UNIT 1 CEMENT

Structure

1.1 INTRODUCTION

You have already studied about the **Cements** under Unit 1 Calcareous Cementing Materials (Engineering Materials Course), in a limited way, more as an engineering material. Now we will study cements in greater detail in this Unit. Special attention will be paid towards manufacture, Classification, Oxide composition, Compound composition, hydration, study of few special types of cements and physical properties of different cements.

Objectives

This unit will help you to develop clearer understanding of cement, its manufacture, composition, hydration, properties and their uses in different situations. At the end of the unit, you should be able to:

* distinguish between wet and dry process of manufacture of cements,
* describe different methods of classification of cement,
* describe the hydration process gel theory, and
* distinguish between different types of cements and their applications.

1.2 MANUFACTURE OF PORTLAND CEMENT

In Unit 1 of Engineering Materials, sub-section 1.4.1, we discussed that there are two processes of manufacture of cement. They are:

i) Wet process

ii) Dry process

Let us have a brief insight into these processes :

i) **Wet process**

This process can be understood in a sequential form as below :

a) Limestone brought from quarry is crushed to smaller fragments.

b) Mixed with clay or shale; ground into a fine consistency in ball mill and converted into slurry by addition of water.

c) The slurry is tested for correct composition and sprayed on to the upper end of the rotary kiln. The rotary kiln is a thick steel cylinder of diameter varying from 3 to 8 metres and length varying from 30 metres to 200 metres.

d) The temperature in the hottest part of the kiln is about 1500 degree C resulting in the slurry getting converted into a fused mass of 3 mm to 20 mm size known as clinker. This clinker is cooled under controlled conditions.

e) Finally this clinker is ground in a ball mill with 2 to 3 percent of gypsum to produce portland cement.

ii) **Dry process**

In this process :

a) The raw materials are crushed dry and fed into a grinding mill in correct proportions, where they are reduced to a fine powder.

b) This powder is then corrected for its composition and fed into a granulator. Water, 12 percent by weight of this powder, is added to convert it into pellets.

c) These pellets are then ground to produce cement.

The dry process is considered to be economical as compared to wet process because of less consumption of fuel in the kiln.

Let us now see as to what is the Oxide composition of cement.

1.3 OXIDE COMPOSITION

The basic raw materials used in the manufacture of cement are:

i) Lime

ii) Silica

iii) Alumina and

iv) Iron oxide

These oxides interact with each other in the rotary kiln to form complex compounds. While during manufacture the rate of cooling and fineness of grinding affect the properties of cement, the relative proportions of these oxides also influence the various properties. As already known to you, and to recapitulate, the approximate oxide composition limits of ordinary portland cement are again given in Table 1.1 :

Table 1.1 : Oxide Composition Limits

Sl. No.	Oxide	Content in Percent
1)	CaO	60 – 67
2)	SiO_2	17 – 25
3)	Al_2O_3	3 – 8
4)	Fe_2O_3	0.5 – 6.0
5)	MgO	0.1 – 4.0
6)	Alkalies, K_2O, Na_2O	0.4 – 1.3
7)	SO_3	1.0 – 3.0

Further the IS code 269 – 1989 specifies the following chemical requirements.

a) The ratio of $\dfrac{CaO - 0.7\,SO_3}{2.8\,SiO_2 + 1.2\,Al_2O_3 + 0.65\,Fe_2O_3}$

is not greater than 1.02 and is not less than 0.66.

b) The ratio of percentage of Alumina / Iron oxide is not less than 0.66.

c) Insoluble residue percent by mass is not greater than 4 percent.

d) Weight of Magnesia is not greater than 6 percent.

e) SO_3 content is not greater than 2.5 and 3.0 when tricalcium aluminate percent by mass is 5 or less and greater than 5 respectively.

f) Total loss on ignition is not greater than 5 percent.

Let us now examine, as to what compounds are formed when these oxides interact with each other under high clinkering temperature.

