Concrete Technology
(18CV44)

Course Outline

Module 1: Concrete Ingredients

Module 2: Fresh Concrete

Module 3: Hardened Concrete

Module 4: Concrete Mix Proportioning as per IS10262: 2019

Module 5: Special Concrete

IA & Exam Pattern

- Three Internal assessments will be conducted for 30 marks and average of all the performances will be considered.
- Assignments will carry 10 marks
- Total IA marks will be awarded for 40 marks
- Ten questions will be asked in the examination; Two from each module.
- Five full question should be answered selecting one from each module.
- Code books – IS 456:2000, IS 10262:2019 shall be referred for the design

Course Outcomes

❖ After studying this course, students will be able to:

1. Relate material characteristics and their influence on microstructure of concrete.

2. Distinguish concrete behavior based on its fresh and hardened properties.

3. Illustrate proportioning of different types of concrete mixes for required fresh and hardened properties using professional codes.

4. Adopt suitable concreting methods to place the concrete based on requirement.

5. Select a suitable type of concrete based on specific application

Module – 1

Concrete Ingredients

Module Outline

- Introduction to Concrete Ingredients
- Cement
- Aggregates
  - Fine Aggregates
  - Coarse Aggregates
- Water
- Admixtures
  - Chemical Admixtures
  - Mineral Admixtures

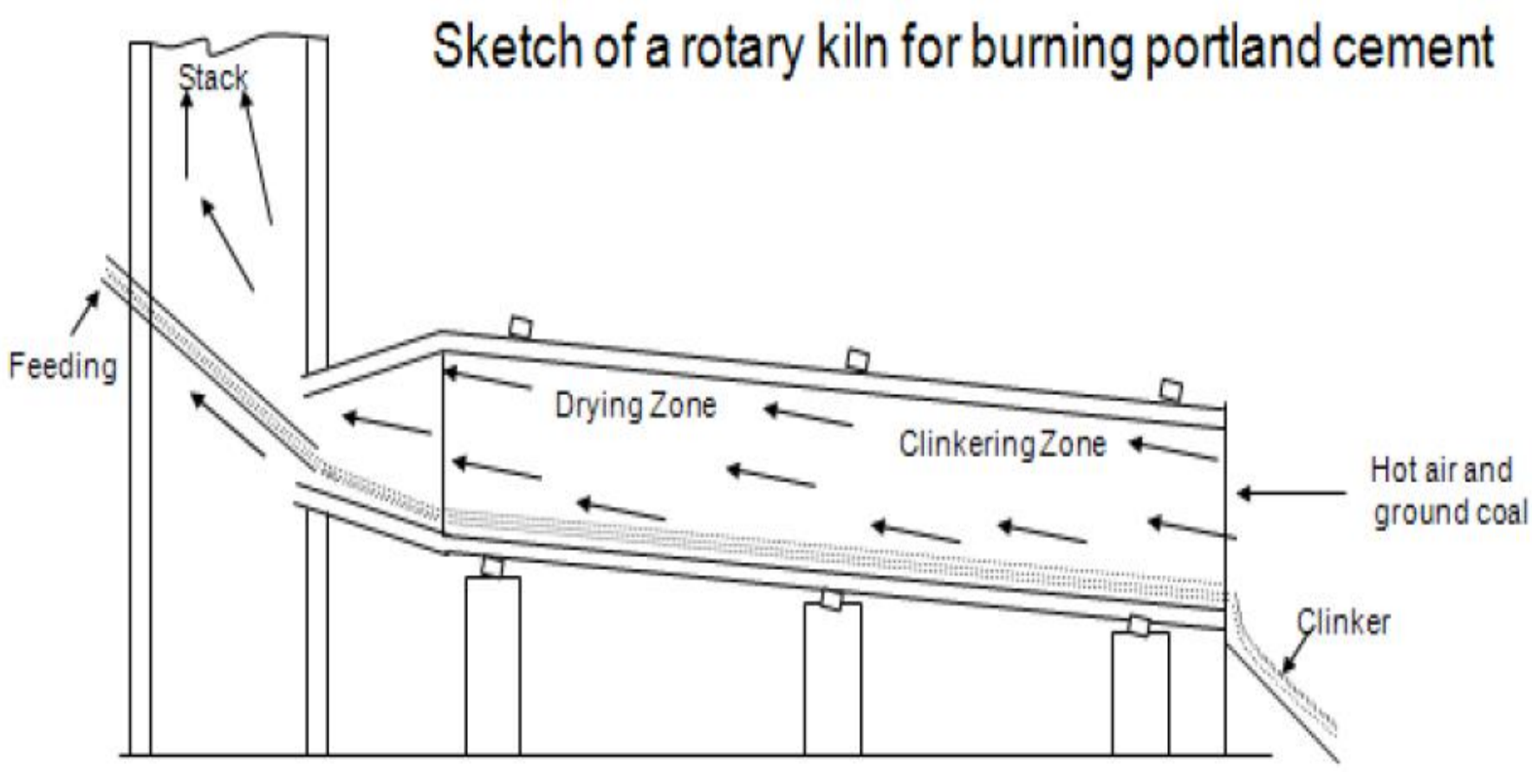
Module Outline

- Concrete Ingredients
  - Cement, Aggregates, Admixtures & water
- Cement – Binder
- Cement can be primary classified as 1) Natural cements and 2) Artificial cements

❖ Natural Cements – Manufactured by burning & crushing of stones containing clay, $CaCO_3$ & $MgCO_3$

Concrete Ingredients

- Artificial Cements – Manufactured by burning a mixture of Calcareous and Argillaceous materials



Concrete Ingredients

Characteristics of cement

- The color of the cement is grey with greenish shade. It gives an indication of excess lime or clay and the degree of burning.
- It should feel smooth when touched or rubbed in between fingers.
- If hand is inserted in a bag of cement or in a heap of cement, it should feel cool and not warm.
- It should be free from any hard lumps.
- It should not contain any excess amount silica, lime, alumina and alkalies.

Concrete Ingredients

Properties of cement

Physical Properties:-

1. It gives strength to the masonry.

2. It is an excellent binding material.

3. It is easily workable.

4. It offers greater resistance to moisture.

5. It possesses a good plasticity.

6. A thin paste of cement held in water should feel sticky between the fingers.

Physical Properties:-

7. When cement thrown in water should sink and should not float on the surface.

8. The particles should have uniformity of fineness and surface area of should not be less than 2250 cm2/gm.

9. The standard consistency of cement should be checked with Vicat apparatus. If the settlement of plunger is between 5 to 7mm from bottom of the mould

10. The initial setting time of ordinary cement is about 30minutes. This initial setting time is the interval between the addition of water to cement and the stage when the square needle of Vicat apparatus ceases to penetrate.

Concrete Ingredients

Physical Properties:-

11. The final setting time for ordinary cement is about 10hrs. The final setting time is the difference between the time at which water was added to cement and time required for needle with annular collar of Vicat's apparatus ceases to make an impression on test block.

12. The cement should be tested for soundness using Le-Chatelier apparatus.

Concrete Ingredients

Mechanical properties:-

1. The compressive strength at the end of 3 days should not be less than 11.5 N/mm2 and at the end of 7 days should not be less than 17 N/mm2.

2. The tensile strength at the end of 3 days should not be less than 2 N/mm2 and at the end of 7 days should not be less than 2.5 N/mm2.

Concrete Ingredients

Chemical properties:-

1. Total loss of ignition should not exceed 4%.

2. Total sulphur content should not be more than 2.75%.

3. Weight of magnesia should not exceed 5%.

4. Weight of insoluble residue should not be more than 1.5%.

Concrete Ingredients

Chemical composition of cement

Approximate oxide composition limits of Ordinary Portland cement

Ingredients	Percentage	Range
Lime	(CaO)..... 62	62 to 67
Silica	(SiO_2) 22	17 to 25
Alumina	(Al_2O_3) 5	3 to 8
Calcium sulphate	($CaSO_4$) 4	3 to 4
Iron oxide	(Fe_2O_3) 3	3 to 4
Magnesia	(MgO) 2	1 to 3
Sulphur	(S) 1	1 to 3
Alkalies	(K_2O, Na_2O) 1	0.2 to 1
	Total = 100	

Concrete Ingredients

Effect of ingredients on properties of cement

1. Lime - if ↑ = unsoundness and if ↓ = Strength decreases and helps in fast setting

2. Silica - if ↑ = Strength increases and Setting time will be delayed

3. Alumina - if ↑ = weakens the cement

4. Calcium sulphate - To alter the setting the time

5. Iron oxide – Color, hardness & Strength to the cement paste

Concrete Ingredients

Role of oxides on Strength of cement paste

6. Magnesia - if ↓ = hardness & color and if ↑ = unsoundness

7. Sulphur- if ↑ = unsoundness

8. Alkalies - if ↑ = Formation of AAR & efflorescence

Harmful constituents of cement

(1) **Alkali oxide k_2O** and **Na_2O**: if amount of these alkali oxides exceeds by 1%, it leads to failure of concrete.

(2) **Magnesium oxide MgO**: if it exceeds 5%, it causes cracks in hardened concrete.

