# CONCRETE TECHNOLOGY


**PROF MRS. S P MADNAIK**

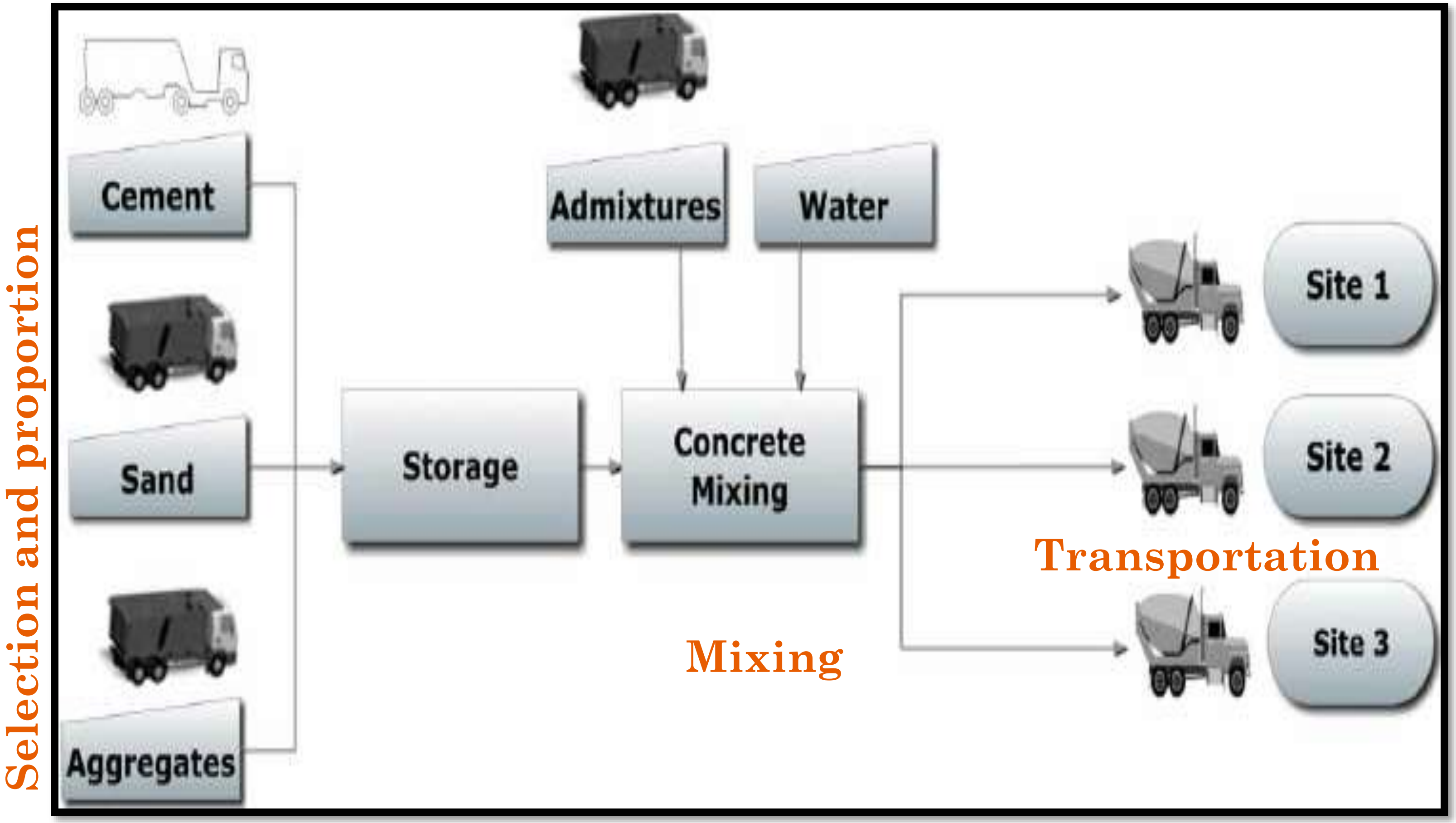
*ASSISTANT PROFESSOR*
*CIVIL ENGINEERING DEPARTMENT*
*DR J J MAGDUM COLLEGE OF ENGINEERING*
*JAYSINGPUR*

# CONCRETE

# WHY CONCRETE IS MOST POPULAR CONSTRUCTION MATERIAL?

- Concrete is a popular material for many construction applications
- It is widely used because of ***its strength, durability, reflectivity, and versatility***

# PRODUCTION OF CONCRETE



# CONSTITUENTS OF CONCRETE

- Concrete is made up of two components

1. **Aggregates-** Aggregates are generally classified into two groups, fine and coarse, and occupy about 60 to 80 percent of the volume of concrete
2. **The paste-** It is composed of cement, water, and entrained air and ordinarily constitutes 20 to 40 percent of the total volume.

# Cement

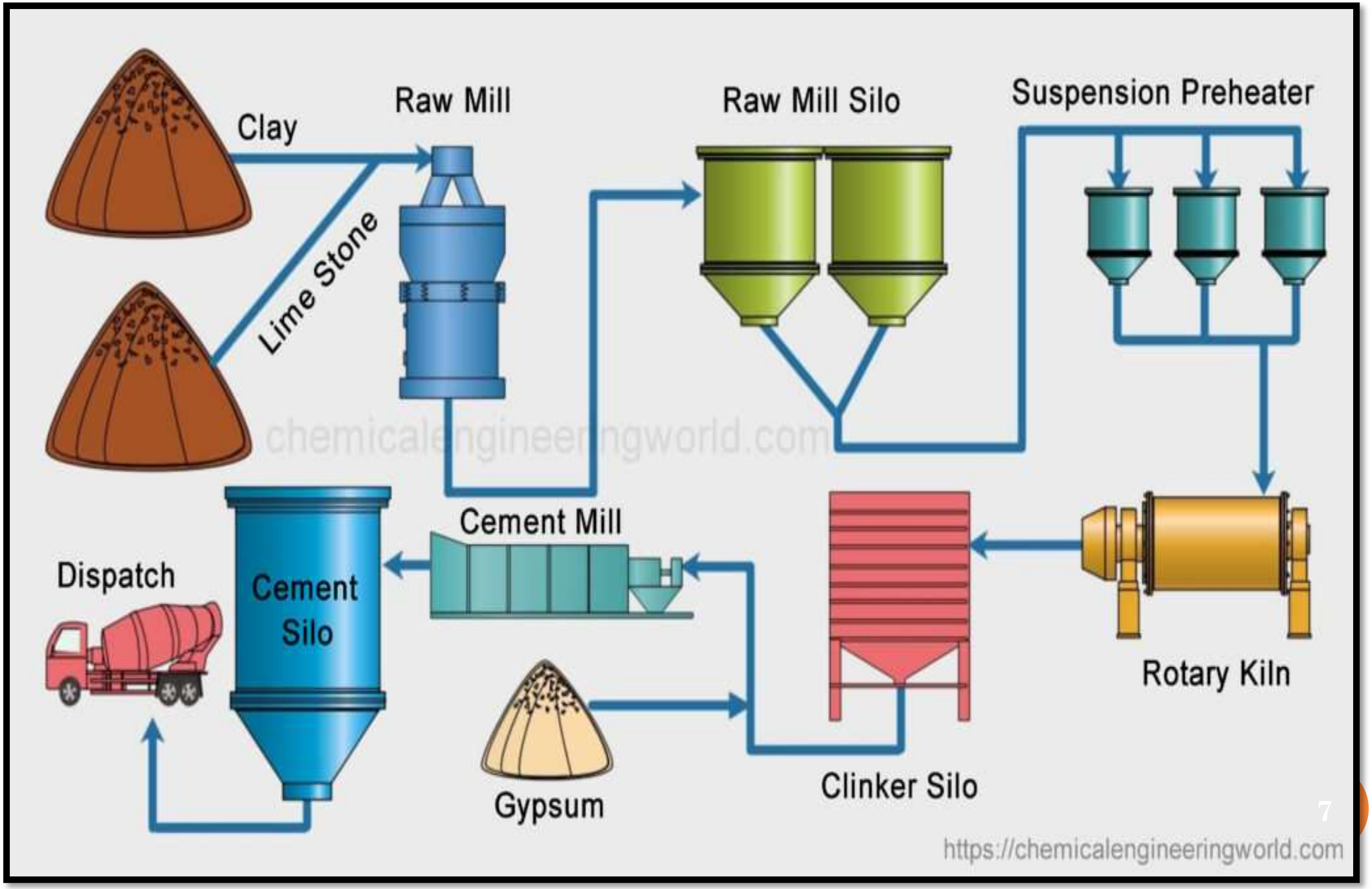
There are four stages in the manufacture of cement:

