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ENGINEERING MATERIALS

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SYLLABUS

1. Classification and general aspects of construction materials
2. Concrete materials
3. Metals and alloys
4. Natural stones, bricks and tiles
5. Timber
6. Rubber, plastic and bituminous materials
7. Insulating materials

BOOKS

1) Engineering Materials by R. K. Rajput
2) Advance concrete technology by John Newman and Ban Seng Choo

CEMENT

WHAT IS CEMENT

Material with adhesive and cohesive properties

Any material that binds or unites-essentially like glue.

FUNCTION OF CEMENT

to bind the sand and coarse aggregate together

to fill voids in between sand and coarse aggregate particle

to form a compact mass

PROPERTIES OF CEMENT

Good quality cement posses the following properties (which depend upon its chemical composition, thoroughness of burning and fineness of grinding).

1. Provide strength to masonry.
2. Stiffens or hardens easily.
3. Possesses good plasticity.
4. Easily workable.
5. Good to moisture resistant.

TYPES OF CEMENT

There are mainly two types of cement, normally used in building industry are as follows:

a) Hydraulic Cement

b) Non hydraulic Cement

HYDRAULIC CEMENT

- Hydraulic Cement sets and hardens by action of water, such as Portland Cement
- In other words it means that hydraulic cement are:
- Any cements that turns into a solid product in the presence of water as well as air, resulting in a material that does not disintegrate in water.

HYDRAULIC CEMENT

Most common Hydraulic Cement is Portland Cement

NONHYDRAULIC CEMENT

- Any cement that does not require water to transform it into a solid product.
- Two common Non hydraulic Cement are
  a) Lime - derived from limestone / chalk
  b) Gypsum

CHEMICAL CONSTITUENTS OF CEMENT

- Percentage of various ingredients should be:

1) Lime (CaO)
2) Silica (SiO_2)
3) Alumina (Al_2O_3)
4) Iron oxide ((Fe_2O_3)
5) Magnesium oxide (MgO)
6) Sulphur trioxide (SO_3)

PRINCIPAL MINERALS IN CEMENT

Shorthand nomenclature	Chemical formula	Mineral name	Typical level (mass %)	Typical range (mass %)
C_3S	$3CaO \cdot SiO_2$ or Ca_3SiO_5	Alite	57	45–65
C_2S	$2CaO \cdot SiO_2$ or Ca_2SiO_4	Belite	16	10–30
C_3A	$3CaO \cdot Al_2O_3$ or $Ca_3Al_2O_6$	Aluminate	9	5–12
C_4AF	$4CaO \cdot Al_2O_3 \cdot Fe_2O_3$ or $Ca_4Al_2Fe_2O_{10}$	Ferrite	10	6–12

PORTLAND CEMENT

Chemical composition of Portland Cement:

a) Tricalcium Silicate C_3S (50%)

b) Dicalcium Silicate C_2S (25%)

c) Tricalcium Aluminate C_3A (10%)

d) Tetracalcium Aluminoferrite C_4AF (10%)

e) Gypsum ($CaSO_4 \cdot 2H_2O$) (5%)

FUNCTION :TRICALCIUM SILICATE

- Hardens rapidly and largely responsible for initial set & early strength
- The increase in percentage of this compound will cause the early strength of Portland Cement to be higher.
- A bigger percentage of this compound will produces higher heat of hydration and accounts for faster gain in strength.

FUNCTION :DICALCIUM SILICATE

- Hardens slowly
- It effects on strength increases occurs at ages beyond one week .
- Responsible for long term strength

FUNCTION :TRICALCIUM ALUMINATE

Contributes to strength development in the first few days because it is the first compound to hydrate.

It turns out higher heat of hydration and contributes to faster gain in strength.

But it results in poor sulfate resistance and increases the volumetric shrinkage upon drying.

FUNCTION :TRICALCIUM ALUMINATE

Cements with low Tricalcium Aluminate contents usually generate less heat, develop higher strengths and show greater resistance to sulfate attacks.

It has high heat generation and reactive with soils and water containing moderate to high sulfate concentrations so it's least desirable.

FUNCTION : TETRACALCIUM ALUMINOFERRITE

Assist in the manufacture of Portland Cement

By allowing lower clinkering temperature also act as a filler

Contributes very little strength of concrete even though it hydrates very rapidly.

Also responsible for grey colour of Ordinary Portland Cement

MANUFACTURING OF PORTLAND CEMENT

The three primary constituents of the raw materials used in the manufacture of Portland Cement are:

- Lime
- Silica
- Alumina

Lime is derived from limestone or chalk, Silica & Alumina from clay, shale or bauxite

MANUFACTURING OF PORTLAND CEMENT

There are two chief aspects of the manufacturing process:

- First to produce a finely divided mixture of raw materials – chalk / limestone and clay / shale
- Second to heat this mixture to produce chemical composition

There two main process that can be used in manufacturing of Portland Cement that is i) wet process ii) dry process

WET PROCESS

- Raw materials are homogenized by crushing, grinding and blending so that approximately 80% of the raw material pass a No. 200 sieve.
- The mix will be turned into form of slurry by adding 30 - 40% of water.
- It is then heated to about 2750º F (1510º C) in horizontal revolving kilns (76-153 m length and 3.6-4.8 m in diameter.