The identification of major compounds of cement is largely based on **Bogue's** equations and hence it is called as **Bogue's compounds**. The four compounds are usually regarded as major compounds are listed below

Concrete Ingredients

Bogue's Compounds

Name of compound	Formula	Abbreviated formula		Percentage by mass in cement
Tricalcium silicate	$3CaO.SiO_2$	C_3S	Alite	30-50
Dicalcium silicate	$2CaO.SiO_2$	C_2S	Belite	20-45
Tricalcium aluminate	$3CaO.Al_2O_3$	C_3A	Celite	08-12
Tetracalcium alminoferrite	$4CaO.Al_2O_3.Fe_2O_3$	C_4AF	Felite	06-10

Hydration of cement

- Anhydrous cement does not bind the fine and coarse aggregates. It acquires adhesive property only when it is mixed with water. The chemical reaction that takes place between cement and water is known as **hydration of cement**.
- When anhydrous cement mixed with water, it starts to dissolve and chemically combines with it to form products. Those products are known as **hydrates** and these hydrates are less soluble in water.

Concrete Ingredients

Hydration of cement can be visualized in two ways.

(1) Through solution mechanism: In this mechanism, when cement is mixed with water, cement compounds dissolve to form super saturated solution from which different hydrated products get precipitated.

(2) Solid state mechanism: In this mechanism, water attacks chemical compounds of cements which are in solid state and converting them to hydrated products starting from surface to interior compounds with time.

There is a possibility of occurrence of both stages in same course of reaction. Solution phase occurs first only when there is large availability of water and then solid state mechanism occurs in the next stage.

Note: 23% of water by weight of cement is required for chemical reaction of cement with water and another 15% of water required for filling up gel pores. Therefore total 38% of water is required for hydration of cement.

Heat of hydration

The quantity of heat evolved in cal/gm of cement after complete hydration of cement.

For 7 days → 89 – 90 cal/gm

28 days → 90 – 100 cal/gm of heat will be evolved.

Structure of Cement Hydrated Paste

- When water is mixed with cement, the chemical compounds react with water to form hydrated products such as
- $C_3S + H_2O \rightarrow$ hydrated Tri-calcium silicate + $Ca(OH)_2$
- $C_2S + H_2O \rightarrow$ hydrated Di-calcium silicate + $Ca(OH)_2$
- $C_3A + H_2O \rightarrow$ hydrated Tri-calcium aluminate + $Ca(OH)_2$

Note: when calcium silicates react with water, it forms Calcium Silicate Hydrates gel called C-S-H gel; C3A reacts to form Calcium Aluminate Hydrates C-A-H and C4AF reacts to form Hydrated Calcium Ferrite C-F-H

Concrete Ingredients

Role of Bogue's compounds with respect to strength and heat of hydration

- **C_3S and C_2S (Tri Calcium Silicates and Di Calcium Silicates):-**
  - ❖ $2C_3S + 6H \rightarrow C_3S_2H_3 + 3Ca(OH)_2$
  - ❖ $2C_2S + 4H \rightarrow C_3S_2H_3 + Ca(OH)_2$
  - ✓ $Ca(OH)_2$ is not desirable in concrete because it imparts low durability to concrete.
  - ✓ $Ca(OH)_2$ readily reacts with sulphates present in soil or water to calcium sulphates which further reacts with C_3A leads to deterioration of concrete. This is known as sulphate attack
  - ✓ C_3S readily reacts with water to produce more heat of hydration & responsible for early strength. C_2S hydrates are formed slowly, hence it is responsible for progressive strength
  - ✓ The quantity & density of product formed by C_3S is slightly inferior when compared to that of C_2S.

Role of Bogue's compounds with respect to strength and heat of hydration

C_3A (Tri Calcium Aluminates):-

- ✓ The reaction of C_3A with water is very fast and may lead to an immediate stiffening of paste, and this process is termed as flash set.
- ✓ To prevent this flash set, 2 to 3 % gypsum is added at the time of grinding the cement clinkers.
- ✓ It provides early strength to cement up to 3 days, but causes deterioration of concrete at later stages.
- ✓ The hydrates of C_3A do not contribute to the strength of concrete.
- ✓ C_3A reacts with water to form C-A-H gels.
- ✓ The cubic compound $C_3A\ H_6$ is probably the only stable compound formed which remains up to 225ºC.

Role of Bogue's compounds with respect to strength and heat of hydration

C_4AF (Tetra Calcium Alumina Ferrite) :-

- ✓ C_4AF hydrates rapidly.
- ✓ A hydrated calcium ferrite of the form C_3FH_6 is more stable but does not contribute anything to the strength of concrete.
- ✓ The hydrates of C_4AF show a comparatively more stable the hydrates of C_3A.
- ✓ The hydrates of C_4AF show a comparatively higher resistance to sulphate attack than the hydrates of C_3A.

Concrete Ingredients

Types of Cements

Ordinary Portland Cement (OPC):

- ✓ This type of cement is manufactured by mixing limestone and clay in proper proportion at very high temperature of about 1400-1500ºC in kiln.
- ✓ The resulting mixture is added with small amount of gypsum to delay the setting action.
- ✓ Initial setting time is not less than 30min and final setting time not more than 600min or 10hrs.
- ✓ Used for the construction of

- Road pavements
- RCC structures
- Water tanks, pipe lines, culverts.

Types of Cements

Rapid Hardening Cement:

- ✓ This cement is similar to that of OPC but with higher percentage of Tri-calcium silicate (C_3S) and finer than OPC.
- ✓ The final strength obtained from this cement is almost same as that of OPC.
- ✓ Initial setting time is not less than 30min and final setting time not more than 600min or 10hrs.
- ✓ This cement is used where a rapid development of strength is desired (Bridge and road repair works)
- ✓ The rapid development of strength is accompanied by higher rate of heat of hydration, so it not suitable for mass concreting
- ✓ It is about 10% costlier than OPC.

Concrete Ingredients

Types of Cements

Quick Setting Cement:

- ✓ This cement sets much faster than OPC.
- ✓ This cement is produced by mixing small percentage of Aluminium sulphate and by finely grinding the cement.
- ✓ Percentage of gypsum to be added is also reduced.
- ✓ Initial setting time is 5min and final setting time is 30min.
- ✓ It is used for making concrete that is required to set early as for laying under water or in running water.

Concrete Ingredients

Types of Cements

High Alumina Cement:

- ✓ It is manufactured by fusing together a mixture of limestone and bauxite in correct proportion at very high temperature and resulting product is grinded finely.
- ✓ The ultimate strength is much higher than OPC and color of this cement is black and proves to be costlier than OPC.
- ✓ Initial setting time is not less than 30min and final setting time not more than 600min or 10hrs.
- ✓ It can be used in low temperatures.
- ✓ They resist chemical attacks.

Concrete Ingredients

Types of Cements

Low Heat Cement:

- ✓ This cement is obtained by increasing the proportion of C_2S and decreasing C_3S and C_3A.
- ✓ This cement gains strength slowly but ultimate strength is same as that of OPC and not suitable for ordinary structures.
- ✓ Initial setting time is not less than 60min and final setting time not more than 600min or 10hrs.
- ✓ This cement is used only when the shuttering has to be kept for long period and curing is prolonged.

Concrete Ingredients

Types of Cements

Sulphate Resisting Cement:

- ✓ This cement is manufactured from well granulated slag (80 to 85%) & calcium sulphate (10 to 15%) along with 1 to 2% of OPC.
- ✓ It gives less heat of hydration, resistance to sulphate attack and strength and physical properties are same as that of OPC.
- ✓ Initial setting time is 2.5 to 4hrs and final setting time is 4.5 to 7hrs.
- ✓ Used in the construction of

•Marine works

•Mass concreting

•Underground waterworks and sewer works.

Concrete Ingredients

Types of Cements

Portland Slag Cement:

- ✓ This cement is made by inter-grinding finely the mixture of clinkers, gypsum and granulated slag in proper portions.
- ✓ This cement is less reactive than OPC and gains strength slowly during 28 days and adequate curing is required.
- ✓ This cement is used for marine works.

Concrete Ingredients

Types of Cements

Portland Pozzolana Cement:

- ✓ This cement has same properties as compared to that of OPC.
- ✓ This cement produces less heat of hydration and more resistant to sulphate attack.
- ✓ This cement can be used in marine works and mass concreting.
- ✓ This cement is manufactured by inter-grinding of clinkers and Pozzolana with the addition of gypsum.
- ✓ Time required to gain the strength is little more and ultimate strength is more than that of OPC.

Concrete Ingredients

Types of Cements

White Cement:

- ✓ This cement has pure white color and it posses same properties as that of OPC.
- ✓ The grey color of the cement is due to the presence of iron oxide.
- ✓ So if the percentage of iron oxide is kept very less, then the color of the cement will be white.
- ✓ This cement is manufacture by mixing white chalk and clay which is free from lime and oil is used instead of coal for burning of the cement.
- ✓ This is costlier than OPC and generally used for architectural and decorative purposes.

Concrete Ingredients

Types of Cements

Colored Cement:

- ✓ Colored cement is manufactured by adding suitable mineral pigments to ordinary cement at the time of grinding.
- ✓ The percentage of these pigments to be added varies from 5 to 10%.
- ✓ Pigments used in cement should be chemically inert and durable.
- ✓ Chromium oxide gives green color, Cobalt gives blue color and Iron oxide in different proportions gives brown, red or yellow color.
- ✓ This cement is used in flooring, exterior surfaces and decorative purposes.

