CEMENT

Ordinary Portland Cement (OPC)

- **It's a product of an intimate mixture of correctly proportioned calcareous (lime) and argillaceous (clay) materials, obtained by calcination (heating of lime) at high temperature.**

- **The calcined product, called clinker, is then finely pulverized by grinding into a fine powder. Finally it is mixed with gypsum ($CaSO_4 . 2H_2O$) to obtain cement.**

- **When water is mixed with cement, a series of chemical reaction takes place. As a result, the cement paste first sets and then hardens into stone like mass.**

- **Calcareous materials (Lime): Compounds, generally oxides, of Ca and Mg; e.g., Limestones, Shell, Dolomites, etc.**

  Argillaceous materials (Clay): Oxides of silicon (silica), aluminium (alumina) and iron as present in clay and shale.

Composition of Ordinary Portland Cement (OPC):

Main ingredients are clay and lime. Besides, cement contains small amount of iron oxide, MgO, SO_3, alkalies (oxides of sodium and potassium) and other materials. Typical percentages of these constituents in OPC may be as follows:

Constituents	Typical %	Average (%)	
1. Calcareous Material, Lime, Calcium Oxide, CaO	60~70	62.2	
2.Calcareous Material, Magnesium Oxide, MgO	1~4	1.5	
3. Argillaceous Material, Silica (component of clay), SiO_2	20~25	22.0	
4. Argillaceous Material, Alumina (component of clay), Al_2O_3	3~8	5.0	
5. Argillaceous Material, Iron Oxide ((component of clay), Fe_2O_3	2~4	3.0	
6. Oxide of sulphur, SO_3	1~5	1.4	-
7. Alkalies, Oxides of Sodium and Potassium (soda or potash)	1	1.0	-
8. Gypsum, $CaSO_4.2H_2O$ (added for retarding setting action)	3~5	4.0	-

Natural cement:

- **Manufactured from natural stones (sandstone) by burning them followed by crushing to powder**

- **These stones contain 20~40% of argillaceous matter and the rest is calcareous matter. The binding property of cement is provided by argillaceous matter (clay).**

- **Since chemical composition of natural cement stones varies considerably from place to place, the properties of natural cement also keep on varying.**

- **Even cement being manufactured in one factory may be varying in properties.**

- **For example, hydraulic properties of cement are entirely dependent on the percentage of clayey materials present. If % clay is high, quick setting cement is produced with low ultimate strength.**

Ordinary artificial cement closely resembles sandstone, which is found abundantly at a place, Portland, England and hence this cement is referred as Portland cement.

Artificial cement:

- **Artificial cement is manufactured by burning at high temperature an intimate mixture of argillaceous and calcareous substances and lastly crushing the resulting mixture (clinker) to a fine powder after adding gypsum to it.**

- **Gypsum is added to delay the setting action of the cement so that it may be properly mixed, applied and finished.**

- **Without gypsum, setting action of cement starts the moment the water is added to cement, thus giving no time for mixing, placing and finishing.**

- **The setting time can be varied by suitably adjusting the percentage of gypsum.**

Characteristics of artificial cement:

Artificial cement is popular because of the following reasons:

- **Can be manufactured in any desired color**
- **Initial setting time can be easily regulated**
- **Rate of hardening can be regulated**
- **Rate of heat of evolution can be regulated**
- **The same quality cement can be produced again and again by maintaining the same composition of raw materials**
- **Can be manufactured in large quantities**

During manufacturing of artificial cement, chemical reaction between the calcareous and argillaceous ingredients leads to the formation of the following four mineral constituents:

1. Tri-calcium silicate:	C_3S	$3CaO.SiO_2$	**48**
2. Di-calcium silicate :	C_2S	$2CaO.SiO_2$	**25**
3. Tri-calcium aluminate:	C_3A	$3CaO.Al_2O_3$	**10**
4. Tetra cal. Al. Ferrite:	C_4AF	$4CaO.Al_2O_3.Fe_2O_3$	**9**
5. Gypsum		$CaSO_4.2H_2O$	**3**

