime can be tested using Le Chatelier apparatus. Unsoundness due to magnesia can be tested using Autoclave test. Unsoundness due to calcium sulphate can be tested using chemical analysis.

(v) **Heat of hydration test:** The reaction of cement with water is exothermic. It is estimated that about 120 calories of heat is generated in the hydration of 1 gm of cement. The total quantum of heat produced in a conservative system such as the interior of a mass concrete dam, a temperature rise of about 50°C has been observed. This unduly high temperature developed at the interior of a concrete dam causes serious expansion of the body of dam and with the subsequent cooling considerable shrinkage takes place resulting in serious cracking of concrete. Heat of hydration test can be easily carried out over a few days by vacuum flask methods, or over a longer period in an adiabatic calorimeter.

(vi) **Chemical composition test:** The raw materials used for the manufacture of cement consist mainly of lime, silica, alumina and iron oxide. The relative proportions of these oxide compositions are responsible for influencing the various properties of cement, in addition to rate of cooling and fineness of grinding. Thus the chemical composition test is carried out in laboratory.

Q.6 Write brief note on white and colored cements.

Solution:

White Cement:

- This is just a variety of ordinary cement and it is prepared from such raw materials which are practically free from colouring agents like oxides of iron, manganese or chromium.
- For burning of this cement, the oil fuel is used instead of coal.
- It is white in colour and it is used for floor finish, plaster work, ornamental work, etc.
- It should not set earlier than 30 minutes. It should be carefully transported and stored in closed containers only.
- It is more costly than ordinary cement because of specific requirements imposed upon the raw materials and the manufacturing process.
- It is quick drying, possesses high strength and has superior aesthetic values.

Coloured Cement:

- The cement of desired colour may be obtained by mixing mineral pigments with ordinary cement.
- The amount of colouring material may vary from 5 to 10%. If this percentage exceeds 10%, the strength of cement is affected.
- The chromium oxide gives green colour. The cobalt imparts blue colour. The iron oxide in different proportions gives brown, red or yellow colour. The manganese dioxide is used to produce black or brown coloured

cement.

- The coloured cements are widely used for finishing of floors, external surfaces, artificial marble, window sill slabs, textured panel faces, stair treads, etc.

Q.7 **Describe the hydration of portland cement and outline the ways in which the Vicat apparatus and the Le-Chatelier apparatus can be used to assess the properties of fresh and hardened cement paste.**

Solution:

The chemical reactions that takes place between cement and water is known as hydration of cement. On account of hydration certain products are formed. These products are important because they have cementing or adhesive properties. The quality, quantity, continuity, stability and the rate of formation of the hydration products are important.

Anhydrous cement compounds when mixed with water, react with each other to form hydrated compounds of very low solubility. The hydration of cement can be visualized in two ways. The first is "through solution" mechanism. In this the cement compounds get dissolved to produce a super saturated solution from which different hydrated products get precipitated. The second possibility is that water attacks cement compounds in the "solid state" converting the compounds into hydrated products starting from the surface and proceeding to the interior of the compounds with time. It is probable that both "through solution" and "solid state" types of mechanism may occur during the course of reactions between cement and water. The former mechanisms may predominate in the early stages of hydration in view of large quantities of water being available and the latter mechanism may operate during the later stages of hydration.

The reaction of cement with water is exothermic. The reaction liberates a considerable quantity of heat. This liberation of heat is called heat of hydration. The hydration process is not instantaneous. The reaction is faster in the early period and continues indefinitely at a decreasing rate. Complete hydration can not be obtained under a period of one year or more unless the cement is very finely ground and reground with excess of water. During the course of reaction of C_3S and C_2S with water, calcium silicate hydrate (C–S–H) and calcium hydroxide $Ca(OH)_2$ are formed. Calcium silicate hydrate is the essence that determines the properties of concrete. It makes up 50-60 per cent of the volume of solids in a completely hydrated cement paste. On the other hand, calcium hydroxide is a compound which is responsible for the lack of durability. The calcium hydroxide also reacts with sulphates presents in soils or water to form calcium sulphate which reacts further with C_3A and cause deterioration of concrete which is known as sulphate attack. The only advantage of $Ca(OH)_2$ is that, being alkaline in nature, it maintains pH value around 13 in the concrete which resist the corrosion of reinforcements.

The hydration of aluminates (C_3A) results in a calcium aluminate system $CaO\text{-}Al_2O_3\text{-}H_2O$. This compound do not contribute anything to the strength of concrete. On the other hand their presence is harmful to the durability of the 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 of concrete.

On hydration, C_4AF is believed to form a system of the form $CaO\text{-}Fe_2O_3\text{-}H_2O$. The hydrates of C_4AF also do not contribute anything to the strength but they show a comparatively higher resistance to the attack of sulphates than the hydrates of calcium aluminate.

Vicat apparatus is used for determining the normal consistency and setting time for cement. A known weight of cement is taken and a paste is prepared with a weighed quantity of water (24% by weight of cement) for the first trial. The paste is then filled in a mould and the plunger of the apparatus is brought down to touch the surface of the paste in test block and quickly released allowing it to sink into the paste by its own weight. Similar, trials are conducted with higher and higher water cement ratios till such time the plunger penetrates for a depth of 33-35 mm from the top. That particular percentage of water is known as the percentage of water required to produce a cement paste of standard consistency.

For setting times, the plunger is replaced by a needle (for initial setting time) or a circular attachment (for final setting time).