Concrete Ingredients

Types of Cements

- ✓ **Air entraining cement:**
- ✓ This is made by mixing a small amount of air entraining agent with OPC at the time of grinding.
- ✓ Some of the air entraining agents are

1. Alkali salts of wood resin.

2. Calcium lingo-sulphate

- ✓ These agents in powder or in liquid form are added to the extent of 0.1 to 0.25% by weight of cement.
- ✓ Air entraining cement will produce at the time of mixing, a tough, tiny discrete air bubbles in the concrete which will modify the properties of plastic concrete wrt to workability, segregation, bleeding and hardness.

Concrete Ingredients

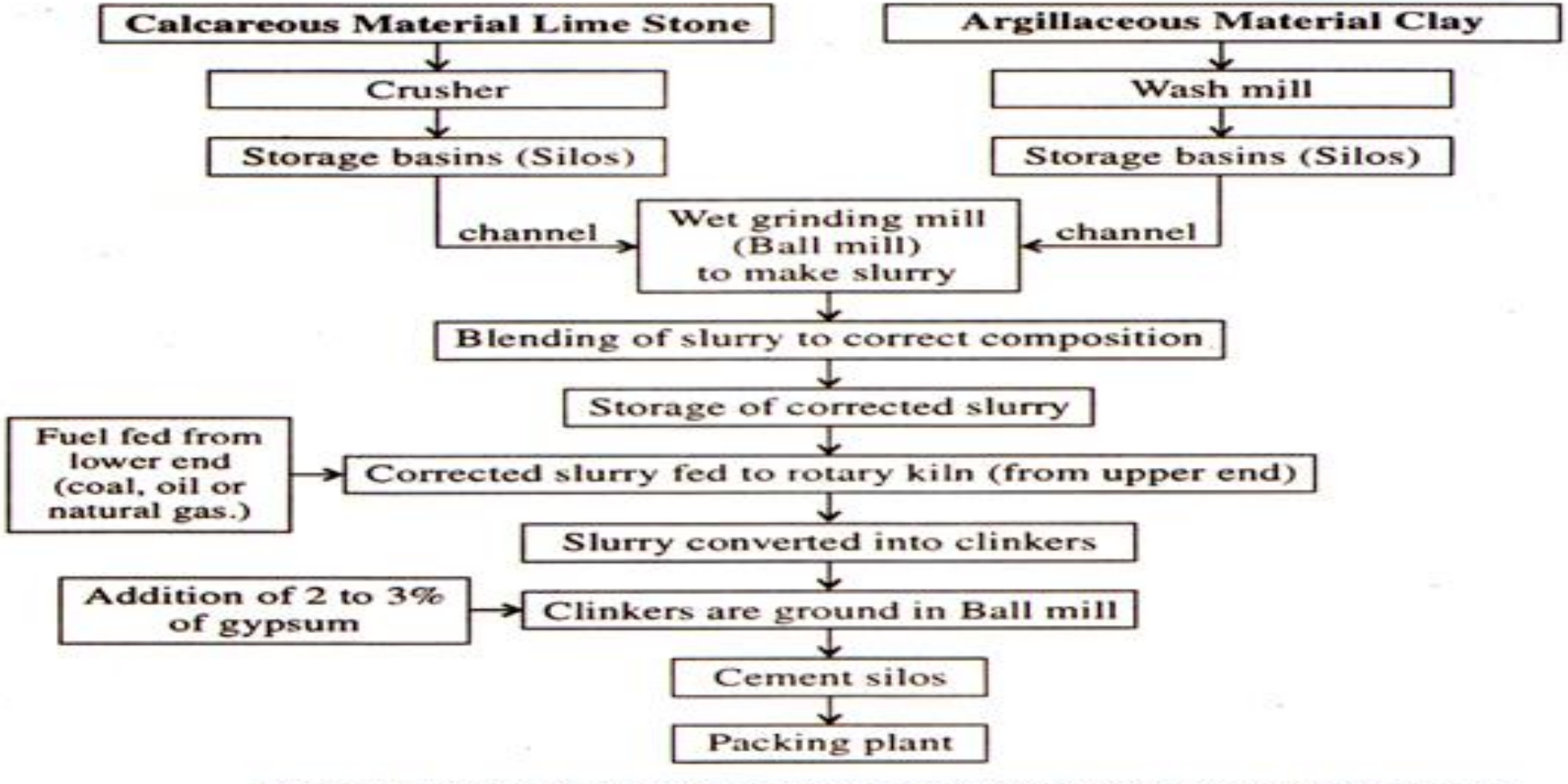
Manufacturing Process of OPC

- ✓ **Mixing of raw materials**
- ✓ **Burning**
- ✓ **Grinding**

Concrete Ingredients

Manufacturing of cement by Wet process (old technology)

Wet process :

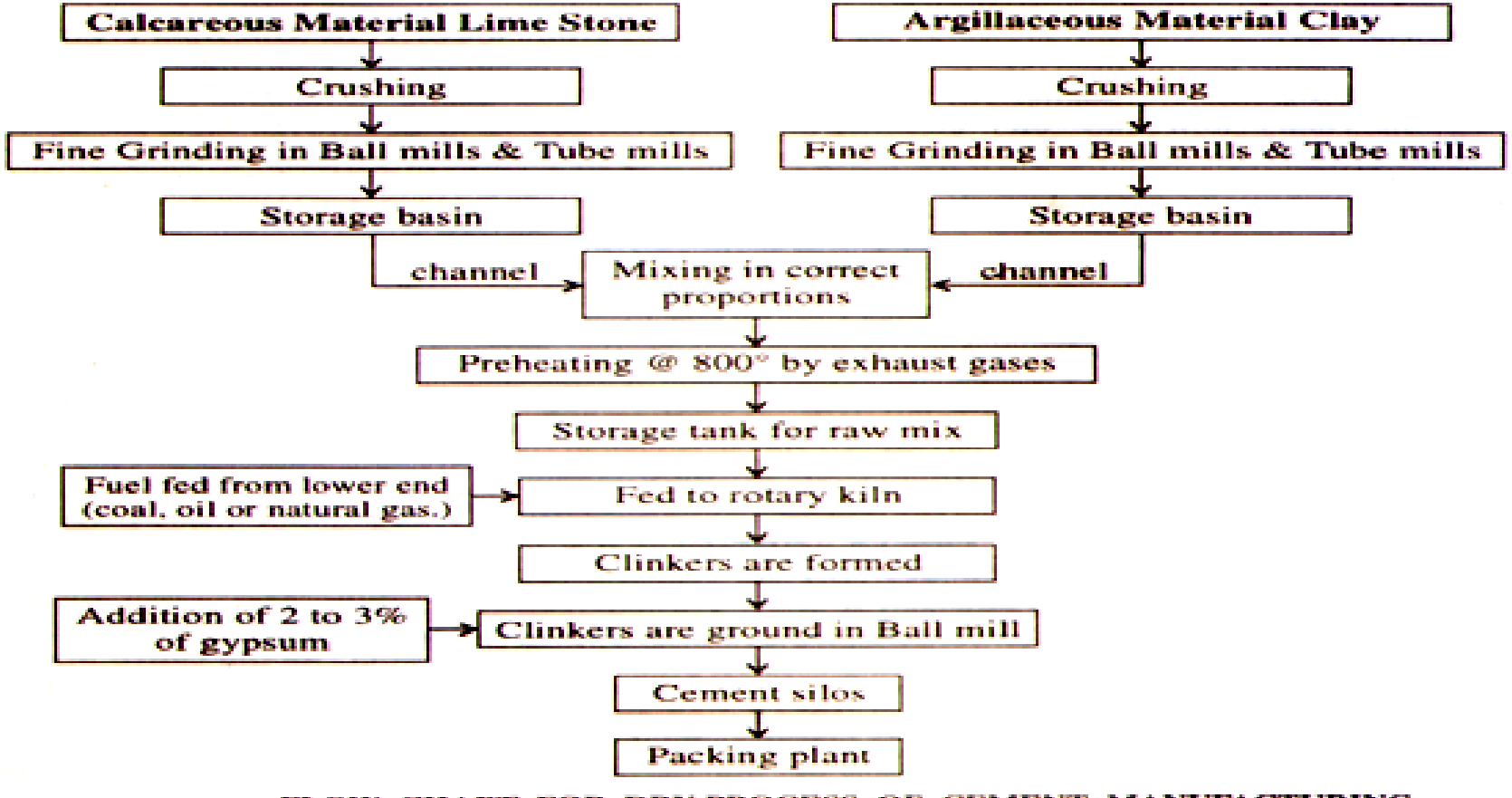


FLOW CHART FOR WET PROCESS OF CEMENT MANUFACTURING

Concrete Ingredients

Manufacturing of cement by Dry process (modern technology)

Dry process :



FLOW CHART FOR DRY-PROCESS OF CEMENT MANUFACTURING

Concrete Ingredients

Testing of cement

Field Test

- ✓ Open the bag and take a good look at the cement. There should be no visible lumps.
- ✓ The color of the cement should be greenish grey
- ✓ When hand is inserted in cement bag it should feel cool.
- ✓ Take a pinch of cement and feel between fingers. It should give a smooth feeling and not a gritty feeling.
- ✓ Take a handful of cement and throw it on a bucketful of water, the particles should float on water for some time before they sink.

