Unit 1

Module 2

Chemical composition of cement:

- The raw materials used for the manufacture of cement consist mainly of lime, silica, alumina and iron oxide. 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
- Before going to comopsition let us see grades of concrete.
- Concrete is generally graded according to its compressive strength.The various grades of concrete as stipulated in IS: 456 -2000 and IS :1343-1980 are given
- Eg : M10,M15,M30,M50 ,M60 etc
- In the designation of concrete mix , the letter M refers to the mix and the number to the specified characteristic strength of 150mm work cubes at 28days ,expressed in Mpa (N/mm^2)

- The concrete of grades M5 and M7.5 is suitable for lean concrete bases,simple or temporary reinforced concrete constructions.these need not be designed.
- The concrete of grades lower than M15 is not suitable for reinforced concrete works and grades of concrete lower than M30 are not to be used in the prestressed concrete work

IS 456 : 2000

Table 2 Grades of Concrete

(*Clause* 6.1, 9.2.2, 15.1.1 *and* 36.1)

Group	Grade Designation	Specified Characteristic Compressive Strength of 150 mm Cube at 28 Days in N/mm^2
(1)	(2)	(3)
Ordinary Concrete	M 10	10
	M 15	15
	M 20	20
Standard Concrete	M 25	25
	M 30	30
	M 35	35
	M 40	40
	M 45	45
	M 50	50
	M 55	55
High Strength Concrete	M 60	60
	M 65	65
	M 70	70
	M 75	75
	M 80	80

Approximate oxide composition limits of ordinary Portland cement

Oxide	Per cent content
CaO	60-67
SiO_2	17-25
Al_2O_3	3.0-8.0
Fe_2O_3	0.5-6.0
MgO	0.1-4.0
Alkalies (K_2O, Na_2O)	0.4-1.3
SO_3	1.3-3.0

Indian standard specification for 33 grade cement, IS 269-1989, specifies the following chemical requirements.

(*a*) Ratio of percentage of lime to percentage of silica, alumina and iron oxide; known as Lime Saturation Factor, when calculated by the formula

$$\frac{CaO - 0.7\,SO_3}{2.8\,SiO_2 + 1.2\,Al_2O_3 + 0.65\,Fe_2O_3}$$ Not greater than 1.02 and not less than 0.66

(*b*) Ratio of percentage of alumina to that of iron oxide	Not less tan 0.66
(*c*) Weight of insoluble residue	Not more than 4 per cent
(*d*) Weight of magnesia	Not more than 6 per cent
(*e*) Total sulphur content, calculated as sulphuric when anhydride (SO_3)	Not more than 2.5% C_3A is 5% or less. Not more than 3%, when C_3A is more than 5%
(*f*) Total loss on ignition	Not more than 5 per cent

- Oxides present in the raw materials of cement when subjected to high clinkering temperature combine with each other to form complex compounds.
- The identification of the major compounds is largely based on R.H. Bogue‘s work and hence it is called —Bogue‘s Compounds
- Following are the major compounds in the cement

Table I - Main crystalline phases in Portland cement.
[Tabela I - Principais fases cristalinas do cimento Portland.]

Crystalline Phase	Composition	Abbreviated notation	Specific gravity (kg/m^3)
Tricalcium silicate	$3CaO\ SiO_2$	C_3S (alite)	3210
Dicalcium silicate	$2CaO\ SiO_2$	C_2S (belite)	3280
Tricalcium aluminate	$3CaO\ Al_2O_3$	C_3A (celite)	3030
Tetracalcium ferroaluminate	$4CaO\ Al_2O_3\ Fe_2O_3$	C_4AF (ferrite)	3730