1.4 COMPOUND COMPOSITION

The identification of major compounds formed is largely based on R H Bogue's work and is popularly known as **Bogue's Compounds**. These Bogue's compounds are given in Table 1.2 :

Table 1.2: Bogue's Compounds

Sl. No.	Name of Compound	Chemical Formula	Abbreviated Formula
1)	Tricalcium Silicate	$3\,CaO.SiO_2$	C3S
2)	Dicalcium Silicate	$2\,CaO.SiO_2$	C2S
3)	Tricalcium Aluminate	$3\,CaO.Al_2O_3$	C3A
4)	Tetracalcium Alumino ferrite	$4\,CaO.Al_2O_3.Fe_2O_3$	C4AF

The symbols in Abbreviated formula are for simplicity sake, as follows :

C for CaO S for SiO_2

A for Al_2O_3 F for Fe_2O_3

H for H_2O

But, you may note that these are not the only compounds formed. There are some minor compounds also. Two of these are K_2O and Na_2O, which are referred to as **Alkalies** in the cement and play an important role in the **Alkali-Aggregate** reaction (See Unit 2: Aggregates of Engineering Materials Course).

Let us now have a look in to Table 1.3 the Oxide composition and the corresponding calculated compound composition for typical portland cement.

Table 1.3: Oxide Composition of Partland Cement

Sl. No.	Oxide	Composition Percent	Abbreviated Formula	Calculated Compound Percent using Bogue's Equation
1)	CaO	63.0	C3S	54.1
2)	SiO_2	20.0	C2S	16.6
3)	Al_2O_3	6.0	C3A	10.8
4	Fe_2O_3	3.0	C4AF	9.1
5)	MgO	1.5		
6)	SO_3	2.0		
7)	K_2O	1.0		
8)	Na_2O			

An analysis of the above data would show that C3S and C2S are the most important compounds responsible for strength. Together, they constitute 70 to 80 percent of cement. The control on oxide composition can be understood from the fact that an increase in lime content by a certain value makes it difficult to combine with other compounds and free lime will exist in the clinker which causes unsoundness in cement. On the other hand an increase in Silica content at the expense of the content of Alumina and ferric oxide will present difficulties during formation of clinkering. Therefore, you will appreciate that oxide composition controls compound composition which controls the quality of cement. The next important aspect is that of what happens when water is added to the cement. This you will study in the following Section.

1.5 HYDRATION OF CEMENT

We have already studied Hydration of Cement under Unit 1 of *Engineering Materials.* Given below is a brief sum up for you :

a) When the reaction of C3S and C2S takes place with water, Calcium Silicate Hydrate and Calcium Hydroxide are produced. Calcium Hydroxide is considered undesirable as it gets leached out causing porosity in Concrete.

b) C3S readily reacts with water, producing more heat of hydration and is responsible for early strength of Concrete.

c) C2S hydrates more slowly, produces less heat of hydration and is responsible for later strength of Concrete. The calcium silicate hydrate formed is dense. The hydration products of C2S are considered better than those of C3S.

d) The reaction of pure C3A with water is very fast and may lead to flash set. Gypsum is added at the time of grinding to prevent this flash set. The hydrated aluminates, do not contribute anything to the strength of the paste. On the other hand, their presence is harmful to the durability of Concrete, in situations where the concrete is likely to be attacked by sulphates.

e) The hydrated product due to C4AF, also, does not contribute anything to the strength, though they are more resistant to sulphate attack. The rate of hydration of these products is shown in the Figure 1.1.