1. crushing and grinding the raw materials
2. blending the materials in the correct proportions
3. burning the prepared mix in a kiln
4. grinding the burned product, known as "clinker," together with some 5 percent of gypsum (to control the time of set of the cement).

The three processes of manufacture are known as

a. **Wet process-** the raw materials are ground wet and fed to the kiln as a slurry
b. **Dry process-** the raw materials are ground dry and fed as a dry powder
c. **Semidry process-** the raw materials are ground dry and then moistened to form nodules that are fed to the kiln.

# Dry process


Clay
Lime Stone
Raw Mill
Raw Mill Silo
Suspension Preheater
chemicalengineeringworld.com
Cement Mill
Dispatch
Cement Silo
Rotary Kiln
Gypsum
Clinker Silo
https://chemicalengineeringworld.com

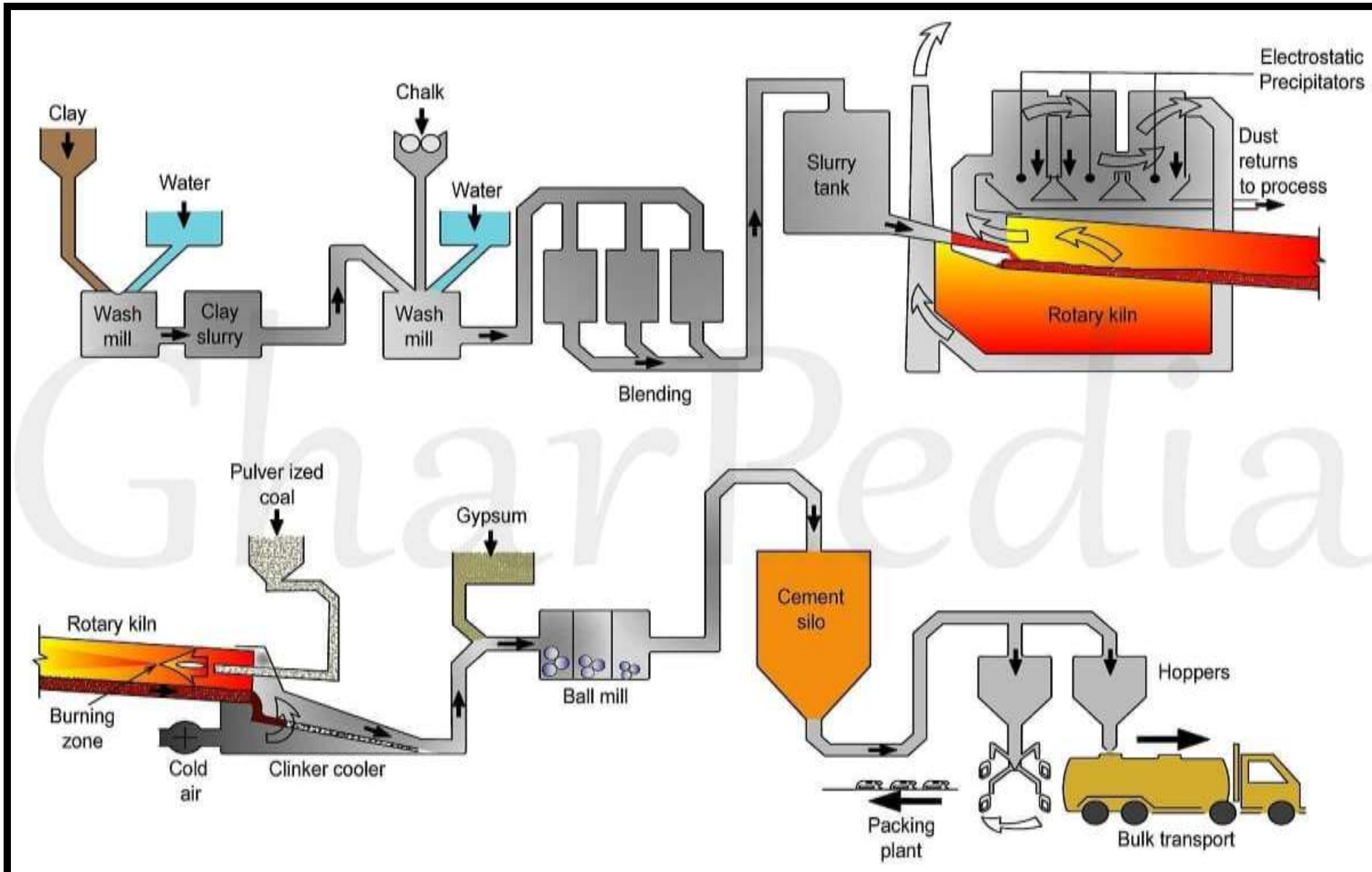
## (a) Dry process:

*In this process, the raw materials are changed to powdered form in the absence of water.*

- In this process calcareous material such as **lime stone** (calcium carbonate) and **argillaceous material such as clay** are ground separately to fine powder in the absence of water and then are mixed together in the desired proportions.
- Water is then added to it for getting thick paste and then its cakes are formed, dried and burnt in kilns.
- This process is usually used when raw materials are very strong and hard.