Concrete Ingredients

Testing of cement

Field Test

- ✓ Take about 100gms of cement, add some water and prepare a stiff paste.
- ✓ From stiff paste, pat a cake with sharp edges.
- ✓ Put it on a glass plate and slowly take it under water in a bucket.
- ✓ The shape of the cake should not be disturbed, while taking it down to the bottom of the bucket.
- ✓ After 24 hours the cake should retain its original shape and at the same time it should also set and gain some strength.

Concrete Ingredients

Testing of cement

Laboratory Test

- Fineness test
- Standard Consistency test
- Initial setting time
- Final setting time
- Soundness of cement

Concrete Ingredients

Testing of cement

Laboratory Test

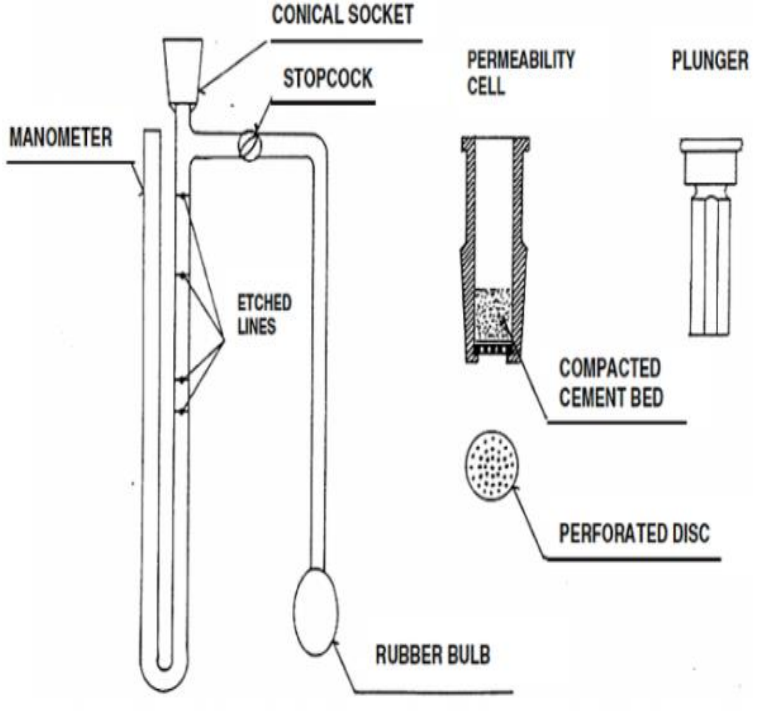
- ❖ Fineness test
- ✓ Weigh correctly 100gms of cement
- ✓ Take it on a standard sieve of 90μ and breakdown the air set lumps in the sample by means of fingers.
- ✓ Sieve the sample continuously for 15mins and weigh the residue left out on the sieve.
- ✓ This weight should not exceed 10% of the sample for the OPC.

Concrete Ingredients

Testing of cement

Laboratory Test

❖ Fineness test



Blaine =k√t

where k is 523.0547

Example: when t is obtained a 29 sec

S=523.0547√29

S=2817 cm^2/gm

- Put a filter paper into the cell then weight 2.84g of cement sample into it.
- Put another filter paper on it and compress with the plunger.
- Attach the cell on top of the U-tube manometer.
- Evacuate the air in the manometer through the side tube using the aspirator bulb until the oil reaches level 1.
- Close the side valve and monitor the oil as it start to fall.
- Using a stop watch, measure the time taken for the oil to fall from level 2 to level 3

Concrete Ingredients

Testing of cement

Laboratory Test

❖ Standard Consistency

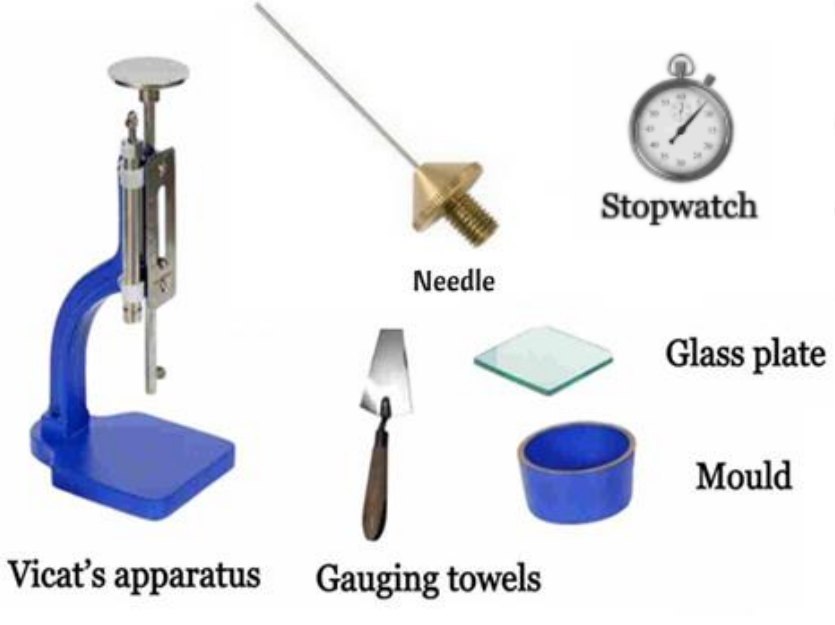
- Take about 400gm of cement
- Make the cement paste with a known quantity of water (let it be 24%)
- Fill this paste into the Vicat mould
- Shake the mould to expel the air
- Bring the mould near to the plunger of Vicat apparatus
- Release the plug in order to allow the plunger to penetrate through the paste
- If the reading is not within 33-35mm from top or 5-7mm from bottom, then repeat the procedure with the increase in % of water by 2% of weight of cement taken

Concrete Ingredients

Testing of cement

Laboratory Test

❖ Initial Setting Time



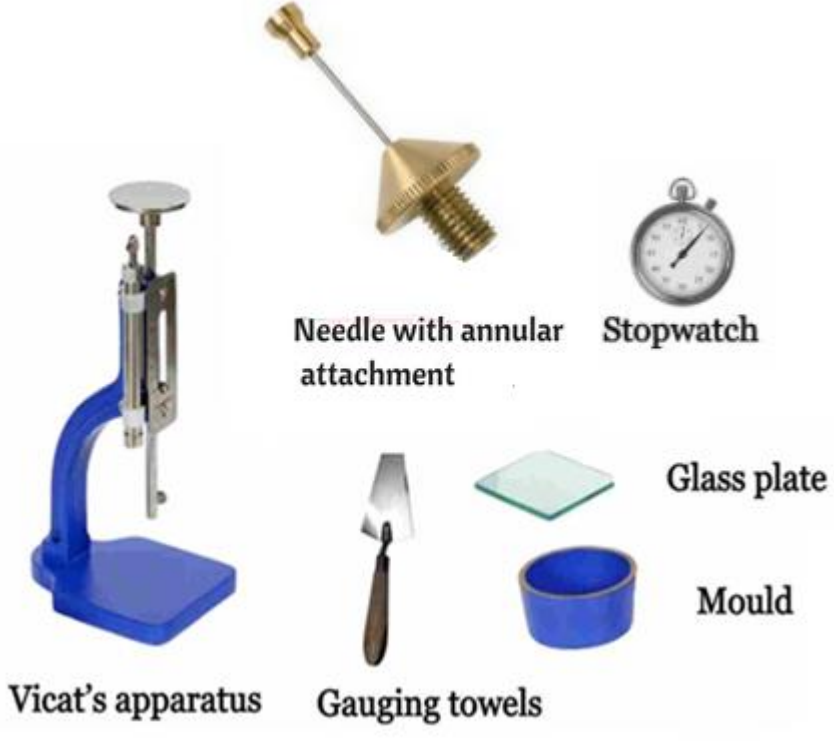
- Mix a known % of water to the cement to make a cement paste simultaneous start the stop clock
- Fill this cement paste into the Vicat mould
- Release the needle so that the needle fall freely.
- Stop the stop clock until the needle fails to pierce the tests block to a point 5 ± 0.5mm from the bottom of the mould

Concrete Ingredients

Testing of cement

Laboratory Test

❖ Final Setting Time



- Mix a known % of water to the cement to make a cement paste simultaneous start the stop clock
- Fill this cement paste into the Vicat mould
- Release the needle with an attachment so that it falls freely
- Cement shall be considered as finally set when the attachment fails to make an impression on the test block

Note

False setting is the rapid development of rigidity in freshly mixed Portland cement paste, mortar, or concrete occurs after few minutes of mixing cement with water without the generation of much heat.