- The equations suggested by Bogue for calculating the percentages of major compounds are given
- below.
- C_3S= 4.07 (CaO) – 7.60 (SiO2) – 6.72 (Al2O3) – 1.43 (Fe2O3) – 2.85 (SO3)
- C_2S= 2.87 (SiO2) – 0.754 (3CaO.SiO2)
- C_3A= 2.65 (Al2O3) – 1.69 (Fe2O3)
- C_4AF= 3.04 (Fe2O3)
- The oxide shown within the brackets represent the percentages in the raw materials.
- In addition to the four major compounds, there are many minor compounds formed in the kiln.
- The influence of these minor compounds on the properties of cement or hydrated compounds is not significant.
- Two of the minor oxides namely K_2O and Na_2O referred to as alkalis in cement
- are of some importance

- Tricalcium silicate and dicalcium silicate are the most important compounds responsible for strength.
- Both the above compounds constitute 70 to 80 per cent of cement. The average C3S content in modern cement is about 45 per cent and that of C2S is about 25 per cent.
- The sum of the contents of C3A and C4AF has decreased slightly in modern cements.
- An increase in lime content beyond a certain value makes it difficult to combine with other compounds and free lime will exist in the clinker which causes unsoundness in cement.
- An increase in silica content at the expense of the content of alumina and ferric oxide will make the Cement difficult to fuse and form clinker

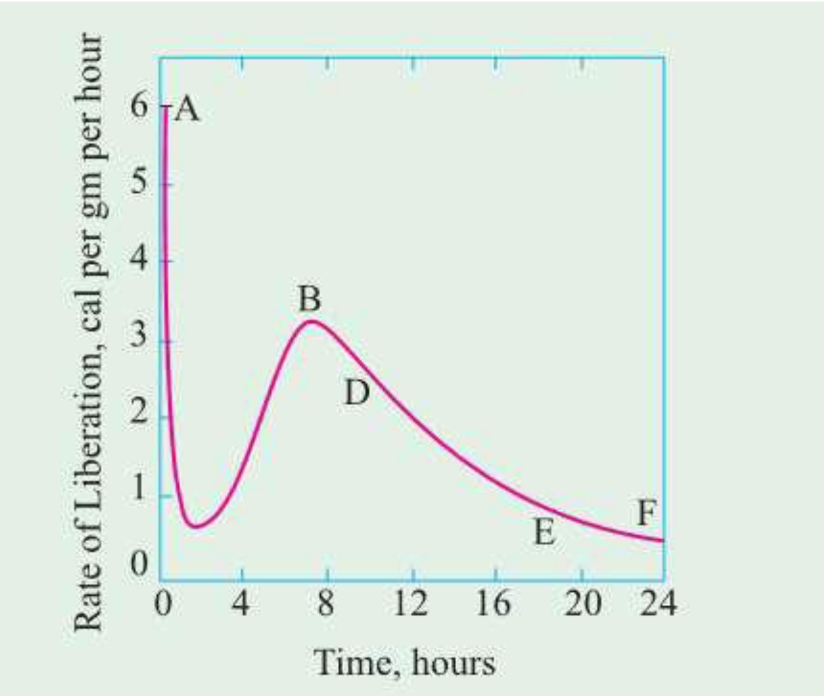
- Bogue's compounds C3S, C2S, C3A and C4AF are sometimes called in literature as Alite,Belite, Celite and Felite respectively.
- Portland cement on hydration gives C – S – H gel + $Ca(OH)_2$.
- Cement does not bind fine and coarse aggregate. It acquires adhesive property only when mixed with water.
- The chemical reactions that take place between cement and water is referred as hydration of cement.
- Properties of concrete depend on the chemistry of the reaction between cement and water.
- On account of hydration certain products are formed. These products are important because they have cementing or adhesive value.
- The quality, quantity, continuity, stability and the rate of formation of the hydration products are important.

Cement and hydration of cement can be represented as below:

Raw material for cement	Limestone, clay shale (calcareous and argillaceous material)
↓	
Component elements in raw materials	O_2 Si Ca Al, Fe
↓	
Oxide composition in raw materials	CaO SiO_2 Al_2O_3 Fe_2O_3
On burning ↓	clinker formed
Compound composition	C_3S C_2S C_3A C_4AF
On ↓	grinding clinker
Portland cements	Various types
On ↓	hydration
Products of hydration	C – S – H gel + $Ca(OH)_2$

Heat 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 study and control of the heat of hydration becomes important in the construction of concrete dams and other mass concrete constructions.
- It has been observed that the temperature in the interior of large mass concrete is 50°C above the original temperature of the concrete mass at the time of placing and this high temperature is found to persist for a prolonged period.
- The figure below shows the pattern of liberation of heat from setting cement and during early hardening period.