| Raw Mill | Preheater | Kiln | Clinker | Gy |
|---|---|---|---|---|
| to grind raw materials into "raw mix” | to heat the raw mix and drive off carbon dioxide and water before it is fed into the kiln | a thermally insulated chamber, a type of oven, that produces temperatures sufficient to complete some process, such as hardening, drying, or chemical changes | Clinker is a nodular material produced in the kilning stage during the production of cement and is used as the binder in many cement | called the retarding agent of cement which is mainly used for regulating the setting time of cement and is an indispensable component. Without gypsum, cement clinker can condense immediately by mixing with water and release heat. |

# WET PROCESS

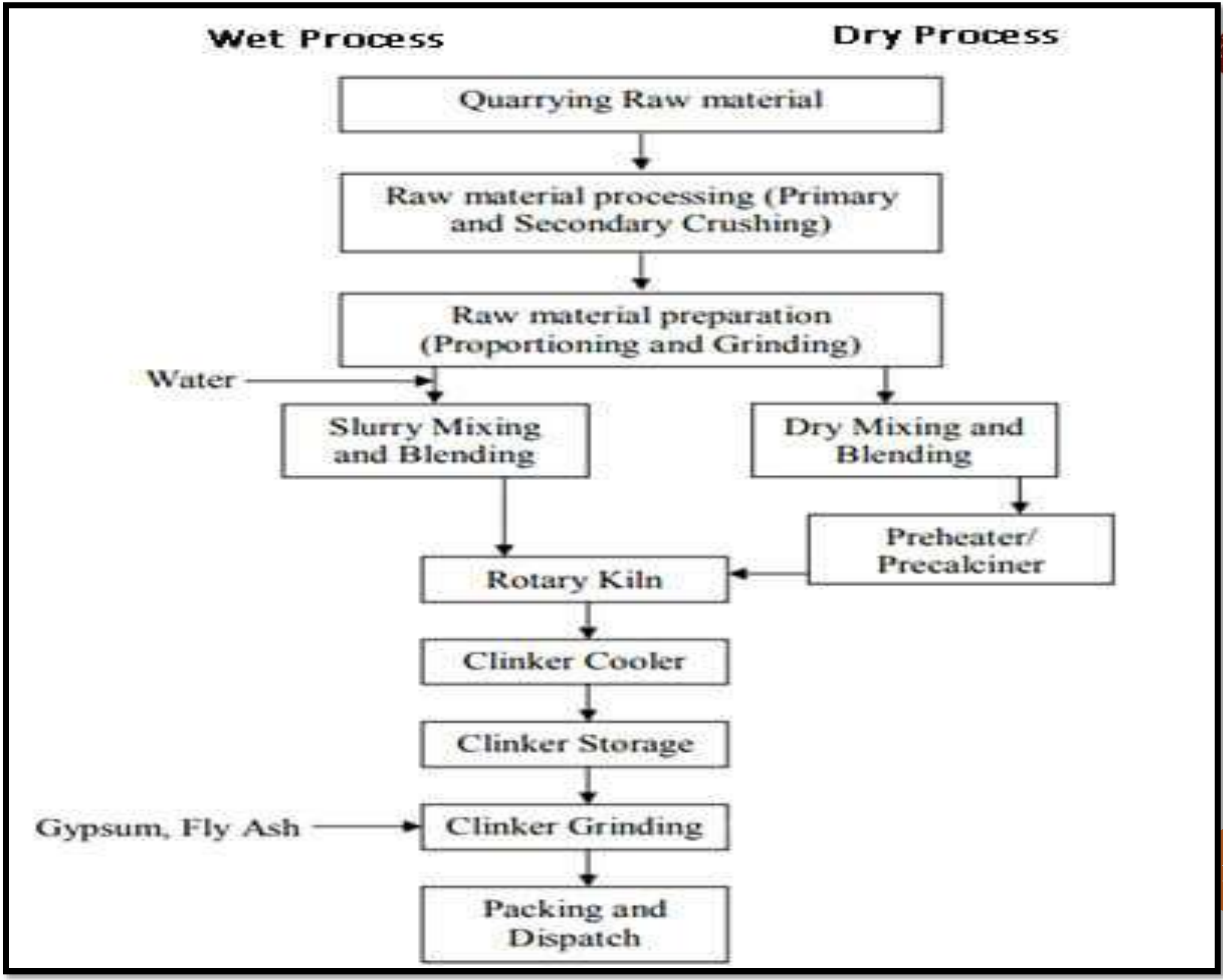



Wet Process for Manufacturing of Cement

(b) <u>Wet process:</u>

*In this process, the raw materials are changed to powdered form in the presence of water.*

- In this process, raw materials are pulverized by using a Ball mill, which is a rotary steel cylinder with hardened steel balls. When the mill rotates, steel balls pulverize the raw materials which form slurry (liquid mixture).
- The slurry is then passed into storage tanks, where correct proportioning is done. Proper composition of raw materials can be ensured by using wet process than dry process. Corrected slurry is then fed into rotary kiln for burning.
- This process is generally used when raw materials are soft because complete mixing is not possible unless water is added.


Wet Process
Dry Process
Quarrying Raw material
Raw material processing (Primary and Secondary Crushing)
Raw material preparation (Proportioning and Grinding)
Water
Slurry Mixing and Blending
Dry Mixing and Blending
Preheater/ Precalciner
Rotary Kiln
Clinker Cooler
Clinker Storage
Gypsum, Fly Ash
Clinker Grinding
Packing and Dispatch

# Chemical composition

| Ingredient | Percentage |
|---|---|
| Lime (CaO) | 62 |
| Silica ($SiO_2$) | 22 |
| Alumina ( $Al_2O_3$) | 5 |
| Calcium Sulphate ($CaSO_4$) | 4 |
| Iron Oxide ($Fe_2O_3$) | 3 |
| Magnesia (MgO) | 2 |
| Sulphur (S) | 1 |
| Alcalies | 1 |
| Total | 100 |

# Function of composition of cement

(i) **Lime(CaO):**

Lime forms nearly two-third (2/3) of the cement. Therefore sufficient quantity of the lime must be in the raw materials for the manufacturing of cement. Its proportion has an important effect on the cement. Sufficient quantity of lime forms di-calcium silicate and tri-calcium silicate in the manufacturing of cement.

Lime in excess, causes the cement to expand and disintegrate.

(ii) <u>Silica ($SiO_2$):</u>

The quantity of silica should be enough to form di-calcium silicate and tri-calcium silicate in the manufacturing of cement. Silica gives strength to the cement. Silica in excess causes the cement to set slowly.

(iii) <u>Alumina ($Al_2O_3$):</u>

Alumina supports to set quickly to the cement. It also lowers the clinkering temperature. Alumina in excess, reduces the strength of the cement.

(iv) <u>Iron Oxide ($Fe_2O_3$):</u>

Iron oxide gives colour to the cement.

(v) <u>Calcium Sulphate (or) Gypsum ($Ca\ SO_4$) :</u>

At the final stage of manufacturing, gypsum is added to increase the setting of cement.