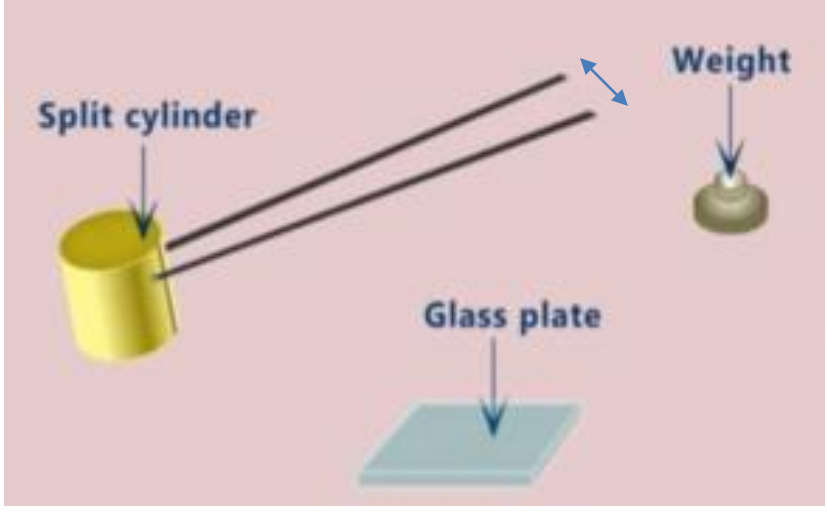
Flash setting is a rapid development of rigidity in freshly mixed Portland – cement paste, mortar, or concrete.

Concrete Ingredients

Testing of cement

Laboratory Test

❖ Soundness Test



- The cement paste is prepared. The % of water used will be equal to % of water determine by the standard consistency test.
- The cylinder is placed on a glass plate and is filled with cement paste. It is covered at top with another glass plate.
- A small weight is placed on the top of the glass plate.
- Then whole assembly is placed in water for 24hrs maintained at 27 +/- 20^0C
- Take it out and measure the distance between the two indicators using measuring scale
- The mould is again immersed in water and brought to boil in 30min and after boiling for 1hr, the mould is removed and after cooling the distance between the indicators is measured again.

Concrete Ingredients

Steps to reduce Carbon footprint in cement manufacturing process

- Increasing energy efficiency by optimizing processes and modernizing factories.
- Substituting fossil fuels with other energy sources.
- Using additives in cement to develop a large range of products according to their application.

Concrete Ingredients

Aggregates

- Aggregates are defined as inert, granular and inorganic materials that normally consist of stone or stone like solids.
- Aggregates can be used alone (in road bases and various types of fill) or can be used with cementing materials (such as Portland cement or asphalt cement) to form composite materials or concrete.
- Since aggregates constitutes about 3/4th of the volume of concrete, it contributes significantly to the structural performance of concrete especially strength, durability and volume stability.
- Aggregates are formed from natural sources by the process of weathering and abrasion or by artificially by crushing a large parent rocks.

Concrete Ingredients

Classification of aggregates

a) In accordance with size:

- Coarse aggregate: if particle size is greater than 4.75mm are regarded as coarse aggregates
- Fine aggregates: if particle size in between 75µ & 4.75mm are regarded as fine aggregates

Classification of aggregates

b) In accordance with sources:

- **Natural aggregates:** This kind of aggregates is taken from natural deposits without changing their nature during the process of production such as crushing and grinding.

  Some examples in this category are sand, crushed limestone and gravel.

- **Manufactured aggregates:** This is a kind of man-made materials produced as main product or an industrial by-product.

  Some examples are blast furnace slag, lightweight aggregate (e.g. expanded perlite), and heavy weight aggregates (e.g. iron ore or crushed steel)

Classification of aggregates

c) In accordance with unit weight:

- **Light weight aggregates:** the unit weight of aggregates is less than 1120kg/m3. (Cinder, blast-furnace slag, volcanic pumice).
- **Normal aggregates:** The aggregates have unit weight of 1520-1680kg/m3.
- **Heavy weight aggregate:** The unit weight is greater than 2100kg/m3. The bulk density of the corresponding concrete is greater than 3200kg/m3.

Concrete Ingredients

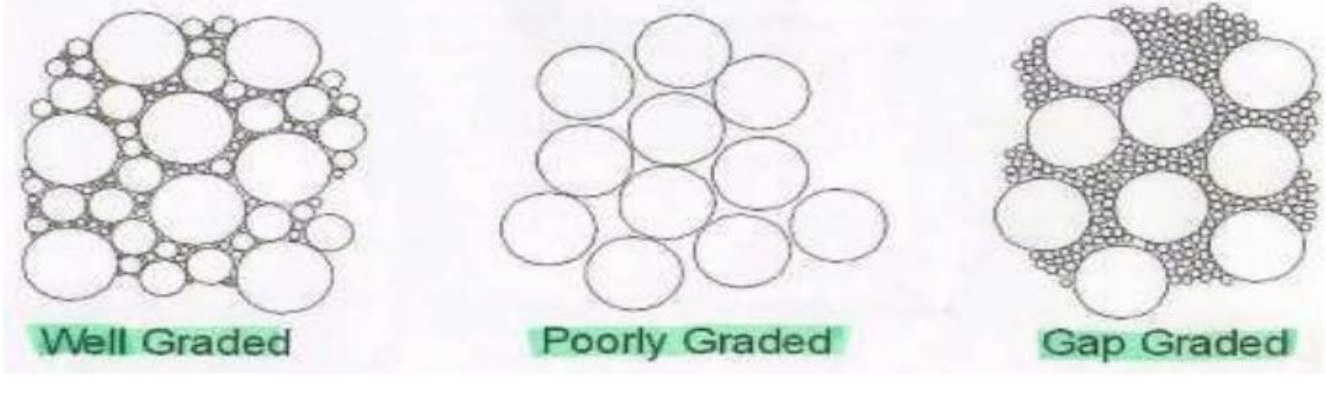
Grading of aggregates

- Particle size distribution of an aggregate is determined by sieve analysis is known as ‘grading of the aggregate’
- One of the most important factors for producing workable concrete is good grading of aggregates.
- Grading of aggregates are of 3 types

Concrete Ingredients

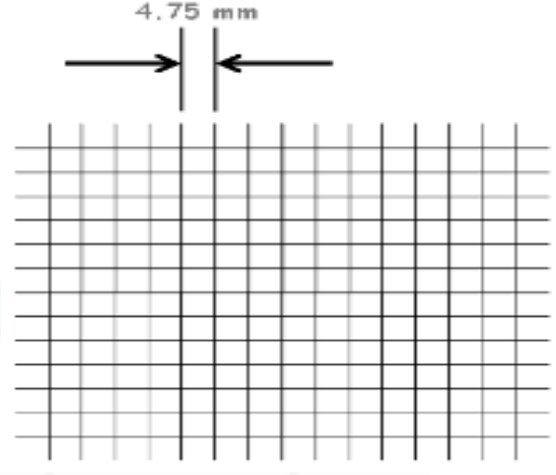
Grading of aggregates

- **Good graded or well graded:** It implies that a given sample of aggregates contains all standard fractions such there will be minimum number of voids.
- **Uniformly graded or poor graded:** It contains aggregate particles that are almost of the same size. This means that the particles pack together, leaving relatively large voids in the concrete.
- **Gap graded:** It consists of aggregate particles in which some intermediate size particles are missing.



Concrete Ingredients

- Sieve: It is a circular disc consists of wire mesh of square aperture.



- **Sieve analysis:** This is the name given to the operation of dividing the given sample of aggregates into various fractions each consisting of particles of same size.
- The sieve analysis is conducted to determine the particle size distribution in a sample of aggregates which is also called as Gradation.

Concrete Ingredients

- The aggregates used for making concrete are normally of the maximum size 80 mm, 40 mm, 20 mm, 10 mm, 4.75 mm, 2.36 mm, 600 micron, 300 micron and 150 micron.
- The aggregate fractions from 80 mm to 4.75 mm are termed as coarse aggregate and those fractions from 4.75 mm to 75 micron are termed as fine aggregate.
- Sieves are placed one above the other, maximum size is placed at the top and minimum size in the bottom. Sieving can be done either manually or by mechanically with sieve shaker. From the sieve analysis, the particle size distribution in a sample is found out; from this fineness modulus can be determined.

Concrete Ingredients

- Fineness Modulus: It is a relative index which indicates the particles are either coarser or finer. The sum of cumulative percentage retained on the sieves divided by 100 gives fineness modulus of given sample of aggregates.