Compound	Heat of hydration at the given age (cal/g)		
	3 days	90 days	13 years
C_3S	58	104	122
C_2S	12	42	59
C_3A	212	311	324
C_4AF	69	98	102

- The hydration process is not an instantaneous one. The reaction is faster in the early period and continues indefinitely at a decreasing rate.
- Complete hydration cannot be obtained under a period of one year or more unless the cement is very finely ground and reground with excess of water to expose fresh surfaces at intervals.
- **Calcium silicate hydrates:**
- During the course of reaction of C3S and C2S with water, calcium silicate hydrate, abbreviated -S-H and calcium hydroxide, $Ca(OH)_2$ are formed.
- Calcium silicate hydrates are the most important products which determine the strength of concrete.
- Calcium silicate hydrates will be up to 50-60 per cent of the volume of solids in a completely hydrated cement paste.

The following are the approximate equations showing the reactions of C3S and C2S with water.

$$2\,(3\,CaO.SiO_2) + 6H_2O \rightarrow 3\,CaO.2\,SiO_2.\,3H_2O + 3Ca(OH)_2$$

or it can be written as $2C_3S + 6H \rightarrow C_3S_2H_3 + 3Ca(OH)_2$

The corresponding weights involved are

$$100 + 24 \rightarrow 75 + 49.$$

Similarly, $2\,(2\,CaO.SiO_2) + 4\,H_2O \rightarrow 3Cao.2\,SiO_2.\,3H_2O + Ca(OH)_2$

or it can be written as

$$2\,C_2S + 4\,H \rightarrow C_3S_2H_3 + Ca\,(OH)_2$$

The corresponding weights involved are

$$100 + 21 \rightarrow 99 + 22$$

- From the above equations, it is found that C_3S produces a comparatively lesser quantity of calcium silicate hydrates and more quantity of Ca(OH)2 than that formed in the hydration ofC_2S.
- Ca(OH)2 is not a desirable product in the concrete mass but it is soluble in water and gets leached out making the concrete porous, particularly in hydraulic structures.
- Under such conditions it is useful to use cement with higher percentage of C_2S content.
- C_3S readily reacts with water and produces more heat of hydration. It is responsible for early strength of concrete.
- Cement with more C_3S content is better for cold weather concreting.
- C_2S hydrates rather slowly. It is responsible for the later strength of concrete.
- It produces less heat of hydration. The calcium silicate hydrate formed is rather dense and its specific surface is higher.
- In general, the quality of the product of hydration of C_2S is better than that produced in the hydration of C_3S

Calcium hydroxide:

- The other product of hydration of C3S and C2S is calcium hydroxide.
- It constitutes 20 to 25 percent of the volume of solids in the hydrated paste.
- The lack of durability of concrete, is an account of the presence of calcium hydroxide.
- The calcium hydroxide also reacts with sulphates present in soils or water to form calcium sulphate which further reacts with C_3A and cause
- deterioration of concrete. This is known as sulphate attack.
- To reduce the quantity of $Ca(OH)_2$ in concrete and to overcome its bad effects by converting it into cementatious product is an advancement in concrete technology. Use of blending materials such as fly ash, silica fume and such other pozzolanic materials are the steps to overcome bad effect of $Ca(OH)_2$ in concrete.
- The only advantage is that $Ca(OH)_2$, being alkaline in nature, maintain pH value around 13 in the concrete which resists the corrosion of reinforcements.