# Bogue's Compound

- The oxides present in raw materials when subjected to high temperature in clinker combine with each other to form a complex compound called as **Bogue's Compound.**
- Every compound possesses its features. The property of cement can be modified by changing the percentage of these compounds at the time of hydration.
- There are numerous types of cement obtainable in the market according to the percentage of bogues compounds originated at the time of the hydration of cement.

| Name of compound | Formula | Abb. | Characteristics |
|---|---|---|---|
| Tricalsium silicate (30-50) | $3CaO.SiO_2$ | $C_3S$ | • Contributes to 50-60% strength (responsible for strength of first 7 days)<br>• Producing a rapid hardening cement |
| Dicalcium silicate (20-45) | $2CaO.SiO_2$ | $C_2S$ | • Responsible for strength after 7days up to 1 year<br>• Important for hydraulic structure |
| Tricalcium aluminate (8-12) | $3CaO.Al_2O_3$ | $C_3A$ | • Early strength of cement<br>• Avoid corrosion of steel<br>• Make it prone to sulphate attack in environments rich in sulphate |
| Tetracalcium aluminate (6-10) | $4CaO.Al_2O_3.Fe_2O_3$ | $C_4AF$ | • Acts as a filler cement<br>• Gives cement grayish tint<br>• Helps cement manufacturing process by providing lower clinker temperature |

## HYDRATION OF CEMENT

- Reaction is exothermic
- The chemical reaction between cement and water is termed as heat of hydration.
- Anhydrous cement does not bind fine and coarse aggregate.
- It acquires adhesive property only when mixed with water.
- The amount of heat released depends on the cement composition, curing temperature, water to cement ratio, and cement fineness.
- High temperature resulting from heat of hydration may cause thermal cracking of concrete and consequent reduction of mechanical properties.

# Products of Cement Hydration

| | | |
|---|---|---|
| Calcium silicate hydrates **(C-S-H gel)** | formed during the reaction of $C_3S$ and $C_2S$ with water | **Affects rate of heat of hydration.**<br>**(1. $C_2S$ hydrates slowly**<br>**2. $C_3S$ hydrates rapidly)** |
| Calcium hydroxide $Ca(OH)_2$ | | **Disadvantage:** It decreases the durability of concrete, it causes the deterioration of concrete, it promotes sulfur attack on concrete.<br>**Advantage**: $Ca(OH)_2$ is of alkaline nature so the pH is maintained around 13, hence it can provide corrosion resistance. |
| Calcium aluminates hydrates ($CaO$-$Al_2O_3$-$H_2O$) | formed upon the hydration of aluminates | •$C_3A$ reacts with water immediately causing a flash set. However, gypsum added during the manufacture of Portland cement acts as a retarder to slow down its reaction.<br>•hydrates of $C_4AF$ show more resistance to sulphate attack as compared to the hydrates of $C_3A$. |

# Which cement to use?

The choice of the cement depends upon the nature of work, local environment, method of construction etc.

**The different type of cement has been achieved by different methods like :**

(a) Changing oxide composition
(b) Changing fineness
(c) Using additives or mineral mixtures like slag, fly-ash or silica fumes etc.

# Types of cement

(*a*) Ordinary Portland Cement
  (*i*) Ordinary Portland Cement 33 Grade
  (*ii*) Ordinary Portland Cement 43 Grade
  (*iii*) Ordinary Portland Cement 53 Grade
(*b*) Rapid Hardening Cement
(*c*) Extra Rapid Hardening Cement
(*d*) Sulphate Resisting Cement
(*e*) Portland Slag Cement
(*f*) Quick Setting Cement
(*g*) Super Sulphated Cement
(*h*) Low Heat Cement
(*j*) Portland Pozzolana Cement
(*k*) Air Entraining Cement
(*l*) Coloured Cement: White Cement
(*m*) Hydrophobic Cement
(*n*) Masonry Cement
(*o*) Expansive Cement
(*p*) Oil Well Cement
(*q*) Rediset Cement
(*r*) Concrete Sleeper grade Cement
(*s*) High Alumina Cement
(*t*) Very High Strength Cement

a) *Ordinary Portland cement:*

- Most important type of cement
- Mostly classified into three types:

1. 33 Grade
2. 43 Grade
3. 53 Grade

b) *Rapid hardening cement (IS 8041–1990) :*

- Develops strength rapidly
- Rapid hardening cement develops at the age of three days, same strength as that is expected of portland cement at 7 days.
- Rapid rate of development of strength is due to higher fineness, higher $C_3S$ and lower $C_2S$ content.

Advantages disadvantages of rapid hardening cement:

1. Used in prefabricated construction work
2. Road repair work
3. Cold weather
4. Where formwork is required to be removed early for reuse somewhere

Disadvantages of rapid hardening cement:

Due to max heat of hydration this cement can not used for mass concrete construction.

## c) *Extra rapid hardening cement*:

- Obtained by integrating calcium chloride with rapid hardening cement. (should not exceed 2% of weight of hardening cement)
- Concrete made with this cement should be transported, placed and compacted within 20 min.
- This cement should not be stored more than one month.
- This cement accelerate the setting and hardening process due to large quantity of heat is evolved in very short time.
- Suitable in cold weather
- This cement is about 25 per cent higher strength than that of rapid hardening cement at one or two days and 10–20 per cent higher at 7 days. 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

## d) *Sulphate resistance cement (IS 12330–1988)*

- Sulphate attack is greatly accelerated if accompanied by alternate wetting and drying which normally takes place in marine structures in the zone of tidal variations.
- Ordinary Portland cement is susceptible to the attack of sulphates, in particular to the action of magnesium sulphate.
- 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 many of its physical properties, sulphate resisting cement is similar to ordinary Portland cement.
- The use of sulphate resisting cement is recommended under the following conditions:

1. Concrete to be used in marine condition
2. Concrete to be used in foundation and basement, where soil is infested with sulphates
3. Concrete used for fabrication of pipes which are likely to be buried in marshy region or sulphate bearing soils
4. Concrete to be used in the construction of sewage treatment works.

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

- Portland slag cement is obtained by mixing Portland cement clinker, gypsum and granulated blast furnace slag 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. (The quantity of granulated slag mixed with portland clinker will range from 25-65%)
- The resultant product is a cement which has physical properties similar to those of ordinary Portland cement.
- In addition, it has low heat of hydration and is relatively better resistant to chlorides.
- Portland blast furnace cement is similar to ordinary Portland cement with respect to fineness, setting time, soundness and strength.

- The heat of hydration of Portland blast furnace cement lower than that of ordinary Portland cement. So this cement can be used in mass concrete structures with advantage.

The major advantages currently recognized are:

1. Reduced heat of hydration
2. Refinement of pore structure
3. Reduced permeability
4. Increased resistance to chemical attack.

*f) Quick setting cement:*

- This cement as the name indicates 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.