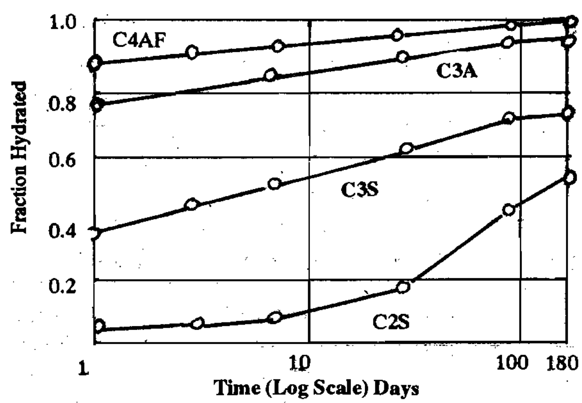

Figure 1.1: Rate of Hydration of the Cement Compounds

1.6 GEL THEORY

It has been said that the significant product of hydration is (CaO SiO_2 H_2O) which for simplicity sake is called Tobermorite Gel, because of its structural similarity to a naturally occurring mineral Tobermorite. It is referred, commonly as C-S-H Gel. It is now accepted that this gel consists of poorly formed, thin, fibrous crystals that are infinitely small. The porosity of the Gel is estimated to be 28% and the pores are filled with water. The specific surface of Gel is of the order of 2 million square cm per gram of cement.

1.6.1 Structure of Hydrated Cement

The concrete is generally considered as a two phase material, consisting of :

a) Paste phase, and

b) Aggregate phase.

It is the paste phase, known as cement paste which is most important and its structure influences the strength, permeability, durability, drying shrinkage, elastic properties, creep and volume change properties of concrete. Therefore, you must pay lot of attention in understanding the cement paste structure, which is described now. Fresh cement paste is a plastic mass consisting of water and cement. One hour after mixing, the hardening paste consists of hydrates of various compounds, unhydrated cement particles and water. With further lapse of time, the quantity of unhydrated cement decreases and there is an increase in hydrated compounds. Some of the mixing water is used for chemical reactions, some occupies the gel pores and the hydrated paste can be considered to be consisting of :

a) 85 to 90% of hydrates of various compounds

b) 10 to 15% of unhydrated cement

c) Water

   i) partly used up in chemical reactions

   ii) partly occupies gel pores

   iii) remaining causes capillary cavities

The diagrammatic representation of progress of hydration and microscopic schematic model showing structure of hardened cement paste is shown in Figures 1.2 and 1.3 which follow. You are advised to have a look at these figures which are self explanatory.

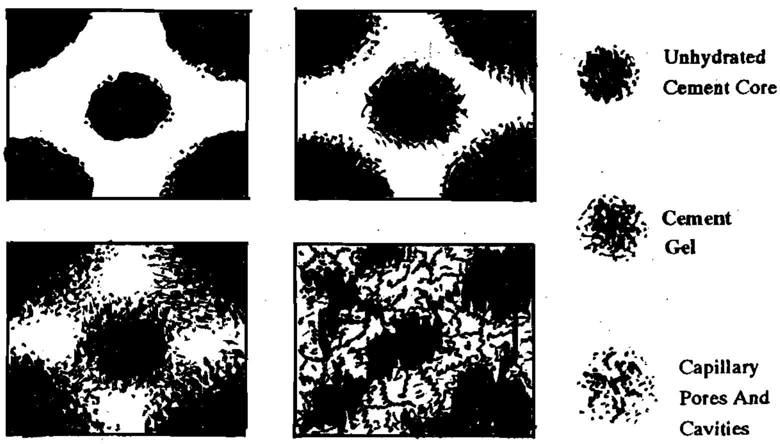

Figure 1.2 : Diagrammatic Representation of the Hydration Process and Formation of Cement gel