WET PROCESS

- Natural gas, petroleum or coal are used for burning. High fuel requirement may make it uneconomical compared to dry process.

DRY PROCESS

- Raw materials are homogenized by crushing, grinding and blending so that approximately 80% of the raw material pass a No. 200 sieve.
- Mixture is fed into kiln & burned in a dry state
- This process provides considerable savings in fuel consumption and water usage but the process is dustier compared to wet process that is more efficient than grinding.

DRY PROCESS & WET PROCESS

- In the kiln, water from the raw material is driven off and limestone is decomposed into lime and Carbon Dioxide.

  limestone ⟶ lime + Carbon Dioxide

- In the burning zone, portion of the kiln, silica and alumina from the clay undergo a solid state chemical reaction with lime to produce calcium Aluminate.

silica & alumina + lime ⟶ calcium Aluminate

DRY PROCESS & WET PROCESS

- ✓ The rotation and shape of kiln allow the blend to flow down the kiln, submitting it to gradually increasing temperature.
- ✓ As the material moves through hotter regions in the kiln, calcium silicates are formed
- ✓ These products, that are black or greenish black in color are in the form of small pellets, called cement clinkers
- ✓ Cement clinkers are hard, irregular and ball shaped particles about 18 mm in diameter.

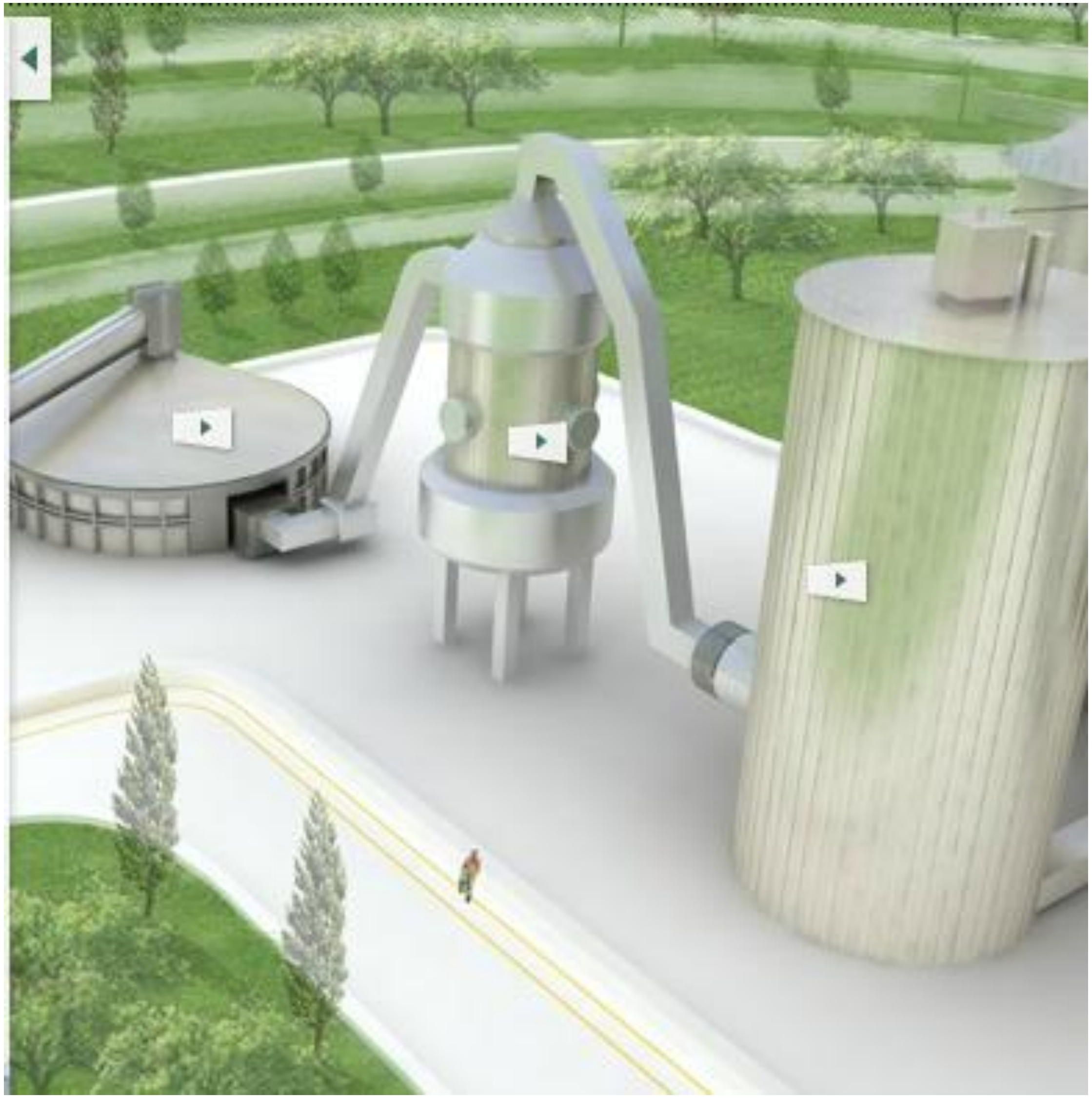
DRY PROCESS & WET PROCESS

- The cement clinkers are cooled to about 150ºF (150ºF) and stored in clinker silos.
- When needed, clinker are mixed with 2-5% gypsum to retard the setting time of cement when it is mixed with water.
- Then, it is grounded to a fine powder and then the cement is stored in storage bins or cement silos or bagged.
- Cement bags should be stored on pallets in a dry place.