Functions of the raw ingredients of artificial cement:

Alumina, Al_2O_3:

- **Forms complex aluminates with silica and calcium (C_3A, C_4AF)**
- **Imparts the setting property to the cement**
- **If present in excess, setting will start very quickly with no time for mixing, placing, etc., and also reduces strength of cement.**

Silica, SiO_2:

- **Goes into chemical combination with calcium and forms hard silicates (C_2S, C_3S)**
- **These silicates C_2S, C_3S are responsible for imparting strength to cement**

Lime, CaO:

- **Important ingredient; its bulk in cement is above 60% by weight**
- **Imparts strength forming hard silicates (C_2S, C_3S)**
- **Its proportion should be carefully decided**
- **Less than the required quantity will cause decrease in the strength of cement as sufficient C_2S, C_3S will not produce**
- **If used in excess, some part of it is left in forms of free lime**
- **Free lime causes expansion and disintegration of cement at the time of setting and hardening**

Iron oxide, Fe_2O_3:

- **Imparts color**
- **Increases strength and hardness of cement**

Magnesium oxide, MgO:

- **Imparts strength and hardness to cement when present in small quantity**

Alkalies or Oxides of Sodium and Potassium:

- **If present in raw ingredients, they are mostly driven out by the flue gases during burning**
- **Still may be present in small amount**
- **If present in excess, it will cause efflorescence in cement**

Functions of mineral constituentsof OPC:

C_3A:

- **The reaction of C_3A with water is violent; responsible for early setting of cement; it does not contribute to the strength of cement**
- **Hydration leads to immediate stiffening of the paste, known as flash setting;**
- **To prevent this from happening, gypsum is added to cement clinker during grinding;**
- **Gypsum and C_3A react to form insoluble calcium sulpho-aluminate (which does not hydrate) for the time being, but eventually a C_3A hydrate is formed. This hydrated C_3A causes the setting action of cement;**
- **The calcium sulpho-aluminate ($3C_3A.3CaSO_4.3H_2O$) has, in general, a retarding action on the starting of initial setting of cement after the water is added;**
- **Gypsum also retards the hydration of C_3S, which is responsible for strength development of cement.**

C_3S:

- **Important mineral constituent imparting strength to cement;**
- **Within a week after water is added to cement, substantial part of tri calcium silicate reacts with water and gets hydrated;**
- **Mainly responsible for imparting strength to cement in early days. (7 days strength)**

C_2S:

- **Slowest mineral compound to hydrate;**
- **Hydration continues for several weeks;**
- **Responsible for the progressive strength of cement, especially strength gain after a week of mixing.**

C_4AF:

- **Instantly reacts with water after mixing and are the first to hydrate;**
- **Having no influence on setting action of cement, neither does on hardening.**

Hydration:

- **The process of hydration is essentially the formation of minute crystals of calcium and gels from the solution of cement and water. It continues for a long time. The hydration rate of different mineral compounds is different as mentioned above.**
- **As the crystals adhere to one another and to the surface of sand or inert particles of aggregate (with which cement is mixed), the entire mixture gets set and hardened resulting in gaining strength.**
- **The strength developed depends on the amount of gel formed, and the degree of crystallization.**
- **After setting is initiated, hardening of cement follows, and in the course of time, hydration process advances further into the interior.**

Heat evolved during setting:

- **The setting action of cement is essentially a process of hydration and is accompanied by 'Evolution of Heat' called heat of hydration.**
- **The C_3A gives out much of the heat. Similarly, C_3S also generates considerable heat during hydration.**
- **One gram of OPC gives out about 120 calories on setting, out of which 80 calories are given out in the first 7 days.**
- **Since hydration of cement continues for a considerable period, extending well over a year, the problem of dissipating heat that generated during hydration becomes important in the case of massive and thick concrete structures like dams, rafts, etc.**
- **A rise in temperature to the extent of 15^0 to 25^0C is observed in many cases. The rise in temperature is the largest during the first few days. But in the large masses of concrete, the maximum temperature is generally reached as late as after 2 to 3 months.**
- **Therefore, in such cases, the devices for cooling down the interior have to be adopted. Otherwise, the heat of hydration causes cracking of the structure on cooling (due to the**

temperature gradient between the surface concrete and the interior concrete) resulting in weakening the concrete.