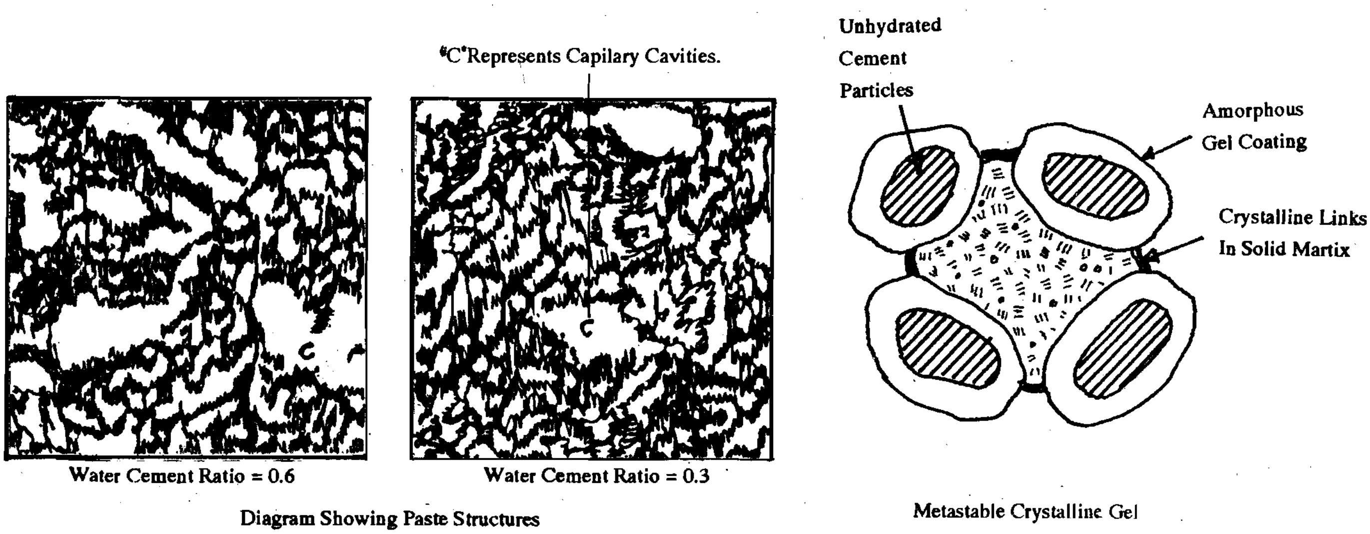

Figure 1.3 : Microscopic Schematic Model Representing the Structure of Hardened Cement Paste

Water Requirements for Hydration

a) C3S requires 24% of water by weight of cement

b) C2S requires 21% of water by weight of cement

On an average, it is estimated that 23% of water by weight of cement is required for chemical reaction with cement compounds and is called **Bound Water**. It is further estimated that about 15% of water by weight of cement is required to fill up the gel-pores.

Therefore, a total of 38% of water by weight of cement is required for complete hydration and to occupy the space within the gel-pores. This has a very important significance. It means that if water mixed with cement is more than 38% by weight of cement, then the remaining water will form undesirable capillary cavities and make concrete porous and will affect its strength.

Thus you have seen that hydration of cement paste will play a major role in deciding the quality of concrete and this is further affected by the water/cement ratio adopted in the cement paste.

SAQ 1

Answer the following questions in the space given below and assess your comprehension by comparing with the preceding text.

a) What are the basic raw materials and oxide composition of OPC ?

b) Describe hydration of cement by discussing behaviour of each of the products of hydration.

c) What are Bogue's compounds and what is their importance in relation to the strength of cement ?

1.7 CLASSIFICATION OF CEMENT

Let us see how the Portland cements are classified.

A) The classification of cement as per BIS is as below :

- i) 33 Grade OPC; IS-269 of 1989
- ii) 43 Grade OPC; IS-8112 of 1989
- iii) 53 Grade OPC; IS-12269 of 1987

The figures 33, 43, 53 refer to minimum 28 days strength of these cements in MPa.

B) Let us examine the classification under the ASTM (American Society for Testing Materials). As per ASTM, cement is designated as Type I to Type V and other minor types like Type IS and Type IP etc.

Type I

These cements are for use in general construction (Ordinary Portland Cement) where special properties specified for Type II to Type IV are not required.

Type II

For use in general concrete construction exposed to moderate sulphate action, or where moderate heat of hydration is required.

Type III

For use when high early strength is required (Rapid Hardening Cement).

Type IV

For use when low heat of hydration is required (Low heat Cement).

Type V

For use when high sulphate resistance is required (Sulphate resisting Cement).