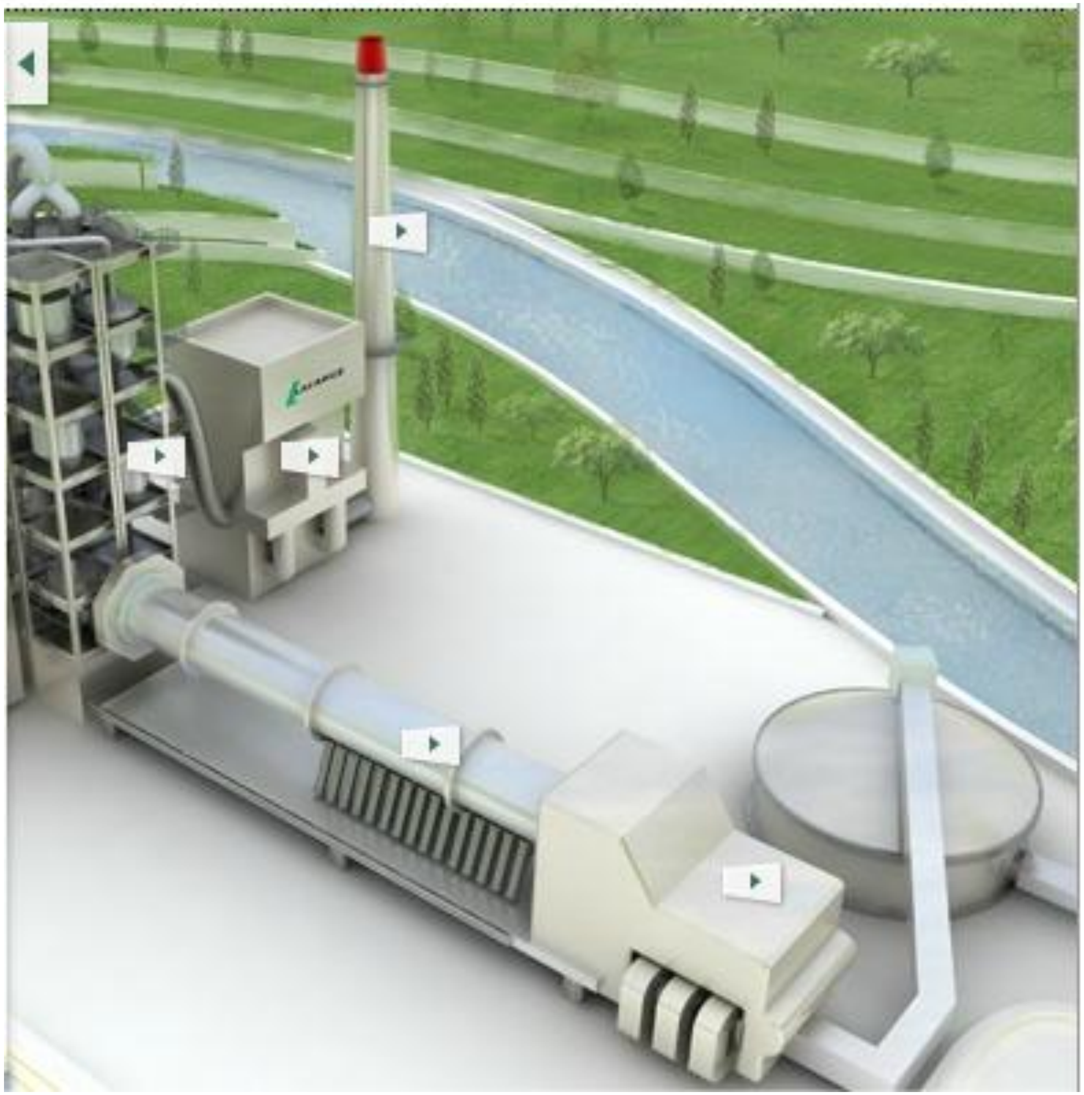
CEMENT MANUFACTURING

EXTRACTION OF RAW MATERIALS

GRINDING AND STORAGE OF RAW MATERIALS

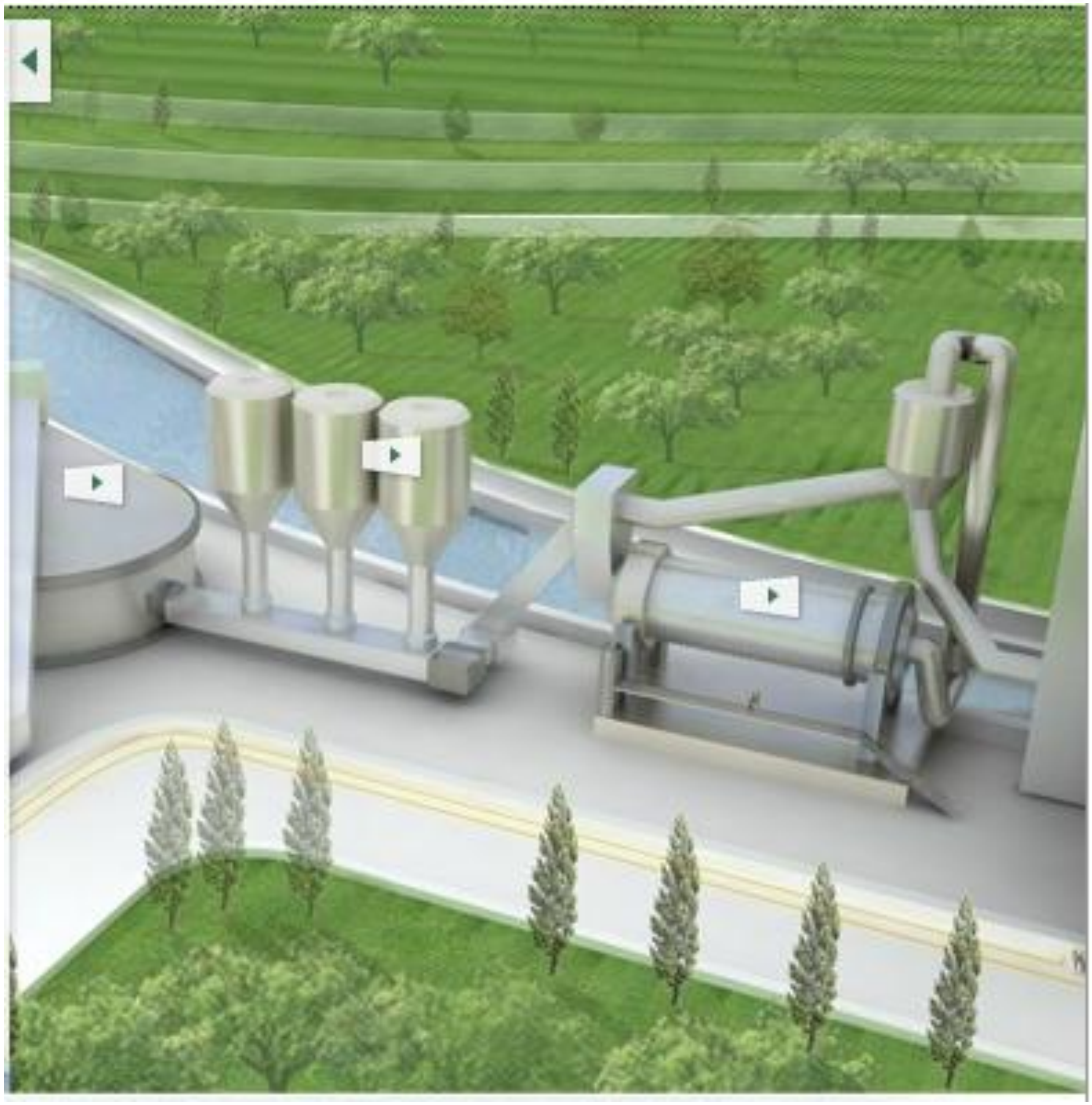


THE FIRING OF RAW MATERIALS

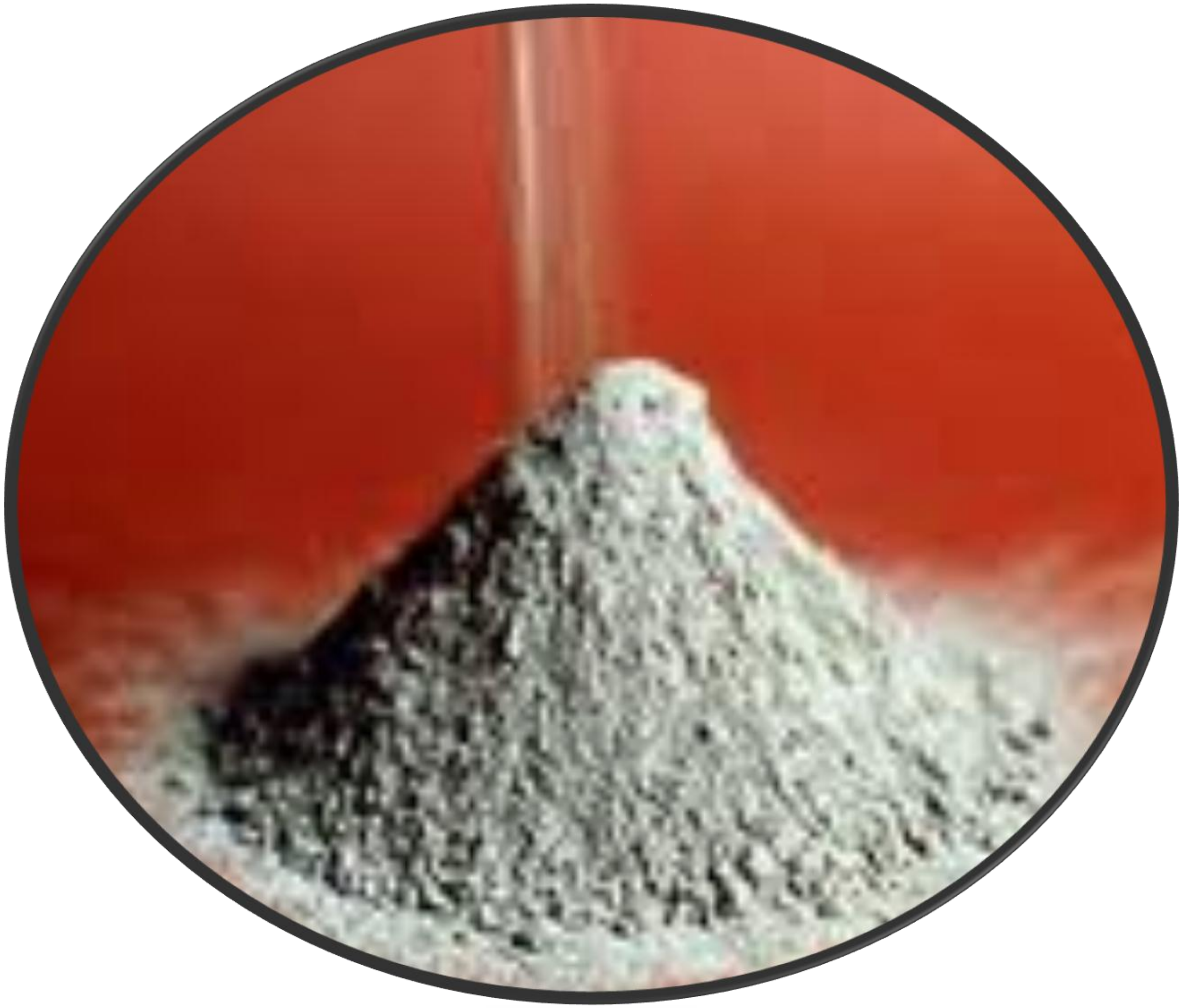


CEMENT CLINKERS

STORAGE AND GRINDING OF CEMENT



CEMENT



PACKING

PACKING AND SHIPMENT

SETTING AND HARDENING OF CEMENT

When cement is mixed with water a stiff and sticky paste is formed, which remains plastic for a short period. With the passage of time the plasticity gradually disappears and the cement paste become stiff due to initial hydration of cement. This phenomenon by virtue of which the plastic cement changes into a soil mass is known as setting of cement.

Cement sets when mixed with water by way of a complex series of chemical reactions still only partly understood. The different constituents slowly crystallise and the interlocking of their crystals gives cement its strength. Carbon dioxide is slowly absorbed to convert the portlandite ($Ca(OH)_2$) into insoluble calcium carbonate. After the initial setting, immersion in warm water will speed up setting. In Portland cement, gypsum is added as a compound preventing cement flash setting.

SETTING AND HARDENING OF CEMENT

On setting the cement binds the aggregates into a solid mass which gain strength as the time lapses, till the hydration of cement is complete. Thus, the phenomenon by virtue of which the cement paste, which is finally set, develops strength is known as hardening of cement.

STANDARD CONSISTENCY TEST

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. The apparatus is called Vicat Apparatus. This apparatus is used to find out the percentage of water required to produce a cement paste of standard consistency. The standard consistency of the cement paste is some time called normal consistency (CPNC).