- For sand the following limits are taken as guidelines

  - ✓ Fine sand → 2.2 – 2.6
  - ✓ Medium sand → 2.6 – 2.9
  - ✓ Coarse sand → 2.9 – 3.2

TABLE 5.7 Sample Calculation of Fineness Modulus

Sieve Size	Percentage of Individual Fraction Retained, by Weight	Cumulative Percentage Retained by Weight	Percentage Passing by Weight
9.5 mm (3/8 in.)	0	0	100
4.75 mm (No. 4)	2	2	98
2.36 mm (No. 8)	13	15	85
1.18 mm (No. 16)	25	40	60
0.60 mm (No. 30)	15	55	45
0.30 mm (No. 50)	22	77	23
0.15 mm (No. 100)	20	97	3
Pan	3	~~100~~	0
Total	100	Σ = 286	

Fineness Modulus = 286/100 = 2.86

Concrete Ingredients

Tests on Fine aggregates

- **Specific Gravity:**
- The specific gravity of an aggregate is the ratio of the mass of solid in a given volume of sample to the mass of equal volume water at the same temperature.
- They are of two types 1) absolute specific gravity and 2) apparent specific gravity.
- **Absolute specific gravity** is defined as ratio of mass or weight excluding voids in the volume of material of solid to the mass of equal volume of water.
- **Apparent specific gravity** is defined as ratio of mass or weight including voids in the volume of material of solid to the mass of equal volume of water.
- Average specific gravity of the rocks varies from 2.6 to 2.8.
- It's required for calculation of the quantity of aggregate for a given volume of concrete

Concrete Ingredients

Tests on Fine aggregates

- **Specific Gravity:**
- The specific gravity of an aggregate is the ratio of the mass of solid in a given volume of sample to the mass of equal volume water at the same temperature.
- They are of two types 1) absolute specific gravity and 2) apparent specific gravity.
- **Absolute specific gravity** is defined as ratio of mass or weight excluding voids in the volume of material of solid to the mass of equal volume of water.
- **Apparent specific gravity** is defined as ratio of mass or weight including voids in the volume of material of solid to the mass of equal volume of water.
- Average specific gravity of the rocks varies from 2.6 to 2.8.
- It's required for calculation of the quantity of aggregate for a given volume of concrete

Concrete Ingredients

Tests on Fine aggregates

❖ Specific Gravity:

Determination of Specific gravity of fine aggregates by Pycnometer method

Procedure

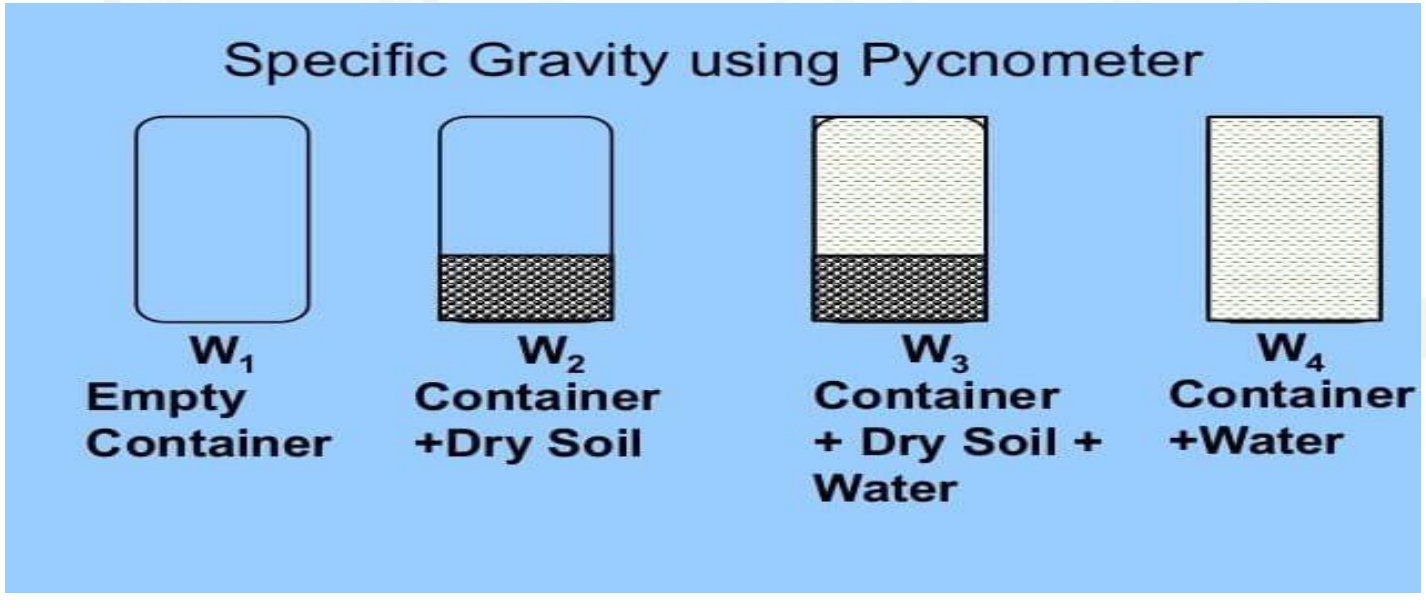
- Find the weight an empty Pycnometer with stopper. Let it be W1 gms.
- Take about 1/3rd the volume of Pycnometer full of sand. Find the weight of Pycnometer with sand and let it be W2 gms.
- Now fill the Pycnometer to its half with water so as to submerge the sand inside. Allow the entrapped air from sand to escape. Then fill the Pycnometer with water. Replace the stopper and find the total weight Pycnometer with its constituents and let it be W3 gms.
- Remove the constituents from the Pycnometer and clean it. Fill completely with water and replace the stopper. Find the weight with water and let it be W4 gms.

Concrete Ingredients

Tests on Fine aggregates

❖ Specific Gravity:

Determination of Specific gravity of fine aggregates by Pycnometer method



$$\text{Specific gravity} = \frac{(W_2 - W_1)}{(W_2 - W_1) - (W_3 - W_4)}$$

Concrete Ingredients

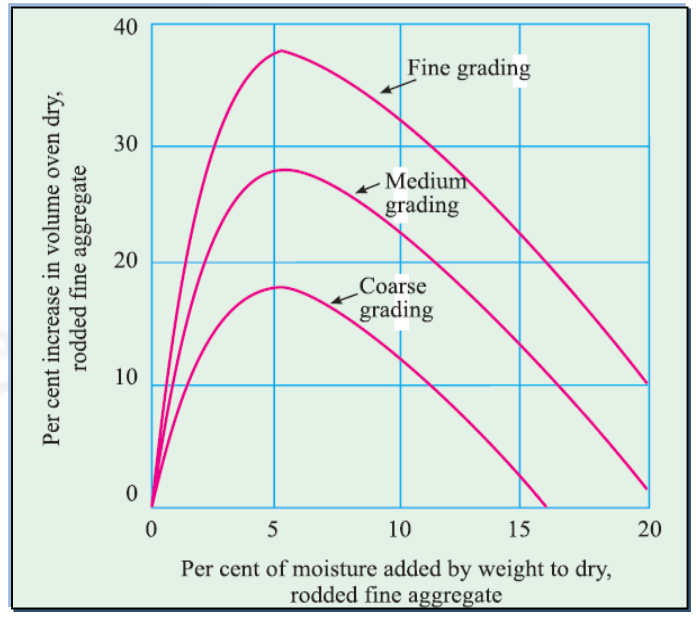
Tests on Fine aggregates

- **Bulking of sand**
- Bulking can be defined as that property of sand by virtue of which it expands in volume when it is wet.
- This is because, when water is added to the sand, each particle will be coated by a film of water and keeps far apart from each other due to surface tension.
- Bulking increases with the increase in water content up to 4% by weight and then decreases.
- Bulking also increases with fineness of particles.

Concrete Ingredients

Tests on Fine aggregates

- **Bulking of sand**
- **Procedure**
- Take about 300gms of dry sand and pour it into a measuring jar. Note down the initial volume of sand.
- Transfer the sand into a non absorbent pan and add 2% (by weight of sand) of water. Mix the sand thoroughly with a glass rod so that a uniform color is obtained.
- Then pour the wet sand into the measuring jar and note down the rise in volume.
- Again transfer the san into the pan and add another 2% of water by weight of sand. Mix thoroughly and pour back into the jar and note down the new volume.
- Repeat this process by increasing the water content at the rate of 2% until the volume starts decreasing.
- Plot a graph of % increase in volume V/S % of water added.



Concrete Ingredients

Tests on Fine aggregates

Measurement of moisture content for fine aggregate

- Moisture content means free water held on the surface of aggregate which includes the absorbed water and the water held in the interior portion of the aggregate.
- **Drying method:**
- The drying method is carried out in a oven and the loss in weight before and after drying will give the moisture content of the aggregate. If drying is done at high temperature for long time, the loss in weight will include not only the surface water but also some absorbed water.
- A fairly quick result can be obtained by heating the aggregate in an open pan and the process can be speed up by pouring inflammable liquid like acetone on the aggregate and igniting it.

Tests on Fine aggregates

Measurement of moisture content for fine aggregate

- **Displacement method:**
- In the laboratory, the moisture content of aggregate can be determined by means of Pycnometer.
- Specific gravity of normal aggregate is higher than that of water and that a given weight of wet aggregate will occupy a greater volume than the same weight of dry aggregate.
- By knowing the specific gravity of dry aggregate, specific gravity of wet aggregate can be calculated.
- From the difference between specific gravity of wet and dry aggregates, the moisture content of the aggregate can be calculated.

Tests on Fine aggregates

Measurement of moisture content for fine aggregate

- **Calcium Carbide method:**
- A quick and reasonably accurate method of determining the moisture of fine aggregate is to mix with excess amount of calcium carbide in a strong air-tight vessel fitted with pressure gas.
- Calcium carbide reacts with surface moisture in the aggregate to produce acetylene gas. The pressure of acetylene gas generated depends upon the moisture content of the aggregates.
- The pressure gauge is calibrated by taking a measured quantity of aggregate of known moisture content and then such a calibrated pressure gauge could be used to read the moisture content of aggregate directly.
- The method is often used to find out the moisture content of fine aggregate at the site of work. The equipment consists of a small balance, a standard scoop and container fixed with dial gauge.

Concrete Ingredients

Tests on Fine aggregates

Measurement of moisture content for fine aggregate

- **Calcium Carbide method:**
- The procedure is as follows; weigh 6gms of wet sand and pour it into the container.
- Take one scoop full of calcium carbide powder and put it into the container. Close the lid of the container and shake it rigorously.
- Calcium carbide reacts with surface moisture and produces acetylene gas, the pressure of which drives the indicator needle on the pressure gauge.
- The pressure gauge is so calibrated, that it gives directly the percentage of moisture present in the sample.
- The whole job takes only less than 5mins and as such, this test can be done at very close intervals of time at the site of work.