Under Unit 1 of *Engineering Materials* we had listed 17 different types of cements and had discussed some of these in detail there. We now discuss the remaining types of cements here, which are special purpose cements.

1.8 TYPES OF CEMENT

1.8.1 Super Sulphate Cement

We have seen earlier in Portland Blast Furnace slag cement in Unit 1 of Engineering Materials that due to use of granulated slag it possesses better resistance to sulphate attack. In super sulphate cement, this property is made use of extensively by grinding together a mixture of 80-85 percent granulated slag, 10-15 percent hard burnt gypsum and about 5 percent portland cement clinker. This is ground finer than OPC. The specific surface must not be less than 4000 cm^2 per gm. Super sulphate cement has low heat of hydration of about 45-50 calories per gm at 28 days and possesses high sulphate resistance.

An important point to be noted by you is that when we use super sulphate cement the water/cement ratio should not be less than 0.5 and wet curing for not less than 3 days after casting is essential as premature drying out results in an undesirable or powdery surface layer. A mix leaner than 1 : 6 is also not recommended.

Uses

a) Super sulphate cement is particularly recomended for use in foundation where chemically aggressive conditions exist.

b) As super sulphate cement has more resistance than portland blast furnace cement to attack by sea-water, it is also used in marine works.

c) In fabrication of reinforced concrete pipes to be used in sulphate bearing soils.

1.8.2 Low Heat Cement

While discussing **heat of hydration** under para 1.4.1 (iii) of Unit 1 of *Engineering Materials*, we had pointed out that the reaction of cement with water is exothermic, resulting in liberation of considerable quantity of heat. We also know that it is the reactions with C3S and C3A which produce most heat. Therefore in low heat cement, the contents of C3S and C3A are reduced and C2S is increased.

A reduction of temperature so obtained retards the chemical action of hardening and so further restricts the rate of evolution of heat. Thus the evolution of heat extends over a long period. Therefore, low heat cement has slow rate of gain of strength, but its ultimate strength is same as that of OPC. The heat of hydration of low heat cement shall be

7 days – not more than 65 calories per gm

28 days – not more than 75 calories per gm

Uses

Because of low and slow rate of evolution of heat, low heat cement is ideally suited for use in mass concrete construction such as Dams.

1.8.3 Air Entraining Cement

This cement is made by mixing a small amount, 0.025 to 0.1 percent by weight of an air entraining agent with ordinary portland cement clinker at the time of grinding. Some of these air entraining agents are :

a) Alkali salts of wood resins.

b) Synthetic detergents of the alkayl-aryl sulphonate type.

c) Calcium ligno sulphate derived from the sulphate process in paper making.

d) Calcium salts of glues and other proteins obtained in the treatment of animal hides.

These and other agents produce tough, tiny, discrete, non-coalescing air bubbles in the body of the concrete which will modify the properties of plastic concrete with respect to workability, segregation and bleeding. It will modify the properties of hardened concrete with respect to its resistance to frost action.

Uses

a) Air entrained cement is ideal for use in structures subjected to freezing and thawing.

b) Its use in improving workability of cement needs to be practised increasingly.

1.8.4 Masonry Cement (IS: 3466–1967)

This cement is made with such combination of materials that, when it is used for making mortar, it incorporates all good properties of lime mortar like workability, water retention, extensibility etc. and discard not so ideal properties of cement mortar like shrinkage etc. Some of the additional materials are limestone, clay, chalk, talc, water repellant materials and gypsum.

Uses

Mostly used for masonry construction in brick or block masonry.

1.8.5 Expansive Cement

You will notice that concrete made with ordinary portland cement shrinks while setting due to loss of free water. Concrete also shrinks continuously for long time. This is known as drying shrinkage. But then there are situations where this affects the functional efficiency of a structure. For example if cement used for grouting anchor bolts in machine foundations or the cement used in grouting the prestress concrete ducts, shrinks, then the purpose for which it has been used gets defeated. Therefore, a cement which does not shrink while hardening and thereafter, has been developed by using an expanding stabilizer very carefully. Generally, about 8 to 20 parts of sulphoaluminate are mixed with 100 parts of portland cement clinker and 15 parts of stabilizer. Curing must be carefully controlled since expansion occurs only as long as concrete is moist.