SETTING TIME TEST

An arbitrary division has been made for the setting time of cement as initial setting time and final setting time. It is difficult to draw a rigid line between these two arbitrary divisions. For convenience, 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. 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.

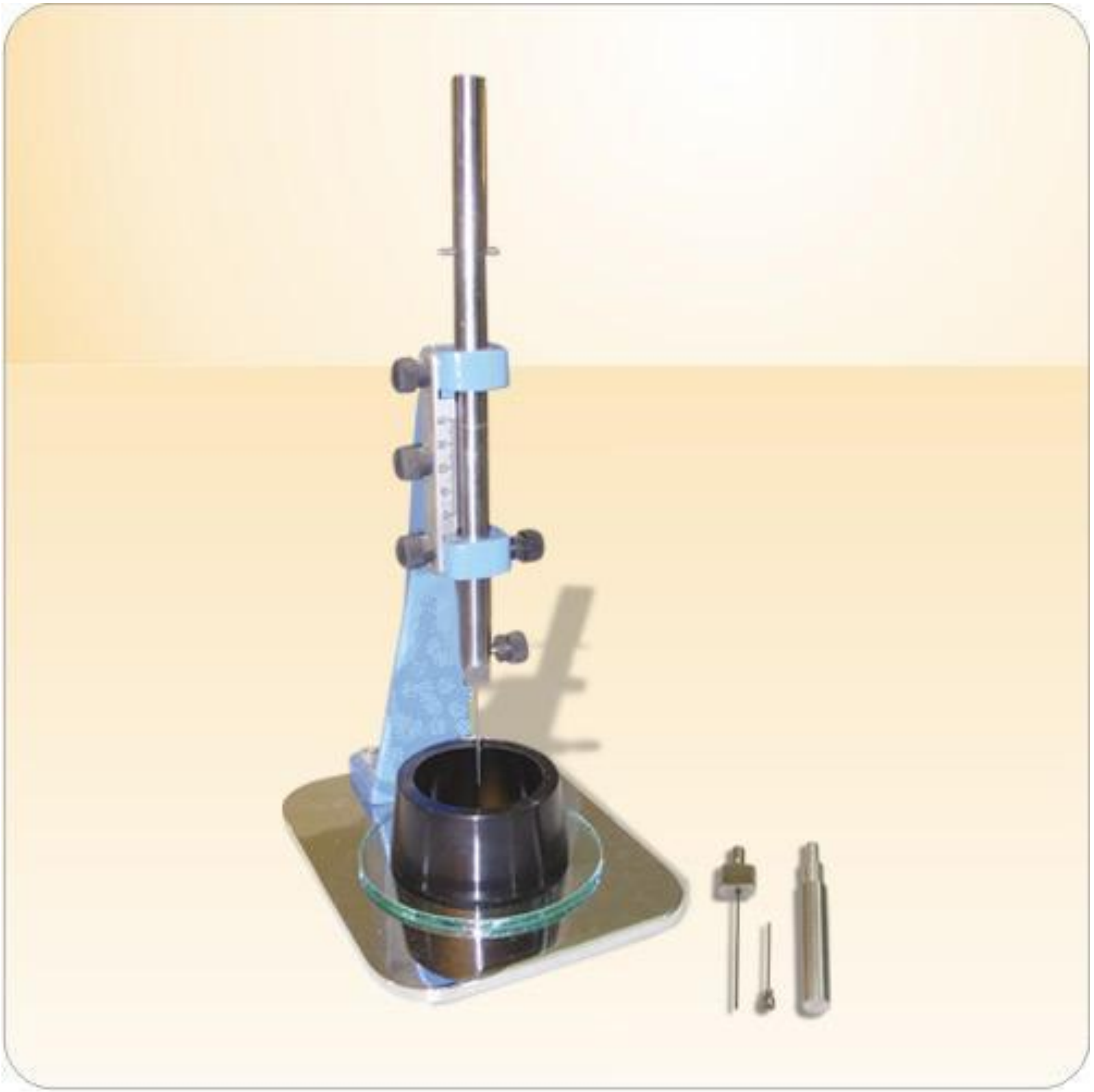
SETTING TIME TEST

Prepare a cement paste by gauging the cement with 0.85 times the water required to give a paste of standard consistency.