Concrete Ingredients

Tests on Fine aggregates

Measurement of moisture content for fine aggregate

- **Electrical meter method:**
- Recently electrical meters have been developed to measure instantaneous or continuous reading of the moisture content of the aggregate.
- The principle that the resistance gets changed with the change in moisture content of the aggregate has been made use in some sophisticated batching plant.
- Electrical meters are used to find out the moisture content and also to regulate the quantity of water to be added to the continuous mixture.
- The whole job takes only less than 5mins and as such, this test can be done at very close intervals of time at the site of work.

Tests on Fine aggregates

Measurement of moisture content for fine aggregate

- **Automatic measurement:**
- In modern batching plants surface moisture in aggregates is automatically recorded by means of some kind of sensor arrangements.
- The arrangement is made in such a way that, the quantity of free water going with aggregate is automatically recorded and simultaneously that much quantity of water is reduced.
- This sophisticated method results in an accuracy of ± 0.2 to 0.6%.

Concrete Ingredients

Alternatives to river sand

- Sand is a vital ingredient in making two most used construction materials viz. Cement Concrete and mortar.
- Traditionally River sand, which is formed by natural weathering of rocks over many years, is preferred as fine aggregate.
- The economic development fueling the growth of infrastructure and housing generates huge demand for building materials like sand.
- The indiscriminate mining of sand from riverbeds is posing a serious threat to environment such as erosion of riverbed and banks, triggering landslides, loss of vegetation on the bank of rivers, lowering the ground water table etc.

Concrete Ingredients

Alternatives to river sand

- Demand for sand is increasing day by day and at the same time mining threats cannot be ignored.
- Hence, sand mining from riverbeds is being restricted or banned by the authorities like

✓ National Green Tribunal,

✓ State Environmental Impact Assessment Authority and

✓ Pollution Control Board

Concrete Ingredients

Some of the Alternatives to River sand

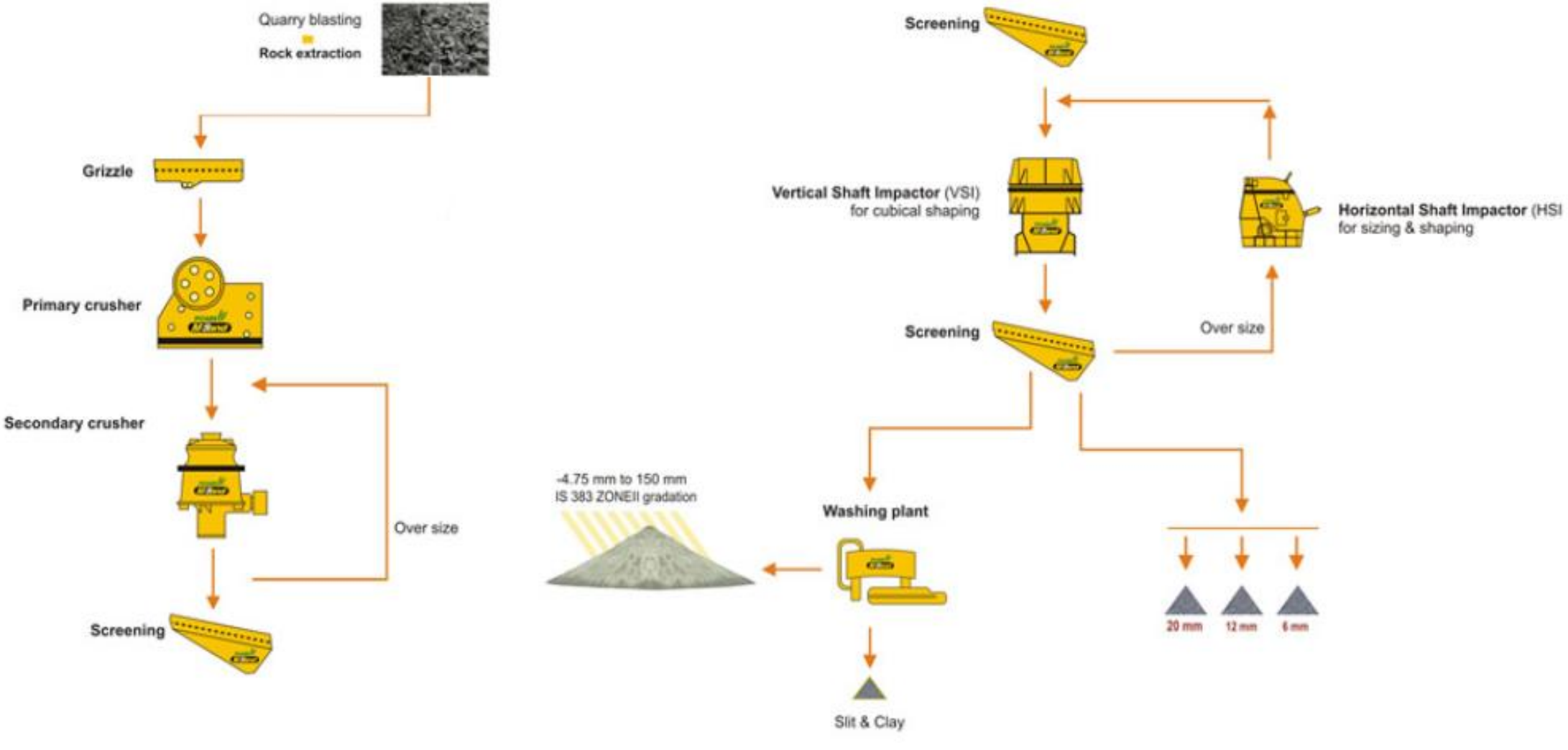
- Manufacture Sand
- Processes Quarry dust
- Processed Crushed rock fines
- Offshore Sand
- Processed glass
- Aluminum saw mill waste
- Granite fines slurry
- Washed soil (filtered sand)
- Fly ash (bottom ash/ pond ash)
- Slag sand
- Copper Slag sand
- Construction Demolition waste.

Concrete Ingredients

Manufacture Sand

Manufactured sand is crushed fine aggregate produced from a source material and designed for use in concrete or for other specific products. Only source materials with suitable strength, durability and shape characteristics should be used.

Concrete Ingredients



Concrete Ingredients

Coarse Aggregates

Importance of size, shape and surface texture of aggregates on workability and strength

Size of aggregate:

- Bigger the size of particles less will be the surface area
- Less amount of water is required
- Less cement paste required for lubricating the surfaces of aggregates
- So bigger the size, gives higher workability

Concrete Ingredients

Coarse Aggregates

Importance of size, shape and surface texture of aggregates on workability and strength

Shape of aggregate:

- Angular, elongated or flaky aggregates make the concrete very harsh when compared to rounded or cubical aggregates.
- Cubical aggregates have less surface area, less voids, the frictional resistance between the aggregates is also less.
- Hence the workability will be more in case of rounded than compared to flaky aggregates.
- Hence the strength will be more by using rounded or cubical aggregates.

Concrete Ingredients

Coarse Aggregates

Importance of size, shape and surface texture of aggregates on workability and strength

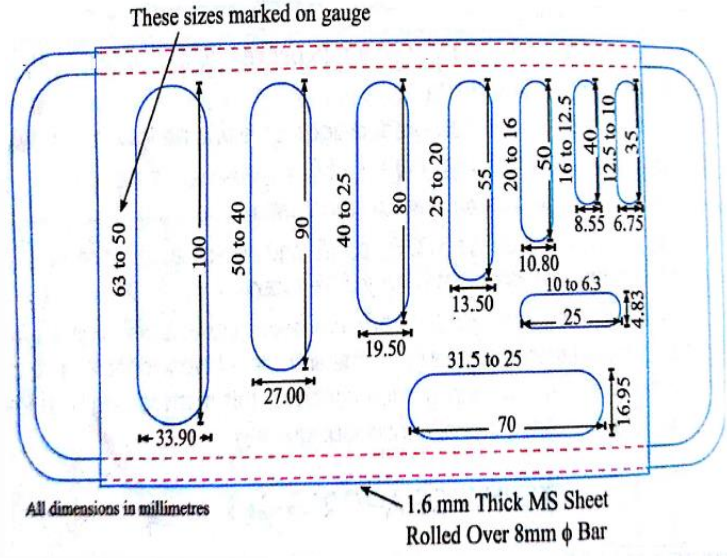
Surface texture:

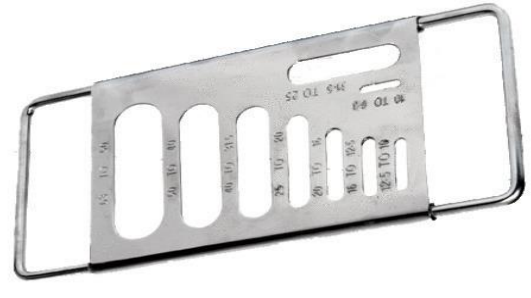
- Surface texture is the property, the measure of which depends upon the relative degree to which particle surface are polished or dull, smooth or rough.
- Surface texture depends on hardness, grain size, pore structure and structure of the rock
- Total surface area of rough texture aggregate is more than that of surface area of smooth rounded aggregates of same volume.
- Rough textured aggregates will show poor workability and smooth textured aggregates will give better workability because of lesser frictional resistance of inner surface particle.