False Setting:

- **False setting is the name given to the abnormal premature stiffening of cement within a few minutes of mixing with water.**

- **It differs from flash setting in:**
  - **(i) In this case, no appreciable heat is evolved;**
  - **(ii) Re-mixing the cement paste without further addition of water restores plasticity of the paste;**
  - **(iii) The restoration will not cause strength loss as long as it does not set in the normal manner.**

- **Some causes of false setting are:**
  - **(i) Dehydration of gypsum while grinding to powder with too hot clinker;**
  - **(ii) Semi-hydrate ($CaSO_4$. 1/2H_2O) or anhydrite ($CaSO_4$) are formed and if cement is mixed with water, these $CaSO_4$ hydrates to form gypsum again ($CaSO_4$. 2H_2O). Thus setting takes place with resulting stiffening of the paste;**
  - **(iii) Excess alkalies present in cement may cause false setting. During storage, the akalies carbonates reacts with $Ca(OH)_2$ liberated by hydrolysis of C_3S to form CaCO3. This precipitates and induces a rigidity of the paste.**

Testing of cement:

i. **Fineness test**
ii. **Test for strength: Tensile and compressive**
iii. **Test for Setting time: Initial and final**
iv. **Test for soundness or Expansion test**

Fineness test:

The chemical activity of cement depends upon the total surface area of cement particles available for chemical reaction in a given weight. Therefore, the necessity of providing a sufficient total surface area of cement particles is of much importance. Consequently, fineness by grinding is essential in cement manufacturing.

Most of the cement particles range in size from 75 to 150 microns. The hydration rate and hence the strength of cement depends upon the uniform distribution of the various particles sizes between these two sizes.

When cement is used in combination with water, sand and broken stone, it has to form a thin paste to cover the combined surface area of the grains of sand and stone pieces. This is more possible if the particles of cement are of required fineness.

Sieve test for fineness:

100 grams of cement are sieved on a US #200 (or I.S.I. #8) test sieve. After sieving, the residue by weight on #200 test sieve (opening is 75 micron) is measured. For OPC, the residue must not exceed 10 gm, while for rapid hardening cement it must be less than 5 gm.

Surface area test for fineness:

Surface area, termed as the specific surface, is expressed as total surface area in square centimeters per gram of cement. It is determined by Air Permeability method or Turbidimeter method.

Methods	**OPC**	**Rapid Hardening cement**	**Low Heat**
After sieving, the residue (gm)	**10**	**5**	**--**
Surface area cm^2/gm: Air P.	**2250**	**3250**	**3200**
Surface area cm^2/gm: Turbid.	**1600**	**1700**	**1700**

Cement paste of Normal Consistency:

1. **Vicat Needle apparatus is used for the purpose of preparing a paste of normal consistency.**
2. **The plunger diameter used in this case is 10 mm.**
3. **Cement is taken and mixed with water to form a neat cement paste.**
4. **The paste is filled in the cylindrical mould of the Vicat apparatus and placed under the plunger. The plunger is then brought to the surface of the paste and suddenly released.**
5. **The penetration of the plunger into the paste is observed from the vertical scale of the needle.**
6. **Trial paste samples are made each time with different percentages of water until the penetration is 25 ±1 mm deep.**
7. **The corresponding quantity of water, expressed as the percentage (P) of the weight of cement is noted. The paste, which allows this penetration, is taken as Cement paste of Normal Consistency.**

The quantity of water required for normal consistency cement paste is used to determine the quantities of water required for:

i. **Preparing for a standard mortar to test tensile and compressive strength.**
ii. **Preparing a cement paste for setting time test.**
iii. **Preparing a cement paste for soundness test.**

Setting time Tests:

i. **Initial setting time**
ii. **Final setting time**

Both the tests are carried out with the aid of Vicat apparatus. A needle of 1 mm square is used. Neat cement paste is prepared by taking only 0.78 P of water. Standard spatula is used for filling in cylindrical mould.