Calcium aluminate hydrates:

- Due to the hydration of C_3A, a calcium aluminate system CaO – Al2O3 – H_2O is formed. The reaction of pure C_3A with water is very fast and this may lead to flash set.
- To prevent this flash set, gypsum is added at the time of grinding the cement clinker. The quantity of gypsum added has a bearing on the quantity of C_3A present
- 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 very fast it may contribute a little to the early strength.
- The amount of gypsum added has significant bearing on the quantity of aluminate in the cement.
- The maintenance of aluminate-to-sulphate ratio balances the normal setting behavior of cement paste.

Water requirements for hydration

- C3S requires 24% of water by weight of cement and C2S requires 21%. It has also been estimated that on an average 23% of water by weight of cement is required for chemical reaction with Portland cement compounds
- This 23% of water chemically combines with cement and,therefore, it is called bound water. A certain quantity of water is imbibed within the gel-pores.This water is known as gel-water.
- It has been further estimated that about 15 per cent by weightof cement is required to fill up the gel-pores.
- Therefore, a total 38 per cent of water by weight ofcement is required for the complete chemical reactions and to occupy the space within gel-pores.
- If water equal to 38 per cent by weight of cement is only used it can be noticed that the resultant paste will undergo full hydration and no extra water will be available for the formation of undesirable capillary cavities.

- On the other hand, if more than 38 per cent of water is used, then the excess water will cause undesirable capillary cavities.
- Therefore greater the water above the minimum required is used (38 per cent), the more will be the undesirable capillary cavities.
- Capillary cavities become larger with increased water/cement ratio. Initially the cement particles are closer together.
- With the progress of hydration, when the volume of cement increases, the product of hydration also increases.

Types of cements:

- Cements exhibit different properties and characteristics depending upon their chemical compositions.
- By changing the fineness of grinding or the oxide composition, cement can be made to exhibit different properties.
- With the extensive use of cement, for widely varying conditions, the types of cement that could be made only by varying the relative proportions of
- the oxide compositions were not found to be sufficient.
- Recourses have been taken to add one or two more new materials, known as additives, to the clinker at the time of grinding, or to the use of entirely different basic raw materials in the manufacture of cement.
- The use of additives,changing chemical composition, and use of different raw materials have resulted in the availability of many types of cements to cater the need of the construction industries for specific purposes.

- Cements are classified as Portland cements and non-Portland cements. The distinction is mainly based on the methods of manufacture.
- Portland and Non-Portland cements generally used are listed below

- 1. Ordinary Portland Cement
- (i) Ordinary Portland Cement 33 Grade
- (ii) Ordinary Portland Cement 43 Grade
- (iii) Ordinary Portland Cement 53 Grade
- 2. Rapid Hardening Cement
- 3. Extra Rapid Hardening Cement
- 4. Sulphate Resisting Cement
- 5. Portland Slag Cement
- 6. Quick Setting Cement
- 7. Super Sulphated Cement
- 8. Low Heat Cement
- 9. Portland Pozzolana Cement
- 10. Air Entraining Cement
- 11. Coloured Cement: White Cement
- 12. Hydrophobic Cement
- 13. Masonry Cement
- 14. Expansive Cement
- 15. High Alumina Cement

Types of Cement

(*a*) Ordinary Portland Cement

(*i*) Ordinary Portland Cement 33 Grade– IS 269: 1989

(*ii*) Ordinary Portland Cement 43 Grade– IS 8112: 1989

(*iii*) Ordinary Portland Cement 53 Grade– IS 12269: 1987

(*b*) Rapid Hardening Cement – IS 8041: 1990

(*c*) Extra Rapid Hardening Cement – –

(*d*) Sulphate Resisting Cement – IS 12330: 1988

(*e*) Portland Slag Cement – IS 455: 1989

(*f*) Quick Setting Cement – –

(*g*) Super Sulphated Cement – IS 6909: 1990

(*h*) Low Heat Cement – IS 12600: 1989

(*j*) Portland Pozzolana Cement – IS 1489 (Part I) 1991 (fly ash based)
– IS 1489 (Part II) 1991 (calcined clay based)