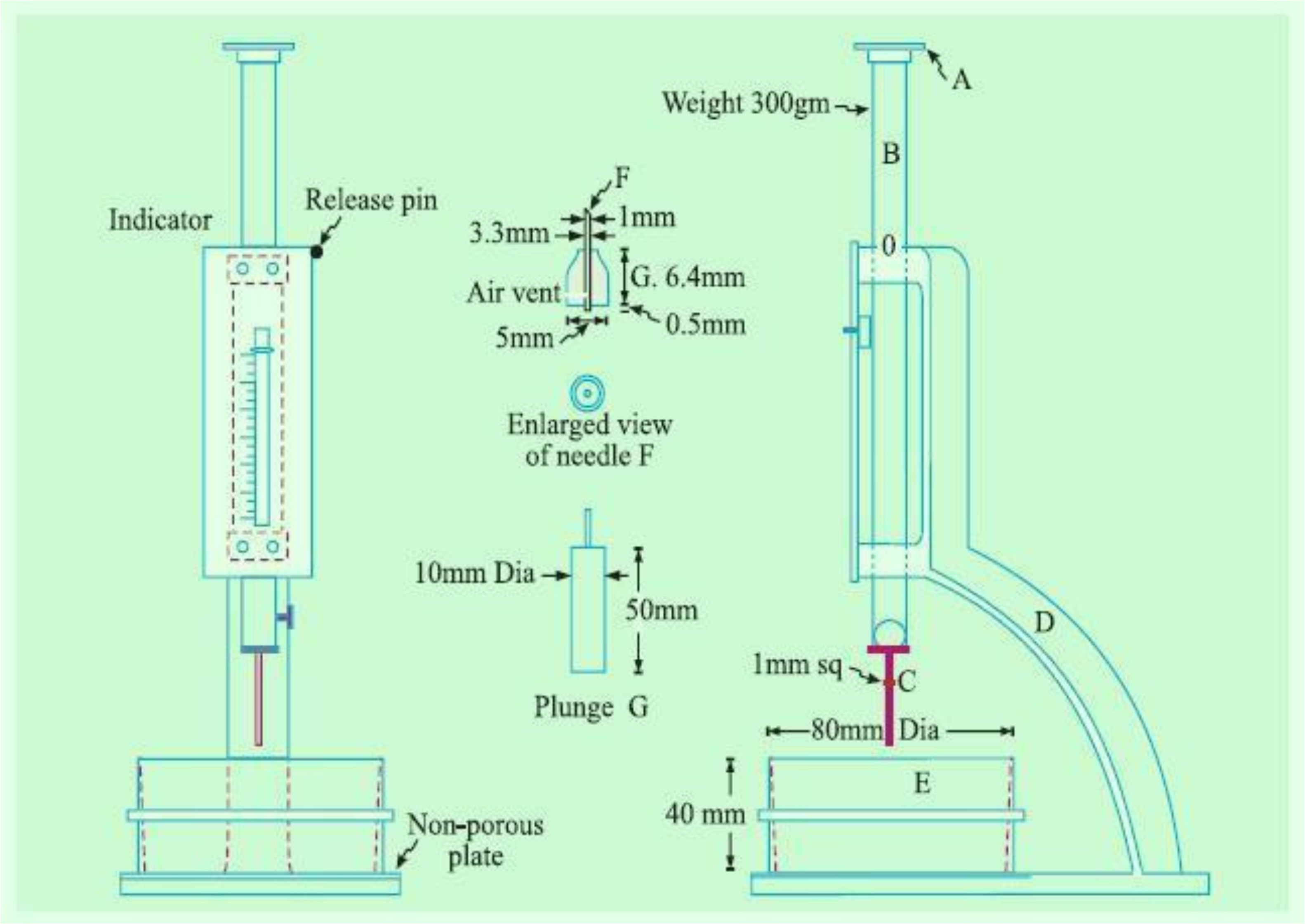
Start a stop-watch, the moment water is added to the cement.

Fill the Vicat mould completely with the cement paste gauged as above, the mould resting on a non-porous plate and smooth off the surface of the paste making it level with the top of the mould. The cement block thus prepared in the mould is the test block.

VICAT APPARATUS



VICAT APPARATUS



SETTING TIME TEST

INITIAL SETTING TIME:-Place the test block under the rod bearing the needle. Lower the needle gently in order to make contact with the surface of the cement paste and release quickly, allowing it to penetrate the test block. Repeat the procedure till the needle fails to pierce the test block to a point 5.0 ± 0.5 mm measured from the bottom of the mould. The time period elapsing between the time, water is added to the cement and the time, the needle fails to pierce the test block by 5.0 ± 0.5 mm measured from the bottom of the mould, is the initial setting time.

SETTING TIME TEST

FINAL SETTING TIME:-Replace the above needle by the one with an annular attachment. The cement should be considered as finally set when, upon applying the needle gently to the surface of the test block, the needle makes an impression therein, while the attachment fails to do so. The period elapsing between the time, water is added to the cement and the time, the needle makes an impression on the surface of the test block, while the attachment fails to do so, is the final setting time.

AGGREGATES

AGGREGATES

Aggregate is the component of a composite material that resists compressive stress and provides bulk to the composite material. Typically include both sand and gravel.