One type of expansive cement is known as **shrinkage compensating cement.** This cement when used in concrete, with restrained expansion induces compressive stress which more or less offset the tensile stress induced by shrinkage.

Another type is known as self stressing cement. This induces significant compressive stress after compensating the shrinkage stress, also gives some sort of prestressing effect in the tensile zone of a flexural member.

A popular non-shrinking grout developed by Associated Cement Co. Ltd. is known as **Shrinkkomp**. For more details of non-shrink grout you may refer to Unit 3.

Uses

The major use of expansive cement is for grouting machine base plates, anchor bolts, rock bolting and grouting of prestress ducts.

1.8.6 Oil Well Cement

As you are aware, oil production has become extremely important for India to improve its balance of payment position and to cut down on imports. Oil wells are drilled through stratified sedimentary rocks through great depths. Oil when struck, could escape together with gas, through the space between the steel casing and the rock formation. To prevent this cement slurry is used. The cement slurry has to be pumped in position at considerable depth where the prevailing temperature may be 175° C, coupled with pressures upto 1300 kg/cm^2. The slurry should remain sufficiently mobile to be able to flow under such conditions for several hours and then harden fairly and rapidly. In addition it may have to resist corrosive actions because of sulphur gases or waters containing dissolved salts.

The type of cement suitable for such situations is called oil well cement. The desired properties are obtained either by adjusting the compound composition of cement or by adding retarders to the OPC. The most common agents are starches or cellulose products or acids. These retarding agents prevent quick setting and impart mobility to slurry to facilitate penetration of all fissures and cavities.

1.8.7 High Strength Cement

In construction engineering, there are special situations which demand use of high strength concrete as in precast concrete, prestressed concrete and air-fields, runways and taxi tracks. For this purpose cements having much higher strength than OPC are required and are known as high strength ordinary Portland cement covered in IS : 8112-1989. The same is now called 43 grade OPC. Another high strength cement called 53 Grade is covered under IS-122 69/1987.

The compressive strength for 43 Grade OPC and 53 Grade OPC are given in Table 1.4.

Table 1.4 : Compressive Strength of 43 Grade & 53 Grade OPC

Sl. No.	Period	43 Grade OPC not less than	53 Grade OPC not less than
1)	72 ± 1 hour	23 MPa	27 MPa
2)	168 ± 2 hours	33 MPa	37 MPa
3)	672 ± 4 hours	43 MPa	53 MPa

Other properties of this cement like soundness and setting time are same as those of OPC.

1.9 PHYSICAL PROPERTIES OF DIFFERENT CEMENTS

In order to enable you to compare the physical properties of different cements like specific surface, soundness, setting time and strength, this information has been compiled in Table 1.5:

Table 1.5 : Physical Properties of Cements

Sl. No.	Type of Cement	Specific Surface by Blains Air permeability not not less than (m^2/kg)	Soundness by Le Chatelier's method not exceeding (mm)	Minimum Initial Setting Time (Minutes)	Maximum Final Setting time (Minutes)
1)	OPC IS-269-1989 (33 Grade)	225	10	30	600
2)	43 Grade Ordinary Portland Cement IS-8112-1989	225	10	30	600
3)	53 Grade OPC IS-12269-1987	225	10	30	600
4)	Low Heat Cement IS-12600-1989	320	10	60	600
5)	Rapid Hardening IS-8041E-1976	325	10	30	600
6)	Portland Pozzolona IS-1489-1976	300	10	30	600
7)	Portland Slag Cement IS-455-1976	225	10	30	600
8)	Hydrophobic Portland IS-6452-1976	350	10	60	600
9)	Oil Well Cement IS-8229E-1976	–	0.8 (autoclave expansion)	–	–
10)	Super Sulphated Cement IS-6909-1973	400	5	30	600