(*k*) Air Entraining Cement – –

(*l*) Coloured Cement: White Cement – IS 8042: 1989

(*m*) Hydrophobic Cement – IS 8043: 1991

(*n*) Masonry Cement – IS 3466: 1988

(*o*) Expansive Cement – –

(*p*) Oil Well Cement – IS 8229: 1986

(*q*) Rediset Cement – –

(*r*) Concrete Sleeper grade Cement – IRS-T 40: 1985

(*s*) High Alumina Cement – IS 6452: 1989

(*t*) Very High Strength Cement – –

As per IS classification

- Ordinary Portland cement:
- The OPC was classified into three grades, namely 33 grade, 43 grade and 53 grade depending upon the strength of the cement at 28 days when tested as per IS 4031-1988.
- If the 28 days strength is not less than 33N/mm2, it is called 33 grade cement, if the strength is not less than 43N/mm2, it is called 43 grade cement, and if the strength is not less than 53 N/mm2, it is called 53 grade cement.

- <u>Rapid hardening cement:</u>
- This cement is similar to ordinary Portland cement but it develops strength rapidly. Hence it is also called high early strength cement.
- Rapid hardening cement which develops higher rate of development of strength should not be confused with quick-setting cement which only sets quickly.
- Rapid hardening cement develops at the age of three days, the same strength as that is expected of ordinary Portland cement at seven days.
- The rapid rate of development of strength is attributed to the higher fineness of grinding (specificsurface not less than 3250 sq. cm per gram) and higher C3S and lower C2S content.
- A higher fineness of cement particles expose greater surface area for action of water and also higher proportion of C3S results in quicker hydration.
- Consequently, rapid hardening cement gives out much greater heat of hydration during the early period. Therefore, rapid hardening cement should not be used in mass concrete construction.

- The use of rapid heading cement is recommended in the following situations:
- (a) In pre-fabricated concrete construction.
- (b) Where formwork is required to be removed early for re-use elsewhere,
- (c) Road repair works,
- (d) In cold weather concrete where the rapid rate of development of strength reduces the vulnerability of concrete to the frost damage.
- **<u>Extra rapid hardening cement:</u>**
- Extra rapid hardening cement is obtained by inter grinding calcium chloride with rapid hardening Portland cement.
- The normal addition of calcium chloride should not exceed 2 per cent by
- weight of the rapid hardening cement. It is necessary that the concrete made by using extra rapid hardening cement should be transported, placed and compacted and finished within about 20 minutes.

- It is also necessary that this cement should not be stored for more than a month.
- Extrarapid hardening cement accelerates the setting and hardening process. A large quantity of heat is evolved in a very short time after placing.
- The acceleration of setting, hardening and evolution of this large quantity of heat in the early period of hydration makes the cement very suitable for concreting in cold weather.
- The strength of extra rapid hardening cement is about 25 per cent higher than that of rapid hardening cement at one or two days and 10–20 per cent higher at 7days.
- The gain of strength will disappear with age and at 90 days the strength of extra rapid hardening cement or the ordinary portland cement may be nearly the same.

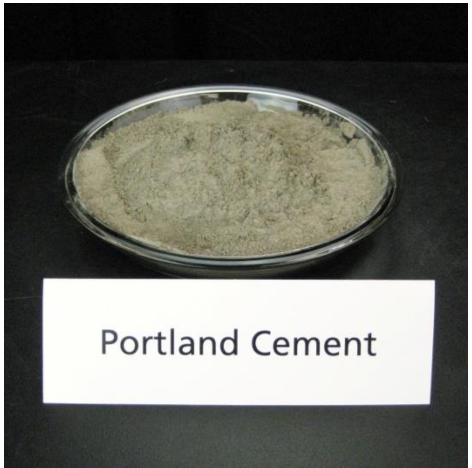
Sulphate resisting cement:

- Ordinary Portland cement is susceptible to the attack of sulphates, in particular to the action of magnesium sulphate.
- Sulphates react both with the free calcium hydroxide in set-cement to form calcium sulphate and with hydrate of calcium aluminate to form calcium sulphoaluminate. The volume of which is approximately 227% of the volume of the original aluminates.
- Their expansion within the frame work of hardened cement paste results in cracks and subsequent disruption.
- Solid sulphates do not attack the cement compound. Sulphates in solution permeate into hardened concrete and attack calcium hydroxide, hydrated calcium aluminate and even hydrated silicates. The above is known as sulphate attack.