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

- Super sulphated cement is manufactured by grinding together a mixture of 80-85 percent granulated slag, 10-15 per cent hard burnt gypsum, and about 5 per cent Portland cement clinker.
- This cement is rather more sensitive to deterioration during storage than Portland cement.
- Super-sulphated cement has a low heat of hydration
- This cement has high sulphate resistance due tothis property cement is particularly recommended for use in foundation, where chemically aggressive conditions exist.
- As super-sulphated cement has more resistance than Portland blast furnace slag cement to attack by sea water, it is also used in the marine works.

## *h) Low Heat Cement (IS 12600-1989):*

- A low-heat evolution is achieved by reducing the contents of C3S and C3A which are the compounds evolving the maximum heat of hydration and increasing C2S.
- A reduction of temperature will retard the chemical action of hardening and so further restrict the rate of evolution of heat. Therefore, the feature of low-heat cement is a slow rate of gain of strength. But the ultimate strength of low-heat cement is the same as that of ordinary Portland cement.
- Used in mass concrete construction, such as dams, where temperature rise by the heat of hydration can become excessively large.

## *i) Portland Pozzolana Cement (IS 1489–1991)*

- Portland Pozzolana cement (PPC) is manufactured by the intergrinding of OPC clinker with 10 to 25 per cent of pozzolanic material
- The pozzolanic materials generally used for manufacture of PPC are calcined clay (IS 1489 part 2 of 1991) or fly ash (IS1489 part I of 1991). Fly ash is a waste material, generated in the thermal power station, when powdered coal is used as a fuel.
- Portland pozzolana cement produces less heat of hydration and offers greater resistance to the attack of aggressive waters than ordinary Portland cement.

**Advantages of PPC**

1. In PPC, costly clinker is replaced by cheaper pozzolanic material - Hence economical.

2. Soluble calcium hydroxide is converted into insoluble cementitious products resulting in improvement of permeability. Hence it offers, durability characteristics, particularly in hydraulic structures and marine construction.
3. It generates reduced heat of hydration and that too at a low rate.
4. PPC being finer than OPC and also due to pozzolanic action, it improves the pore size distribution and also reduces the micro cracks at the transition zone.
5. As the fly ash is finer and of lower density, the bulk volume of 50 kg bag is slightly more than OPC. Therefore, PPC gives more volume of mortar than OPC.
6. The long term strength of PPC beyond a couple of months is higher than OPC if enough moisture is available for continued pozzolanic action.

## *j) Colored Cement (White Cement IS 8042–1989)*

- For manufacturing various colored cements either white cement or grey Portland cement is used as a base. The use of white cement as a base is costly. With the use of grey cement only red or brown cement can be produced.
- Colored cement consists of Portland cement with 5-10 per cent of pigment. The properties required of a pigment to be used for colored cement are the durability of color under exposure to light and weather.
- The properties of white cement is nearly same as OPC. Generally white cement is ground finer than grey cement. Whiteness of white cement as measured by ISI scale shall not be less than 70%.

## *k) Hydrophobic cement (IS 8043-1991)*

- 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 improve the workability of concrete.
- In India certain places such as Assam, Shillong etc., get plenty of rainfall in the rainy season had have high humidity in other seasons.
- The transportation and storage of cement in such places cause deterioration in the quality of cement such places with poor communication system, cement perforce requires to be stored for long time.
- Ordinary cement gets deteriorated and loses some if its strength, whereas the hydrophobic cement which does not lose strength is an answer for such situations.

## *l) Masonry Cement (IS 3466 : 1988)*

- 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 so 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 receptivity.

## *m) IRS-T 40 Special Grade Cement*

- IRS-T-40 special grade cement is manufactured as per specification laid down by ministry of Railways under IRST40: 1985.
- It is a very finely ground cement with high C3S content designed to develop high early strength required for manufacture of concrete sleeper for Indian Railways.

## n) Expansive Cement

- Concrete made with ordinary Portland cement shrinks while setting due to loss of free water. This is known as drying shrinkage.
- There has been a search for such type of cement which will not shrink while hardening and thereafter. As a matter of fact, a slight expansion with time will prove to be advantageous for grouting purpose. 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.
- One type of expansive cement is known as shrinkage compensating cement which is used in concrete, with restrained expansion, induces compressive stresses by shrinkage.
- Another similar type of cement is known as Self Stressing cement which is used in concrete induces significant compressive stresses after the drying shrinkage has occurred.

## *o) Rediset Cement*

### ***Properties of "Rediset"***

- The cement allows a handling time of just about 8 to 10 minutes.
- Strength achieved with "REDISET" in 3 to 6 hours can be achieved with normal concrete only after 7 days.
- "REDISET" releases a lot of heat which is advantageous in winter concreting.
- The rate of shrinkage is fast but the total shrinkage is similar to that of OPC concrete.
- The sulphate resistance, is however, very poor.

### ***Applications***

- patch repairs and emergency repairs,
- quick release of forms in the precast concrete products industry,
- slip-formed concrete construction
- construction between tides.

## *p) High Alumina Cement (IS 6452 : 1989)*

- High alumina cement is obtained by fusing or sintering a mixture, in suitable proportions, of alumina and calcareous materials and grinding the resultant product to a fine powder.
- The raw materials used for the manufacture of high alumina cement are limestone and bauxite.
- These raw materials with the required proportion of coke were charged into the furnace.

## *q) Very High Strength Cement*

***a) Macro-defect-free cements (MDF)***

- MDF refers to the absence of relatively large voids or defects which are usually present in conventional mixed cement pastes because of entrapped air and inadequate dispersion.
- the MDF process 4-7% of one of several water-soluble polymers is added to permit cement to be mixed with very small amount of water.

***b) Densely Packed System (DSP)***

- New materials termed DSP is yet another innovation in the field of high strength cement. Normal Portland cement and ultra-fine silica fume are mixed.

***(c) Pressure Densification and Warm Pressing***

***(d) High Early Strength Cement***

- Development of high early strength becomes an important factor, sometimes, for repair and emergency work.
- Lithium salts have been effectively used as accelerators in high alumina cement. This has resulted in very high early strength in cement and a marginal reduction in later strength.

***(e) Pyrament Cement***

- This product is a blended hydraulic cement. In this cement no chlorides are added during the manufacturing process. Pyrament cement produces a high and very early strength of concrete and mortar which can be used for repair of Air Field Run-ways.

***(f) Magnesium Phosphate Cement (MPC)***

- Magnesium Phosphate Cement, an advanced cementing material, giving very high early strength mortar and concrete has been developed by Central Road Research Institute, New Delhi. This cement can be used for rapid repair of damaged concrete roads and airfield pavements.

# TEST ON CEMENT

Testing of cement can be brought under two categories:

(a) Field testing

(b) Laboratory testing.