Table 1.6 : Compressive Strength of Mortar cubes for Different Cements

Sl. No.	Type of Cement	Average Compressive Strength of 3 Mortar cubes; 1 cement, 3 std. sand and $\left(\frac{P}{4} \pm 3\right)$ water combined mass of cement & sand Not Less Than (MPa)			
		24 hrs. ± 30 mm	72 hrs. ± 1 hr.	168 hrs. ± 2 hrs.	672 hrs. ± 4 hrs.
1)	OPC IS-269-1989 (33 Grade)	–	16	22	33
2).	High Strength Ordinary IS-8112-1989 (43 Grade)	–	23	33	43
3)	High Strength Ordinary as per IS-12269-1987 (53 Grade)		27	37	53
4)	Low Heat Cement IS-12600-1989	–	10	16	35
5)	Rapid Hardening Cement IS-8041E-1976	16	27.5	–	–
6)	Portland Pozzolona Cement IS-1489-1976 (Revised in 1990)	–	–	22	31
7)	Portland Slag Cement IS-455-1976	–	16	22	–
8)	Hydrophobic Portland Cement IS-6452-1976		16	22	31
9)	Oil Well Cement IS-8229E-1976		Refer to IS-8229 for this.		
10)	Super Sulphated Cement IS-6909-1973		15	22	30

SAQ 2

a) List the different types of cements used for construction works. Point out the main difference in their composition and properties, explain how each type of cement is designed to suit the purpose for which it is used ?

b) Which cement would you choose for the following situations ?

   a) In high humidity, remote areas involving long storage.

   b) In mass concreting.

   c) In soils where chemically aggressive conditions exist.

   d) In high altitudes where freezing and thawing is a perpetual problem.

   e) For grouting of bolts in machine foundations.

1.10 TESTING OF CEMENT

The following tests are usually conducted in the laboratory on cement :

i) Fineness test

ii) Setting time test

iii) Compressive Strength test

iv) Soundness test

v) Heat of hydration test

vi) Chemical composition test

You will find complete details of these tests under Testing For Quality Control, Block 1 : Tests for Concrete; Unit 1 : Test for Cement and Water. However, some of these tests are now described briefly to give you an idea of their concept. For more details you are advised to refer to IS:4031-1988 and connected codes.

i) **Fineness Test**

The fineness of cement affects rate of hydration and hence the rate of gain of strength of concrete. It can be tested in two ways :

a) **By Air Permeability Apparatus :** Here air is passed through a cement bed of specified size at a specified rate in the Air permeability apparatus and the difference in level (h_1) of the manometer and difference in level (h_2) of the flowmeter is noted, by taking several observations. The specific surface is calculated as :

$$S_w = K \times \sqrt{\frac{h_1}{h_2}} \text{ in sq cm/gm}$$

where

$$K = \frac{14}{d\,(1-x)} \times \sqrt{x^3 \times \frac{A}{(C \times L)}}$$

where

x = porosity = 0.475,

A = area of cement bed,

L = length of cement bed,

d = density of cement,

C = flowmeter constant.

The specific surface for OPC is specified as 225 m^2/kg.

Another Air Permeability apparatus is called Blaine Air Permeability Apparatus which is now discussed.

b) **Blaine Air Permeability Apparatus (IS: 4031-1988)** The air permeability method of determining the specific surface is based on the relationship between the surface area of the particles in a porous bed and the rate of fluid flow through the bed. This test is described in BS 4550: Part 3. Section 3.1. The basic equation developed by Carman is:

$$S = \frac{14\sqrt{\epsilon^3}\,Ai}{D\,(l-\epsilon)\,v\,Q}$$

where,

S = specific surface cm^2/g

D = the powder density

ϵ = porosity of the bed

A = cross–sectional area of the bed

i = hydraulic gradiant

ν = kinematic viscosity
Q = rate of flow

In this method, a given volume of air is passed through a bed of standard porosity at a steady diminishing rate and the time, t, required is measured.