Initial setting time:

- **The mould is brought below the Vicat Needle;**
- **The needle is allowed to sink into the paste;**
- **Time elapsed after mixing water is recorded until the needle ceases to sink into the cement paste completely, but only for a depth of about 35-mm. At this state, time elapsed is called the initial setting time.**

Initial setting time (ASTM C150)	
OPC and RHC	**: Not less than 45 minutes;**
Low heat cement	**: Not less than 60 minutes**
Aluminous cement	**: Not less than 2 hrs.**

Final setting time:

- **Final setting is determined by 1-mm diam. needle fitted with a metal attachment hollowed out so as to leave a circular edge of 5-mm in diameter and that setting 0.5 mm behind the tip.**
- **The final setting is said to have taken place when the needle gently lowered to the surface of the paste makes an impression on it, but the circular cutting edge fails to do so.**
- **The final setting time is reckoned from the moment when water is added to the cement.**

Final setting time (ASTM C150)

OPC, Rapid hardening cement, Low heat cement & Blast furnace PC: Not more than 375 minutes
Aluminous cement: Not more than 2 hrs after initial setting.

Note that the speed of setting and the rapidity of hardening (i.e., gaining strength) are entirely independent of one another. For instance, the prescribed setting times of RHC are of no different from those for OPC, although the two cements harden at different rates.

Soundness test:

Importance: If cement contains excess free lime and magnesia, they will hydrate very slowly; the mortar and concrete prepared with this cement expand and crack after a few months.

This test is carried out by subjecting cement to an increased rate of hydration (by performing the test at the elevated temperature) and observing how it behaves.

Method of testing:

The cement paste is prepared by using 0.78 P percent of water.

The Le Chatelier apparatus is used to conduct this test. The test mould is cured for 24 hrs at at 15^0C. The distance P_1 between the pointers is noted. The mould is then submerged in water, which is brought to the boiling point in about 30 minutes for accelerated hydration.

The water is kept boiling for one hour and is then allowed to cool down to room temperature. If now d_2 is the distance between the pointers, then d_2-d_1 is the expansion of the sample of cement. This should not be more than 10 mm.

Compressive strength (ASTM Type-I):

Type	3 days, psi	7 days, psi	28 days, psi
OPC	1800	2800	4000
RHC	3480	--	--

Types of Portland cement:

No.	English Description (BS)	American Description (ASTM)
1	Ordinary Portland	Type I
2	Modified Portland i. Air Entraining ii. Expanding	Type II
3	Rapid Hardening Portland	Type III
4	Quick setting Portland	--
5	Low Heat Portland	Type IV
6	Sulphate resisting Portland	Type V
7	Blast furnace	Type IS
8	Pozzolana Portland	Type IP
9	White Portland	--

Air entraining cement:

- **Use 0.01% to 0.05% by weight air entraining or foaming agents. Agents are resinous materials such as vinsol, resin, darex, etc. They are added during grinding the clinker.**

- **Concrete made with such cement contains minute, well-distributed air bubbles throughout the mass; air bubble reduces strength by 10 to 15%; the bubbles should not be more than 3 to 4% of the volume of concrete.**

- **Air entrainment improves workability and durability of concrete; such concrete is resistant to severe frost action, fire, surface scaling and other similar effects.**

Rapid hardening cement:

- **Used for high-way slabs, which is to be open to the traffic at the earliest possible moment; also used for manufacturing of precast elements; cold weather concreting because its rapid hardening and high rate of heat evolution protects concrete against freezing.**

- **This type of cement could be produced by:**
    i. **Increasing the fineness of cement (i.e., by increasing their specific surface)**

    ii. **Allowing a low percentage of alumina. Since Al_2O_3 sets early and offers a covering layer over Calcium and Silica compounds, presence of alumina retards their hydration and hence retards hardening.**

    iii. **Increasing the C_3S content to impart rapid hardening. This requires increase in lime content and consequent careful clinkering at a higher temperature. With the increase in lime content in raw materials, however, there is always a danger of the presence of free lime in cement.**

Quick setting cement:

- **Cement possessing initial setting time of 5 min. and final setting time of 30 minutes; Difficult to work with this cement, as little time is allowed for mixing and laying of paste and/or concrete; i.e., these works have to be completed in 5 minutes;**

- **Quick setting property is achieved by (i) increasing fineness, (ii) adding small percentage of $Al_2(SO_4)_3$, and (iii) adding very little or no percentage of gypsum to the clinker during grinding;**

- **$Al_2(SO_4)_3$ together with Al_2O_3 (as an ingredient of cement) hydrates quickly to form C_3A and C_4AF more in quantity than OPC.**

- **Used for concreting under running water; Quick setting action prevents cementing material from being washed out by running water.**

Low heat cement:

- **In mass concrete structures such as dams, retaining walls, bridge abutment, raft, etc., the rate of dissipation of heat of hydration from the surface is much lower than that generated. It causes rise in temperature inside the concrete mass and may result in thermal and shrinkage cracks if proper precautions for dissipating the thermal gradient are not taken. Under this circumstance, the low heat cement can be effectively used.**

- **Cement ingredients are proportioning in such a way that C_3A and C_3S (those that hydrate at faster rate) are formed in less amount, but C_2S is formed in increased amount so that C_2S and C_3S collectively impart the same strength as OPC.**

- **The rate of heat evolution is slow initially (as the hydration rate is slow), so both setting and hardening rates are slow initially. But in the latter stage, both rates are faster than the OPC. Typical composition of low heat cement:**

Type	C_3S (%)	C_2S (%)	C_3A (%)	C4AF (%)
OPC	48	24	10	9
LHC	24	48	5	14

Portland Pozzolana cement (PPC):

- **Pozzolanic materials are mainly burnt/calcined clay like surkhi, fly-ash, volcanic ash, coal waste, silica fumes, etc. They could be added to cement to react with free lime present in OPC. These materials, though inert, are capable of combining with lime when wet and form cementitious products.**
- **These materials are pulverized and then mixed with cement. Or, they could be mixed with clinker and ground with it;**
- **Usually 15% (by weight) pozzolona are mixed with 80% clinker and 5% gypsum to get the finished PPC;**
- **Pozzolana cements impart plasticity and workability to mortars and cement; they possess less heat of hydration and hence suitable for mass concreting;**
- **The free lime present in OPC products is liable to leaching action by percolating waters in dams and other hydraulic structures, which are thereby rendered permeable. Pozzolanic cements, on the other hand, will impart impermeability to hydraulic structures;**
- **An excess of pozzolanic materials makes mortars and concrete shrink more. Their strength also is proportionately reduced.**

Portland Pozzolana Cement (PPC) is ideally suited for the following construction:

- **Hydraulic structures;**
- **Mass concreting works (because of less heat of hydration);**
- **Marine structures;**
- **Masonry mortars and plastering;**
- **Under aggressive conditions;**
- **Applications where OPC is used;**

The compressive strength of PPC as per BIS code at present is equivalent to that of 33 grade OPC.