***A) Field Testing***

It is sufficient to subject the cement to field tests when it is used for minor works. The following are the field tests:

1. Open the bag and take a good look at the cement. There should not be any visible lumps. The colour of the cement should normally be greenish grey.
2. Thrust your hand into the cement bag. It must give you a cool feeling. There should not be any lump inside.
3. Take a pinch of cement and feel-between the fingers. It should give a smooth and not a gritty feeling.
4. Take a handful of cement and throw it on a bucket full of water, the particles should float for some time before they sink.

*B) Laboratory test*

1. *Fineness test:*

**WHY?**

The fineness of cement has an important bearing on the rate of hydration and hence on the rate of gain of strength and also on the rate of evolution of heat. Finer cement offers a greater surface area for hydration and hence faster the development of strength

Fineness of cement is tested in two ways :

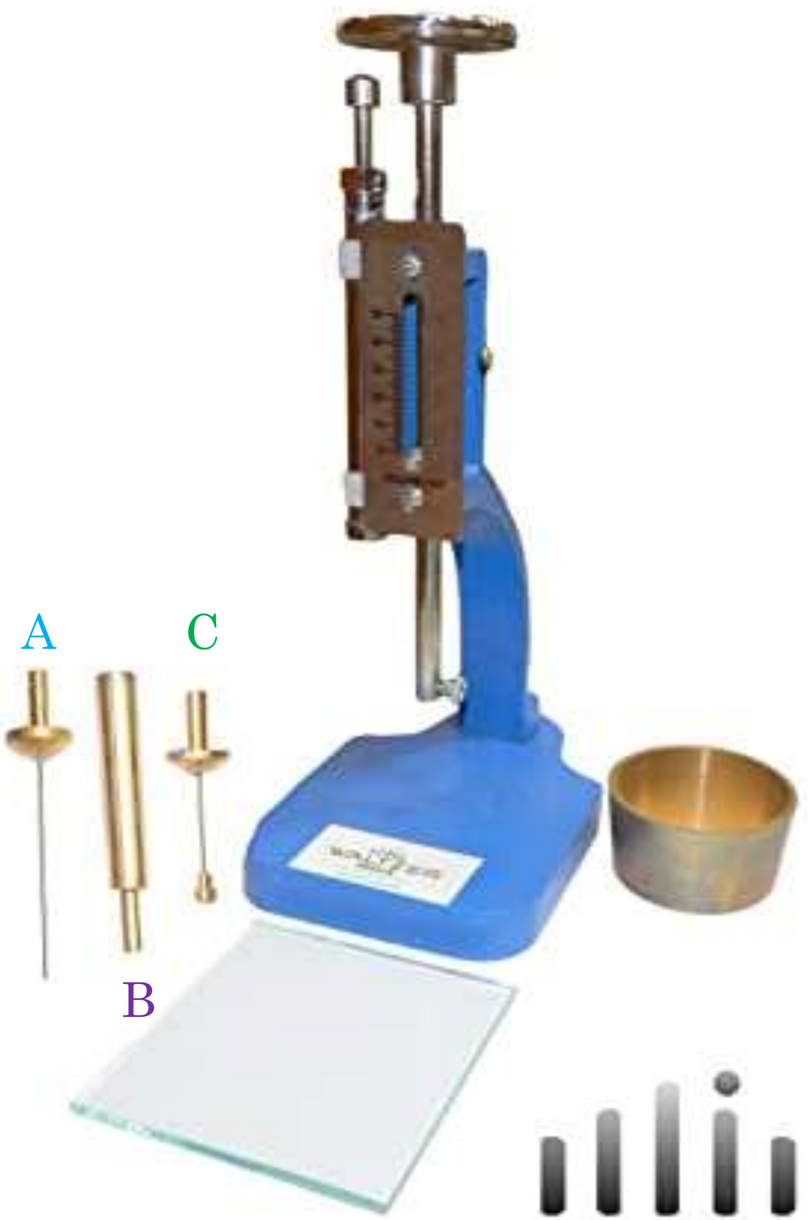
- By sieving
- By determination of specific surface (total surface area of all the particles in one gram of cement) by air premeability apparatus.

## *2. Standard Consistency Test*

Why?

For finding out initial setting time, final setting time and soundness of cement, and strength a parameter known as standard consistency has to be used.

The standard consistency of a cement paste is defined as that consistency which will permit a Vicat plunger having 10 mm diameter and 50 mm length to penetrate to a depth of 33-35 mm from the top of the mould shown in Fig.




A- For initial setting time
B- for standard consistency
C- for final setting time

### *3. Setting Time Test*

- An arbitrary division has been made for the setting time of cement as initial setting time and final setting time.
- ***Initial setting time*** is regarded as the time elapsed between the moment that the water is added to the cement, to the time that the paste starts losing its plasticity. (minimum of 30 minutes)
- ***The final setting time*** is the time elapsed between the moment the water is added to the cement, and the time when the paste has completely lost its plasticity and has attained sufficient firmness to resist certain definite pressure. (time should not be more than 10 hours)

### *4. Soundness Test*

Why?

Certain cements have been found to undergo a large expansion after setting causing disruption of the set and hardened mass. This will cause serious difficulties for the durability of structures when such cement is used. The testing of soundness of cement, to ensure that the cement does not show any appreciable subsequent expansion is of prime importance.

The unsoundness in cement is due to

- the presence of excess of lime
- inadequate burning
- Insufficiency in fineness of grinding or thorough mixing of raw materials
- high proportion of magnesium content or calcium sulphate content may cause unsoundness in cement. For this reason the magnesia content allowed in cement is limited to 6 per cent.

# Aggregate

***Classification***

Aggregates can be classified as i) Normal weight aggregates ii) Light weight aggregates iii) Heavy weight aggregates.

- Normal weight aggregates can be further classified as

a. Natural aggregates- Sand, Gravel, Crushed Rock such as Granite, Quartzite, Basalt and Sandstone

b. Artificial aggregates- Broken Brick, Air-cooled Slag, Sintered fly ash, Bloated clay

- Aggregates can also be classified on the basis of the size of the aggregates as coarse aggregate and fine aggregate.

## ***Classification based on Source***

Almost all natural aggregate materials originate from bed rocks. There are three kinds of rocks, namely, igneous, sedimentary and metamorphic. These classifications are based on the mode of formation of rocks.

### **1. Aggregates from Igneous Rocks**

- igneous rocks are formed by the cooling of molten magma or lava at the surface of the crest (trap and basalt) or deep beneath the crest (granite).
- Most igneous rocks make highly satisfactory concrete aggregates because they are normally hard, tough and dense
- The igneous rocks as a class are the most chemically active concrete aggregate and show a tendency to react with the alkalies in cement

## 2. **Aggregates from Sedimentary Rocks**

- The sedimentary rocks are formed originally below the sea bed and subsequently lifted up.
- Some siliceous sand stones have proved to be good concrete aggregate. Similarly, the limestone also can yield good concrete aggregate.
- Such rocks may also yield flaky aggregates.