- To remedy the sulphate attack, the use of cement with low C3A content is found to be effective. Such cement with low C3 A and comparatively low C4AF content is known as Sulphate Resisting Cement
- In other words, this cement has high silicate content. The specification generally limits the C_3A content to 5 per cent.
- The use of sulphate resisting cement is recommended under the following conditions:
- (a) Concrete to be used in marine condition;
- (b) Concrete to be used in foundation and basement, where soil is infested with sulphates;
- (c) Concrete used for fabrication of pipes which are likely to be buried in marshy region or sulphate bearing soils;
- (d) Concrete to be used in the construction of sewage treatment works.

Portland slag cement:

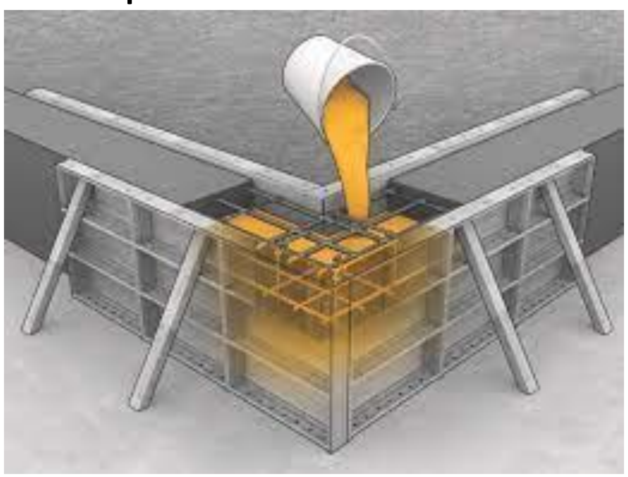
- Portland slag cement is obtained by mixing Portland cement clinker, gypsum and granulated blast furnace slag (blast furnace slag is a waste product from steel manufacturing plants) in suitable proportions and grinding the mixture to get a thorough and intimate mixture between the constituents.
- It may also be manufactured by separately grinding Portland cement clinker, gypsum and ground granulated blast furnace slag and later mixing them intimately.
- It has low heat of hydration and is relatively better resistant to chlorides, soils and water containing excessive amount of sulphates or alkali metals, alumina and iron, as well as, to acidic waters, and therefore, this can be used for marine works

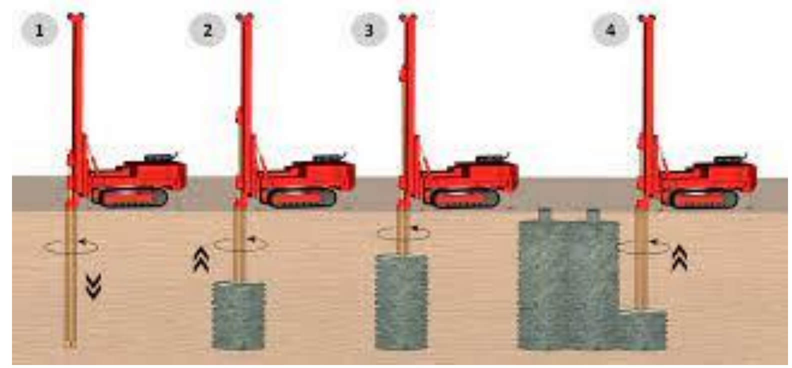


- The quantity of granulated slag mixed with portland clinker will range from 25-65 per cent.
- Early strength is mainly due to the cement clinker fraction and later strength is that due to the slag fraction.
- The rate of hardening of Portland blast furnace slag cement in mortar or concrete is somewhat
- slower than that of ordinary Portland cement during the first 28 days, but thereafter increases.
- The major advantages currently recognized are:
- (a) Reduced heat of hydration;
- (b) Refinement of pore structure;
- (c) Reduced permeability
- (d) Increased resistance to chemical attack.
- Combining GGBS and OPC at mixer is treated as equivalent to factory made PSC.