Then $S = K\sqrt{t}$

K = Constant

In practice K is not determined directly. It is determined by comparing the sample to a standard sample of known specific area.

ii) **Standard Consistency Test**

Standard consistency test helps in finding initial and final setting times and soundness of cement. A cement paste with 500 gm of cement and different percentages of water say 24-25 percent is put under a standard plunger and the penetration is noted. The particular percentage of water which allows plunger to penetrate only to a depth of 33-35 mm from top is known as percentage of water required to produce a cement paste of standard consistency. This percentage of water is usually denoted as "P".

a) **Initial Setting Time Test :** A sample of 500 gm cement + 0.85 P water is prepared and the needle of Vicat Apparatus is allowed to penetrate it. The period elapsed between the time when water was added to prepare the paste and when the needle has penetrated the paste to a depth of 33-35 mm is taken as initial setting time.

b) **Final Setting Time :** Now the needle is replaced by a center needle with a circular attachment which is lowered on to the sample which was tested for initial setting time. Time interval when the centre needle makes an impression on the sample (pierces the sample by just about 0.5 mm) while the circular attachment fails to do, is taken as the final setting time.

c) **Compressive Strength Test :** This is one of the most important tests. In this test 555 gms of standard sand (Ennore Sand),185 gms of cement are mixed with water ($P/4$ + 3.0) percent of combined weight of cement and sand for about 3 to 4 minutes. 7.06 cm cubes are made out of this mortar, which are then cured under standard conditions for 24 hours. Three cubes each are tested for compressive strength at periods of 3 days and 7 days for OPC. For OPC the minimum strength at 3 days, 7 days and 28 days shall not be less than 16, 22 and 33 MPa respectively.

1.11 SUMMARY

Cement is one of the most important cementing materials which is widely used in construction. The manufacture of cement, as you have studied, is done by either wet or dry process. The dry process is more economical with lower fuel consumption. The quality of the manufactured cement depends upon the Oxide composition and the resulting compound composition. You would recall that the CaO and SiO_2 constitute the bulk of the oxide content while C3S and C2S known as Bogue's compounds are the most important compounds responsible for the strength of the cement. The hydration of cement occurs on addition of water and the important hydration products on account of C3S and C2S are Calcium Silicate Hydrate and Calcium Hydroxide. Calcium hydroxide is considered undesirable as it leaches out causing porosity. Calcium silicate hydrate for simplicity sake is also called Gel which has porosity of about 28 percent and these pores are filled with water. It is estimated that about 38 percent of water by weight of cement is required for complete hydration and gel pore therefore, as stated earlier, you will do well to remember that if water mixed with cement is more than 38 percent by weight of cement, then the remaining water will form undesirable capillary cavities and make concrete porous and affect its strength.

Next, we examined the different methods of classification of cements which either depended on their usage or 28 days strength. We then studied some special purpose cements like super sulphate cement, low heat cement, air entraining cement, masonry cement, expansive cement, oil well cement, high strength cement. The special properties in these cements could be achieved either by varying contents of C3S and C2S or by adding certain agents.

Finally, like any other material, testing of cement is also essential to ensure quality. For this purpose several tests have been evolved which are given under Testing For Quality Control : Block 1 : Tests For Concrete , Unit 1 : Tests for Cement and Water.

1.12 KEY WORDS

Bound water	:	Water required for chemical reaction with cement compounds.
Concrete	:	A mixture of cement, aggregates and water in certain proportions.
Clinker	:	Fused mass of 3 mm to 20 mm size.
Gel	:	Calcium silicate hydrate. Thin infinitely small fibrous crystals.
Hydration	:	Activity which occurs on addition of water to cement.
Heat of hydration	:	Heat liberated on addition of water to cement.
OPC	:	Ordinary Portland Cement.

1.13 ANSWERS TO SAQs

SAQ 1

Check your answers with preceding text.

SAQ 2

Check your answers with preceding text.