## **3. Aggregates from Metamorphic Rocks**

- Metamorphic rocks are originally either igneous or sedimentary rocks which are subsequently metamorphosed due to extreme heat and pressure.
- Many metamorphic rocks particularly quartizite and gneiss have been used for production of good concrete aggregates.

## *Classification based on Size*

- The largest maximum size of aggregate practicable to handle under a given set of conditions should be used. Perhaps, 80 mm size is the maximum size that could be conveniently used for concrete making. Using the largest possible maximum size will result in

(i) reduction of the cement content

(ii) reduction in water requirement

(iii) reduction of drying shrinkage.

- However, the maximum size of aggregate that can be used in any given condition may be limited by the following conditions:

(i ) Thickness of section

(ii ) Spacing of reinforcement;

(iii ) Clear cover

(iv ) Mixing, handling and placing techniques

- Aggregates are divided into two categories from the consideration of size

(i) Coarse aggregate (The size of aggregate bigger than 4.75 mm )

(ii) Fine aggregate (aggregate whose size is 4.75 mm and less)

## ***Classification based on Shape***

- The shape of aggregates is an important characteristic since it affects the workability of concrete.
- The shape of the aggregate is very much influenced by the type of crusher and the reduction ratio i.e., the ratio of size of material fed into crusher to the size of the finished product.
- Flat particles in concrete aggregates will have particularly objectionable influence on the workability, cement requirement, strength and durability.


Angular Aggregate
Recyled Aggregate
Types of Aggregate used in Construction
Rounded Aggregate
Irregular Aggregate

## Classification of particles on the basis of shape of the aggregate

| Classification | Description | Examples |
|---|---|---|
| Rounded | Fully water worn or completely shaped by attrition | River or seashore gravels; desert, seashore and windblown sands |
| Irregular or Partly rounded | Naturally irregular or partly shaped by attrition, having rounded edges | Pit sands and gravels; land or dug flints; cuboids rock |
| Angular | Possessing well-defined edges formed at the intersection of talus; roughly planar faces | Crushed rocks of all types; screes |
| Flaky | Material, usually angular, of which the thickness is small relative to the width and/or length | Laminated rocks |

- From economy point in cement requirement for a given water/cement ratio, rounded aggregates are preferable to angular aggregates but angular aggregate gives higher strengths and sometimes greater durability due to interlocking texture in hardened concrete and higher bond characteristic between aggregate and cement paste.
- Flat particles in concrete aggregates will have particularly objectionable influence on the workability, cement requirement, strength and durability.
- In general, excessively flaky aggregate makes very poor concrete.

Round Flacky Crushed

- While discussing about shape of aggregate, the texture of the aggregate also enters the discussion because of its close association with the shape.
- Generally, rounded aggregates are smooth textured and angular aggregates are rough textured.
- Rounded aggregate yields poor concrete, due to lack of bond between the smooth surface of the aggregate and cement paste. So suggest that if at all the rounded aggregate is required to be used for economical reason, it should be broken and then used.
- Angular aggregates exhibit a better interlocking effect in concrete, which property makes it superior in concrete used for roads and pavements.
- The total surface area of rough textured angular aggregate is more than smooth rounded aggregate for the given volume. By having greater surface area, the angular aggregate may show higher bond strength than rounded aggregates.

## *Properties of Aggregate*

### *Strength*

From a weak rock or aggregate strong concrete cannot be made. By and large naturally available mineral aggregates are strong enough for making normal strength concrete. The test for strength of aggregate is required to be made in the following situations:

(i ) For production of high strength and ultra high strength concrete.

(ii ) When contemplating to use aggregates manufactured from weathered rocks.

(iii ) Aggregate manufactured by industrial process.

## A )Aggregate Crushing Value

- Strength of rock is found out by making a test specimen of cylindrical shape of size 25 mm diameter and 25 mm height. This cylinder is subjected to compressive stress. Different rock samples are found to give different compressive strength varying from a minimum of about 45 MPa to a maximum of 545 MPa.
- Aggregate crushing value gives a relative measure of the resistance of an aggregate sample to crushing under gradually applied compressive load.
- Generally, this test is made on single sized aggregate passing 12.5 mm and retained on 10 mm sieve. The aggregate is placed in a cylindrical mould and a load of 40 ton is applied through a plunger.
- The material crushed to finer than 2.36 mm is separated and expressed as a percentage of the original weight taken in the mould. This percentage is referred as aggregate crushing value.

Aggregate crushing value apparatus

Aggregate  impact value apparatus

**B) Aggregate Impact Value**

- With respect to concrete aggregates, toughness is usually considered the resistance of the material to failure by impact.
- The most successful is the one in which a sample of standard aggregate kept in a mould is subjected to fifteen blows of a metal hammer of weight 14 Kgs. falling from a height of 38 cms.
- The quantity of finer material (passing through 2.36 mm)
- resulting from pounding will indicate the toughness of the sample of aggregate.
- The ratio of the weight of the fines (finer than 2.36 mm size) formed, to the weight of the total sample taken is expressed as a percentage. This is known as aggregate impact value
- IS 283-1970 specifies that aggregate impact value shall not exceed 45 per cent by weight for aggregate used for concrete other than wearing surface and 30 per cent by weight, for concrete for wearing surfaces, such as run ways, roads and pavements.

## C) Aggregate Abrasion Value

- Testing the aggregate with respect to its resistance to wear is an important test for aggregate to be used for road constructions, ware house floors and pavement construction.
- Three tests are in common use to test aggregate for its abrasion resistance.

(i) Deval attrition test

(ii) Dorry abrasion test

(iii) Los Angels test

***Bulk Density***

- The bulk density of aggregate is measured by filling a container of known volume in a standard manner and weighing it. Bulk density shows how densely the aggregate is packed when filled in a standard manner. The bulk density depends on the particle size distribution and shape of the particles.
- The higher the bulk density, the lower is the void content to be filled by sand and cement. The sample which gives the minimum voids or the one which gives maximum bulk density is taken as the right sample of aggregate for making economical mix.

## *Specific Gravity*

- Specific gravity of aggregate is required to be considered when we deal with light weight and heavy weight concrete.
- Average specific gravity of the rocks vary from 2.6 to 2.8.

## *Absorption and Moisture Content*

- Some of the aggregates are porous and absorptive. Porosity and absorption of aggregate will affect the water/cement ratio and hence the workability of concrete.
- The porosity of aggregate will also affect the durability of concrete when the concrete is subjected to freezing and thawing and also when the concrete is subjected to chemically aggressive liquids.

- The aggregate absorbs water in concrete and thus affects the workability and final volume of concrete.
- Free moisture in both coarse aggregate and fine aggregate affects the quality of concrete in more than one way. In case of weigh batching, determination of free moisture content of the aggregate is necessary and then correction of water/cement ratio to be effected in this regard.
- But when volume batching is adopted, the determination of moisture content of fine aggregate does not become necessary but the consequent bulking of sand and correction of volume of sand to give allowance for bulking becomes necessary.