Quick setting cement:

- This cement sets very early. The early setting property is brought out by reducing the gypsum content at the time of clinker grinding.
- This cement is required to be mixed, placed and compacted very early.
- It is used mostly in under water construction where pumping is involved.
- Use of quick setting cement in such conditions reduces the pumping time and makes it economical.
- Quick setting cement may also find its use in some typical grouting operations.





Low heat cement:

- Hydration of cement is an exothermic action which produces large quantity of heat during hydration.
- In mass concrete construction, such as dams, where temperature rise by the heat of hydration can become excessively large and cracks will form in large body of concrete.
- Hence, there is a need to produce cement which produces less heat or the same amount of heat, at a low rate during the hydration process.
- Low-heat evolution is achieved by reducing the contents ofC_3S and C_3A which are the compounds evolving the maximum heat of hydration and increasing C_2S.
- A reduction of temperature will retard the chemical action of hardening and so furtherrestrict the rate of evolution of heat.
- The rate of evolution of heat will, therefore, be less and evolution of heat will extend over a longer period.
- Therefore, the feature of low-heat cement is as low rate of gain of strength. But the ultimate strength of low-heat cement is the same as that of ordinary Portland cement.

- As per the Indian Standard Specification the heat of hydration of lowheat
- Portland cement shall be as follows:
  - 7 days — not more than 65 calories per gm.
  - 28 days — not more than 75 calories per gm.
- The specific surface of low heat cement as found out by air-permeability method is not less than3200 sq. cm/gm.
- The 7 days strength of low heat cement is not less than 16 MPa in contrast to 22 MPa in the case of ordinary Portland cement.
- Other properties, such as setting time and soundness are same as that of ordinary Portland cement.

Portland pozzolana cement:

- Portland Pozzolana cement (PPC) is manufactured by the intergrinding of OPC clinker with 10to 25 per cent of pozzolanic material (as per the latest amendment, it is 15 to 35%).
- A pozzolanic material is essentially a silicious or aluminous material which while in itself possessing no cementitious properties, which will, in finely divided form and in the presence of water, react with calcium hydroxide, liberated in the hydration process, at ordinary temperature, to form compounds possessing cementitious properties.
- The pozzolanic materials generally used for manufacture of PPC are calcined clay (IS 1489 part 2 of 1991) or fly ash (IS 1489 part I of
- 1991).
- Fly ash is a waste material, generated in the thermal power station, when powdered coal is used as a fuel. These are collected in the electrostatic precipitator

- The pozzolanic action is shown below:
- **Calcium hydroxide + Pozzolana + water → C – S – H (gel)**
- Portland pozzolana cement produces less heat of hydration and offers greater resistance to the attack of aggressive waters than ordinary Portland cement.
- Moreover, it reduces the leaching of calcium hydroxide when used in hydraulic structures. It is particularly useful in marine and hydraulic construction and other mass concrete constructions.
- Advantages of PPC
- (a) In PPC, costly clinker is replaced by cheaper pozzolanic material - Hence economical
- (b)Soluble calcium hydroxide is converted into insoluble cementitious products resulting in improvement of permeability

- PPC consumes calcium hydroxide and does not produce calcium hydroxide as much as that of OPC.
- It generates reduced heat of hydration and that too at a low rate.
- PPC being finer than OPC and also due to pozzolanic action, it improves the pore size distribution and also reduces the micro cracks.
- All the above advantages of PPC are mainly due to the slow conversion of calcium hydroxide in the hydrated cement paste into cementitious product
- All the above advantages of PPC are mainly due to the slow conversion of calcium hydroxide in the hydrated cement paste into cementitious product.
- In one investigation, 20 per cent calcium hydroxide in one year old OPC paste was found to be only 8.4 per cent calcium hydroxide in a
- similarly hydrated paste containing 30 per cent pozzolana.