Sulphate Resisting Portland cement (SRC)

Sulphate Resisting Portland Cement is a type of Portland cement in which the amount of Tricalcium aluminate (C_3A) is restricted to lower than 5 % and (2 C_3A + C_4AF) is lower than 25%. SRC can be used for structural concrete wherever OPC or Portland Pozzolona Cement PPC or Slag Cement is usable under normal conditions. The use of SRC is particularly beneficial in such conditions where the concrete is exposed to the risk of deterioration due to sulphate attack.

Blue Circle High Sulphate Resisting Cement is a type of Portland Cement having a low tricalcium aluminate (C_3A) content and conforms to the British Standard, BS 4027. This standard stipulates a maximum C_3A content of 3.5% to effectively provide the necessary resistance to Sulphate attack.

The use of SRC is recommended for following applications:

- **Foundations, piles;**
- **Basements and underground structures;**
- **Sewage and Water treatment plants;**
- **Chemical, Fertilizers and Sugar factories;**
- **Food processing industries and Petrochemical projects**
- **Coastal works;**
- **Also for normal construction works where OPC is used;**
- **Construction of building along the coastal area within 50 km from sea.**

Sulphate Attack:

Sulphate attack is by far the most common type of chemical attack, causing disruption and cracking of the concrete. Sulphates of Sodium, Calcium and Magnesium are the main types occuring naturally in soil, ground water, sea water as well as industrial waste, sewerage. Reactions occur between the sulphate and the hydrates from the C_3A lead to deterioration of the concrete. By limiting the content of C_3A in Blue Circle High Sulphate Resisting Cement to below 3.5%, the best resistance to sulphate attack is ensured.

When the salinity on the sea water temperatures are high, or there is a hydrostatic pressure on one side of the concrete, or the concrete is of thin or slender section, Blue Circle High Sulphate Resisting Cement should be used.

Buried pipelines may be subjected to the same aggressive conditions as foundations and the same considerations apply to cement choice and concrete quality.

In the areas of waste management, some effluents are aggressive and these are normally found where waste products from industrial processes predominate. Other effluents, initially innocuous, may become corrosive by processes, involving bacteria in the sea water. Especially when the effluent is warm, protein and sulphur compunds present are converted to hydrogen sulphide; this leads to the formation of sulphates and sulphuric acid. Blue Circle High Sulphate Resisting Cement is useful in helping to improve resistance to the attacks.

OPC and some modified OPC's with composition of ingredients:

	Clinker (%)	Gypsum (%)	Other ingredients (%) and their name	
OPC, grey cement	95%	5%		It accounts for 70 per cent of the total consumption.
PPC: Portland Pozzolona cement	80%	5%	15% pozzolona; utilizes flyash, calcined clay, coal waste, silica fumes, volcanic ash, etc.	It accounts for 18 per cent of the total cement consumption
Portland Blast Furnace Slag Cement (PBFSC)	45	5	50% blast furnace slag; It has a heat of hydration even lower than PPC and is generally used in mass concreting.	accounts for 10 per cent of the total cement consumed
Water Proof Cement	similar to OPC	5	with small portion of calcium stearate or non-saponifibale oil to impart waterproofing properties	
White cement	similar to OPC	5	Clinker using fuel oil (instead of coal) with iron oxide content below 0.4 per cent to ensure whiteness. A special cooling technique is used in its production.	It is used to enhance aesthetic value in tiles and flooring. White cement is much more expensive than grey cement.

Cement manufacturing:

The Wet Process

This consists of the following stages:

Stage 1: To prepare cement slurry:

- **Obtain the raw materials from quarries;**
- **Crush the raw materials;**
- **Mix the raw materials and wet grinding of them in mills to obtain slurry;**
- **Correct the slurry;**
- **Stored the corrected slurry;**
- **Prepared a suitable fuel of pulverized coal;**

Stage 2: To obtain cement clinker:

- **Pump the corrected slurry into rotary kiln;**
- **Feed the rotary kiln with slurry and fuel;**
- **Prepare cement clinker in rotary kiln;**
- **Cool the clinker and store it;**