AGGREGATES

Essentially aggregates can refer to any granular material formed from a natural rock substance. It is usually further defined either:

By its source: primary, secondary, recycled

By its geology: limestone, granite, sand and gravel, etc,

By its grading: coarse, fine,

By its end use: concrete aggregates, etc.

Mostly confined to sand, gravel and rock chippings.

CONCRETE

Concrete is a composite construction material, composed of cement (commonly Portland cement) and other cementitious materials such as fly ash and slag cement, aggregate (generally a coarse aggregate made of gravel or crushed rocks such as limestone, or granite, plus a fine aggregate such as sand), water and chemical admixtures.

TERMINOLOGIES

- Workability
- Flowability
- Compactability
- Stability
- Pumpability

WORKABILITY

Workability-that property of freshly mixed concrete or mortar which determines the ease and homogeneity with which it can be mixed, placed, consolidated and finished is called the workability of concrete (ACI).

Workability depends on water content, aggregate (shape and size distribution), cementitious content and age (level of hydration) and can be modified by adding chemical admixtures, like super plasticizer.

WORKABILITY

Raising the water content or adding chemical admixtures will increase concrete workability. Excessive water will lead to increased bleeding (surface water) and/or segregation of aggregates (when the cement and aggregates start to separate), with the resulting concrete having reduced quality.

WORKABILITY

The use of an aggregate with an undesirable gradation can result in a very harsh mix design with a very low slump, which cannot be readily made more workable by addition of reasonable amounts of water.

Workability can be measured by the concrete slump test, a simplistic measure of the plasticity of a fresh batch of concrete following the ASTM C 143 or EN 12350-2 test standards.

FLOWABILITY

Flowability-The flowability of SCC is measured in terms of spread when using a modified version of the slump test (ASTM C 143). The spread (slump flow) of SCC typically ranges from 18 to 32 inches (455 to 810 mm).

FLOWABILITY

Compactability- The ease by which a concrete can be compacted is called Compactability.

Stability-

Pumpability- the ease by which concrete slurry can be pumped to the point to the placement is called the Pumpability.

COMPOSITION OF CONCRETE

the main ingredients of concrete are

- Cement
- Water
- Aggregates (i.e., coarse aggregate and fine aggregate)
- Reinforcement
- Chemical admixtures

MIXING CONCRETE

Mixing concrete correctly is vital for durable and long lasting foundations. Thorough mixing is essential for the production of uniform, high quality concrete. For this reason equipment and methods should be capable of effectively mixing concrete materials containing the largest specified aggregate to produce *uniform mixtures* of the lowest slump practical for the work.

MIXING CONCRETE

Separate paste mixing has shown that the mixing of cement and water into a paste before combining these materials with aggregates can increase the compressive strength of the resulting concrete. The paste is generally mixed in a *high-speed*, shear-type mixer at a w/cm (water to cement ratio) of 0.30 to 0.45 by mass. The cement paste premix may include admixtures such as accelerators or retarders, superplasticizers, pigments, or silica fume.

MIXING CONCRETE

The premixed paste is then blended with aggregates and any remaining batch water and final mixing is completed in conventional concrete mixing equipment.

CONCRETE MIXING

PLACING AND COMPACTION

The methods chosen for placing and compacting the concrete will depend on the type of construction, the total volume to be placed, the required rate of placing and the preferences and expertise of the construction companies involved. There are, however, several basic rules which should be followed to ensure that the concrete is properly placed and compacted into a uniform, void free mass once it has been delivered to the formwork in a satisfactory state:

PLACING AND COMPACTION

The concrete should be discharged as close as possible to its final position, preferably straight into the formwork;

A substantial free-fall distance will encourage segregation and should therefore be avoided;

With deep pours, the rate of placing should be such that the layer of concrete below that being placed should not have set; this will ensure full continuity between layers, and avoid cold joints and planes of weakness in the hardened concrete;

PLACING AND COMPACTION

Once the concrete is in place, vibration, either internal or external, should be used to mould the concrete around embedment e.g. reinforcement, and to eliminate pockets of entrapped air, but the vibration should not be used to move the concrete into place;

High-workability mixes should not be over vibrated – this may cause segregation.

PLACING AND COMPACTION

TYPES OF CONCRETE

1) Regular concrete
2) High-strength concrete
3) Stamped concrete
4) high-performance concrete
5) Self-consolidating concretes
6) Vacuum concretes
7) Shotcrete
8) Pervious concrete

REGULAR CONCRETE

Regular concrete- is the lay term describing concrete that is produced by following the mixing instructions that are commonly published on packets of cement, typically using sand or other common material as the aggregate, and often mixed in improvised containers. This concrete can be produced to yield a varying strength from about 10 MPa (1450 psi) to about 40 MPa (5800 psi), depending on the purpose, ranging from blinding to structural concrete respectively.