- A few of the disadvantages are that the rate of development of strength is initially slightly slower than OPC.
- Secondly reduction in alkalinity reduces the resistance to corrosion of steelreinforcement.
- But as permeability of PPC is low, corrosion of steel reinforcement will not bethere. Setting time is generally longer.

Air entraining cement

- This cement is made by mixing a small amount of an air-entraining agent with ordinary Portland cement clinker at the time of grinding.
- The following types of air-entraining agents could be used:
- (a) Alkali salts of wood resins.
- (b) Synthetic detergents of the alkyl-aryl sulphonate type.
- (c) Calcium lignosulphate derived from the sulphite process in paper making.
- (d) Calcium salts of glues and other proteins obtained in the treatment of animal hides.
- These agents in powder, or in liquid forms are added to the extent of 0.025–0.1 per cent by weight of cement clinker.
- Air-entraining cement will produce at the time of mixing, tough, tiny, discrete non-coalesceing
- air bubbles in the body of the concrete which will modify the properties of plastic concrete with respect to workability, segregation and bleeding

Colored concrete (white cement):

- Colored cement consists of Portland cement with 5-10 per cent of pigment
- The pigment cannot be satisfactorily distributed throughout the cement by mixing, and hence, it is usual to grind the cement and pigment together.
- The process of manufacture of white Portland cement is nearly same as OPC.
- The raw materials used are high purity limestone (96% $CaCo_3$ and less than0.07% iron oxide).
- The other raw materials are china clay with iron content of about 0.72 to
- 0.8%, silica sand, flourspar as flux and selenite as retarder

Hydrophobic cement:

- Hydrophobic cement is obtained by grinding ordinary Portland cement clinker with water repellant film-forming substance such as oleic acid, and stearic acid.
- The water-repellant film formed around each grain of cement, reduces the rate of deterioration of the cement during long storage, transport, or under unfavorable conditions.
- The film is broken out when the cement and aggregate are mixed together at the mixer exposing the cement particles for normal hydration.
- The film forming water-repellant material will entrain certain amount of air in the body of the concrete which incidentally will improve the workability of concrete.

- The hydrophobic cement is made actually from ordinary Portland cement clinker.
- After grinding,the cement particle is sprayed in one direction and film forming materials such as oleic acid, or stearic acid, or pentachlorophenol, or calcium oleate are sprayed from another direction
- such that every particle of cement is coated with a very fine film of this water repellant material which protects them from the bad effect of moisture during storage and transportation

Masonry cement:

- Ordinary cement mortar, though good when compared to lime mortar with respect to strength and setting properties, is inferior to lime mortar with respect to workability, water-retentivity, shrinkage property and extensibility.
- Masonry cement is a type of cement which is particularly made with such combination of materials, which when used for making mortar, incorporates all the good properties of lime mortar and discards all the not ideal properties of cement mortar.
- This kind of cement is mostly used, as the name indicates, for masonry construction.
- It contains certain amount of air-entraining agent and mineral admixtures to improve the plasticity and water retentivity.

Expansive cement:

- 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.
- Cement used for grouting anchor bolts or grouting machine foundations or the cement used in grouting the pre-stressed concrete ducts, if shrinks, the purpose for which the grout is used will be to some extent defeated.
- This type of cement which suffers no overall change in volume on drying is known as expansive cement.
- Cement of this type has been developed by using an expanding agent and a stabilizer very carefully.
- Proper material and controlled proportioning are necessary in order to obtain the desired expansion. Generally, about 8-20 parts of the sulphoaluminate clinker are mixed with 100 parts of the Portland cement and 15 parts of the stabilizer. Since expansion takes place only so long as concrete is moist, curing must be carefully controlled.

- Special grade cement, oil well cement, rediset cement, high alumina cement, very high strength cement are other types of cements.
- Macro defect free cement, densely packed system, pressure densification and warm pressuring, high early strength cement, pyrament cement and magnesium phosphate cement are some types of very high strength cements.