Stage 3: To prepare cement:

- **Grind cement clinker to very fine powder with a retarder (gypsum);**
- **Elevate and store the cement in silos;**
- **Fill the bags and store it for sale or use.**

The Dry Process

This consists of the following stages:

- **The difference between the dry process and the wet process of manufacture of cement lies in the preparation of the correctly proportioned feed required for the rotary kiln.**
- **The feed is a very finely ground powder, which is correctly proportioned and thoroughly mixed;**
- **On the other hand, in the wet process, it is the slurry that is feed for the rotary kiln.**

Cement storage:

i. **<u>Cement silos</u>: In factory, cement is stored in a large sized reinforced concrete vertical cylinders, called cement silos. Their diameter varies from 7 to 10 m and height from 15 to 24 m. Cement is drawn from them at the bottom.**

ii. **<u>Cement packing</u>: Cement is packed in gunny bags or in bags of cloth or paper; Packed with the aid of automatic weighing and packing machines; A special rotary type screw feeding device armed with a 'trigger' is provided for filling the bags.**

When a specific quantity of cement is admitted in each bag, the 'trigger' is operated by the weight of the filled bag, and the feed is automatically closed. OPC weighs 50 kg per bag, which is equivalent to 1.25 cft in volume.

iii. **Cement storage by user: The following precautions should be taken for the storage of cement on works:**

a. **Cement should be stored in a dry place and on a raised platform, which is covered and guarded from sun, wind and rain. A maximum of 15 bags is placed vertically.**
b. **As far as possible, long periods of storage should be avoided.**
c. **Cement exposed to atmosphere may absorb water vapour and CO_2 and consequently hydrates and loses strength. Heat and humidity accelerates hydration. Under these conditions, cement is said to deteriorate.**
d. **Storage of cement in rainy season is not recommended.**

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Proportioning of Cement Ingredients:

Acidic constituents: SiO_2, Al_2O_3 & Fe_2O_3 (Argillaceous materials)
Alkaline constituents: CaO & MgO (Calcareous materials)

Neglecting the rest (i.e., CaSO4 & other compounds ≈ 8% of total mass), the % of acidic and alkaline constituents are 32 and 63.5, respectively. The ratio of these constituents is given by:

Alkaline/Acidic = (CaO & MgO) / (SiO_2, Al_2O_3 & Fe_2O_3)=63.5/32≈ 2.0

Sometimes the index of cementation Value (or cement moduli) is used for proportioning raw materials of cement, which is given by:

Cementation Value (CV) =

$$(2.8\ SiO_2 + 1.1\ Al_2O_3 + 0.7\ Fe_2O_3) / (CaO + 1.4\ MgO)$$

In the above index, % molecular weight of the individual ingredients is used. Thus,

$$CV= (2.8x0.37 + 1.1x0.07+ 0.7x0.02) / (1.0x1.1 + 1.4x0.04)$$
$$= 1.13 / 1.15 \approx 1.0 \text{ (approx.)}$$

Either index can be used for proper proportioning of cement constituents. It is clearly understandable that the calcareous and argillaceous materials should be carefully selected and proportioned.

On the other hand, clinkering helps in a thorough and intimate mixing of raw materials. It ensures a thorough and complete chemical reaction between the ingredients to form the following four mineral constituents:

Differences Between cement & Lime:

a. **Color of lime is always whitish. Cement is generally grey, but it can be manufactured in other desired colors.**

b. **When mixed with water, cement starts to set which completes in 10 to 30 minutes and acquires sufficient strength in a day or two. Lime does set at such a small time. It takes rather a long period before hardening.**
c. **Cement is several times stronger binding material than lime.**
d. **Lime eats away iron girders or others made of metals if come in direct contact. While cement, on the other hand, protects iron and other metallic fitting from atmospheric action.**
e. **When water is added to quick lime, a lot of heat is generated. Heat generation is unnoticeable in case of cement.**