## Measurement of Moisture Content of Aggregates

- Determination of moisture content in aggregate is of vital importance in the control of the quality of concrete particularly with respect to workability and strength.
- The measurement of the moisture content of aggregate in the field must be quick, reasonably accurate and must require only simple appartus which can be easily handled andused in the field.
- Some of the methods that are being used for determination

(i ) Drying Method (ii ) Displacement Method

(iii ) Calcium Carbide Method (iv ) Measurement by electrical meter.

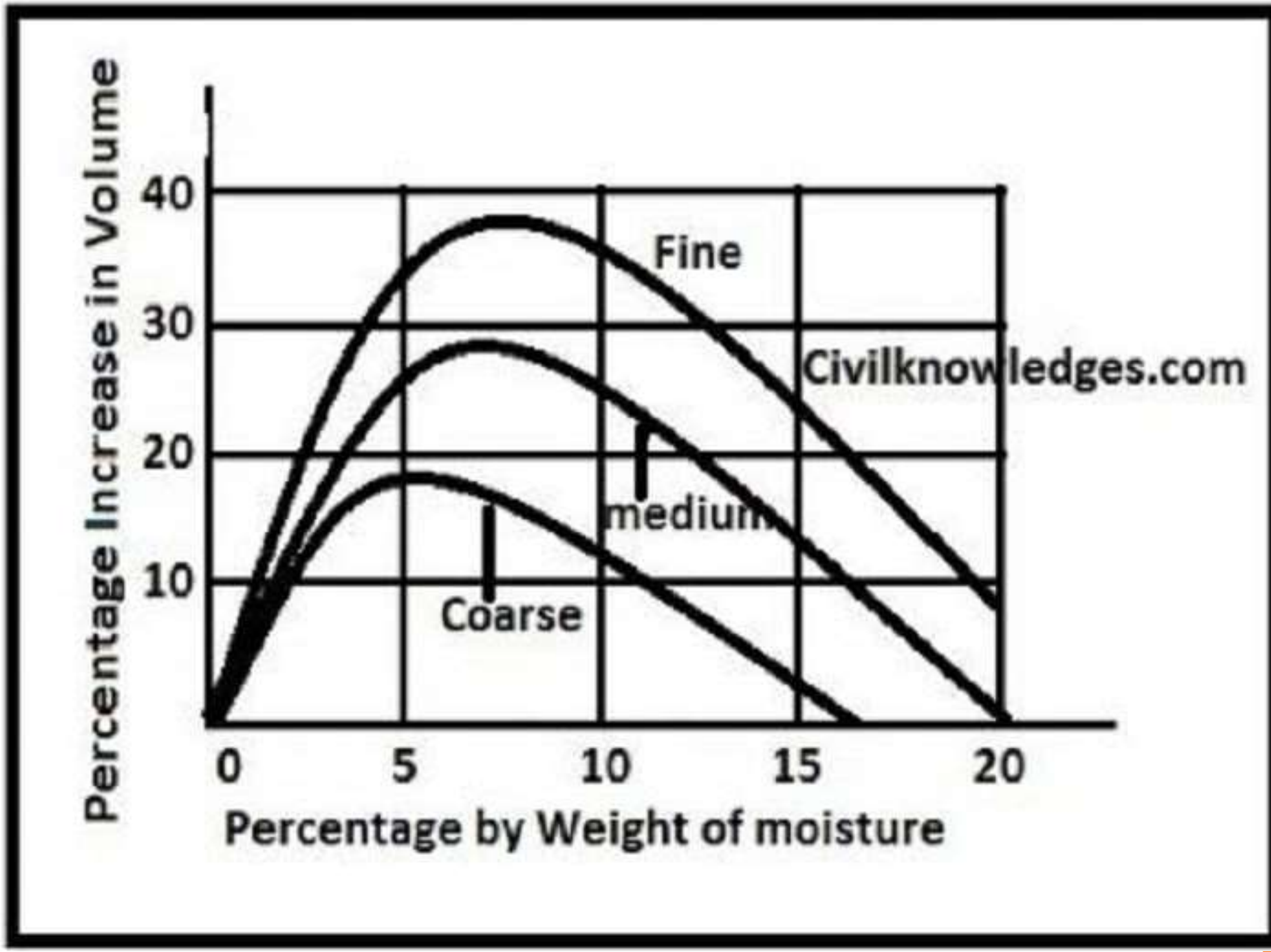
(v ) Automatic measurement

## *Soundness of Aggregate*

- Soundness refers to the ability of aggregate to resist excessive changes in volume as a result of changes in physical conditions.
- These physical conditions that affect the soundness of aggregate are the freezing the thawing, variation in temperature, alternate wetting and drying under normal conditions and wetting and drying in salt water.
- Aggregates which are porous, weak and containing any undesirable extraneous matters undergo excessive volume change when subjected to the above conditions.
- Aggregates which undergo more than the specified amount of volume change is said to be unsound aggregates.
- If concrete is liable to be exposed to the action of frost, the coarse and fine aggregate which are going to be used should be subjected to soundness test.

## Bulking of Aggregates

- The free moisture content in fine aggregate results in bulking of volume.
- Free moisture forms a film around each particle. This film of moisture exerts what is known as surface tension which keeps the neighboring particles away from it. Similarly, the force exerted by surface tension keeps every particle away from each other. Therefore, no point contact is possible between the particles. This causes bulking of the volume.
- The bulking increases with the increase in moisture content up to a certain limit and beyond that the further increase in the moisture content results in the decrease in the volume and at a moisture content representing saturation point, the fine aggregate shows no bulking.


Percentage Increase in Volume
40
30
20
10
Fine
Civilknowledges.com
medium
Coarse
0
5
10
15
20
Percentage by Weight of moisture

- The bulking is determined by following expression Bulking,

b = Vm/Vd x100

Where Vm is the volume with moist and Vd is the dry or fully saturated volume and b is the bulking percentage.

# WATER

- Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. Since it helps to form the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully.
- Water for making concrete if the pH value of water lies between 6 and 8 and the water is free from organic matter.

| Impurity | | Tolerable Concentration |
|---|---|---|
| Sodium and potassium carbonates and bi-carbonates | : | 1,000 ppm (total). If this is exceeded, it is advisable to make tests both for setting time and 28 days strength |
| Chlorides | : | 10,000 ppm. |
| Sulphuric anhydride | : | 3,000 ppm |
| Calcium chloride | : | 2 per cent by weight of cement in non-pre stressed concrete |
| Sodium iodate, sodium sulphate, sodium arsenate, sodium borate | : | very low |
| Sodium sulphide | : | Even 100 ppm warrants testing |
| Sodium hydroxide | : | 0.5 per cent by weight of cement, provided quick set is not induced. |
| Salt and suspended particles | : | 2,000 ppm. Mixing water with a high content of suspended solids should be allowed to stand in a s ettling basin before use. |
| Total dissolved salts | : | 15,000 ppm. |
| Organic material | : | 3,000 ppm. Water containing humic acid or such organic acids may adversely affect the hardening |