Concrete Ingredients

Test for determination of flakiness index

- An aggregate having least dimension less than 3/5th of mean dimension is termed as flaky.
- This test is not applicable to aggregates less than 6.3mm.
- This test is conducted by using a metal thickness gauge.
- A sufficient quality of aggregates is taken ie, a minimum of 200 pieces of any fraction to be tested.
- Each fraction is gauged in terms of thickness on metal gauge.
- The total amount of aggregate pieces passing through each gauge is weighed accurately.
- Flakiness index is calculated by taking the ratio of total weight of materials passing through the various thickness gauges to the total weight of aggregate sample taken.





Concrete Ingredients

Test for determination of elongation index

- The elongation index of an aggregate is the particle having largest dimension (length) is greater than 9/5th of mean dimension.
- The elongation index is not applicable to sizes lesser than 6.3mm. This test is conducted by using metal length gauge.
- A sufficient quantity of aggregate is taken to provide a minimum number of pieces of 200 of any fraction to be tested.
- Each fraction shall be gauged individually for the length on metal gauge.
- The amount retained by the gauge length shall be weighed to an accuracy of 0.1% of the weight of sample taken.
- The elongation index is calculated in percentage by taking the ratio of total weight of materials retained on various length gauges to the total weight of aggregate sample taken.

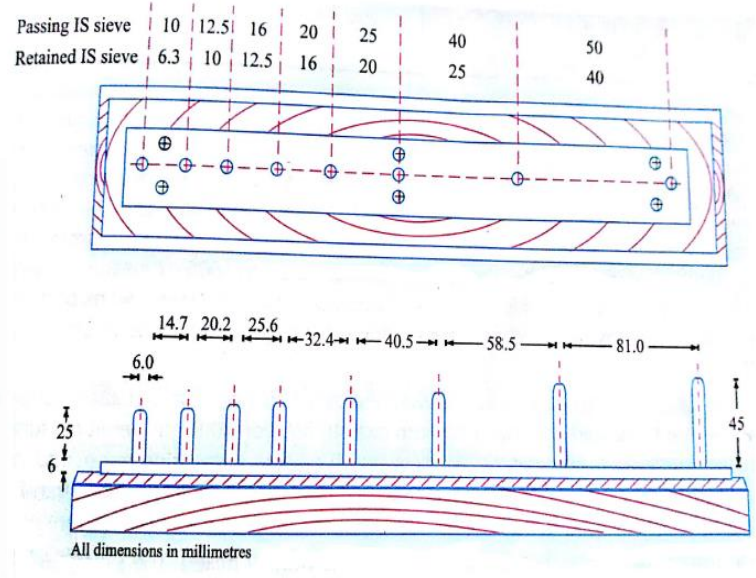


Fig. 3.10. Length Gauge.

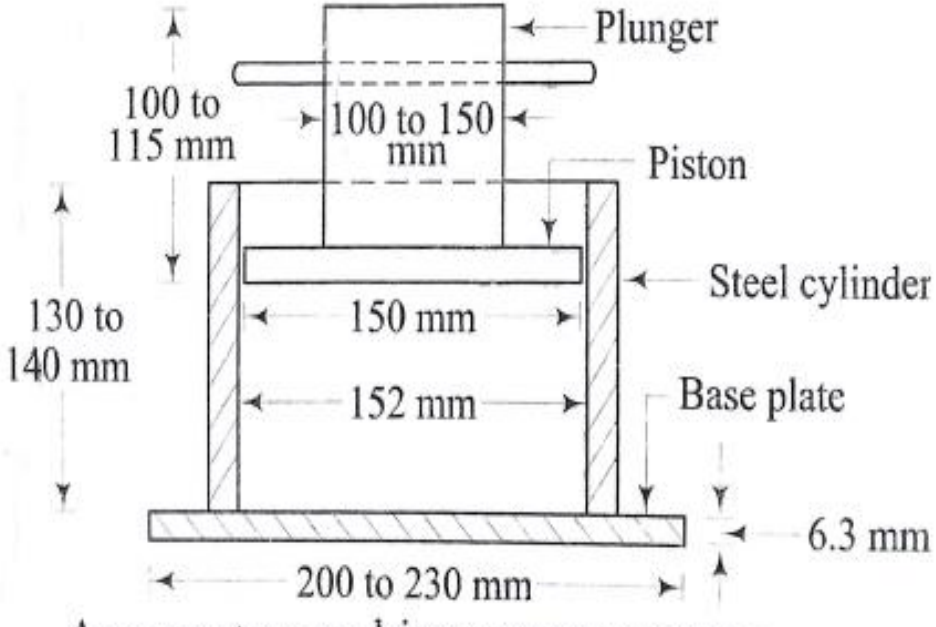
Concrete Ingredients

Testing of mechanical properties of aggregates

Test for determination of aggregate crushing value

- The aggregate crushing value gives a relative measure of the resistance of an aggregate to crushing under a gradually applied compressive load.
- Apparatus required for this test are as follows

1. Steel cylinder (dia-15.2cm, height-14cm)
2. Cylindrical measure (dia-11.5cm, height-18cm)
3. Steel tamping rod (dia-1.6cm, height- 40 to 60cm)
4. Balance
5. Compression testing machine



Aggregate crushing test apparatus

Concrete Ingredients

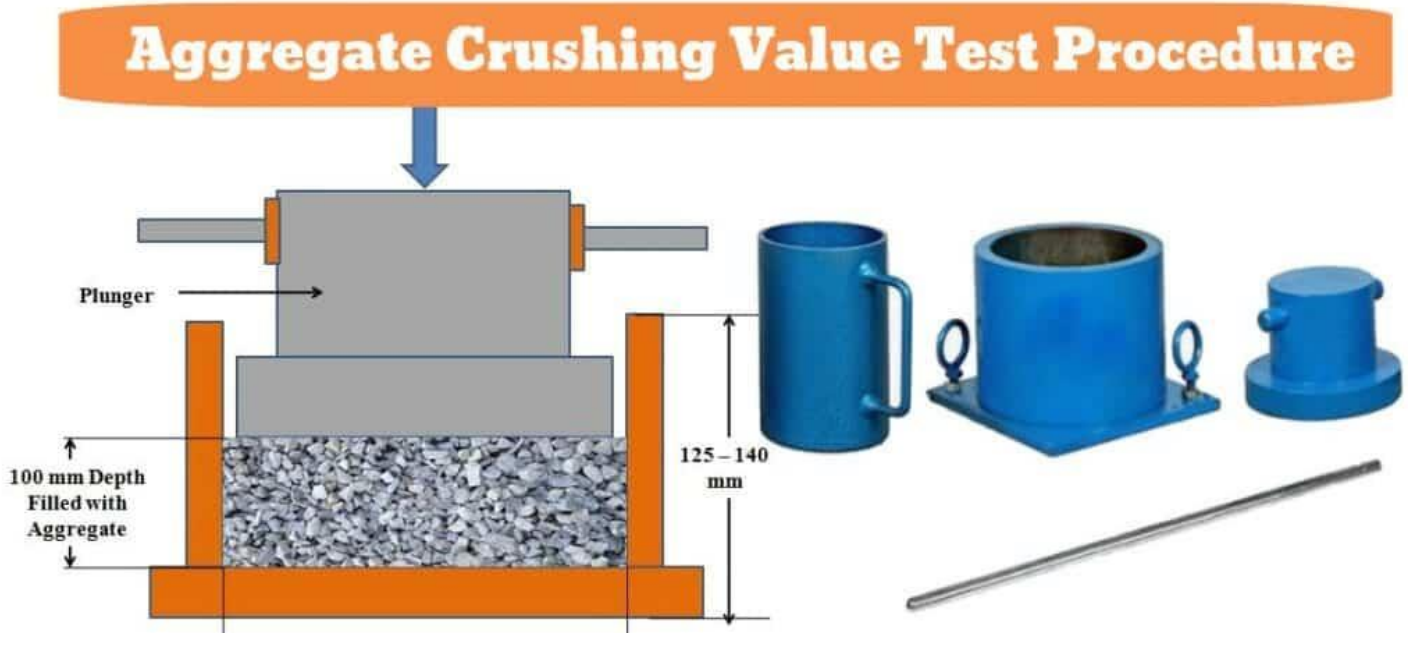
Procedure

1. Oven dry aggregate passing 12.5mm IS sieve and retained on 10mm IS sieve is selected for the test.

2. The sample aggregates in filled three layers and each layer being tamped 25 blows by rounded end of the tamping rod.

3. After tamping the third layer, the top surface is leveled using the tamping rod as straight edge. The test sample weight is taken as W1 gms.

4. The cylinder of the test apparatus is placed in position on the base plate and the test sample is transferred into the cylinder in three layers and each layer is tamped with 25blows.



Concrete Ingredients

Procedure

5. The surface of the aggregate is leveled and the plunger inserted.

6. The cylinder with the test sample and plunger in position is placed on CTM.

7. Load is then applied through the plunger at a uniform rate of 4tones/min until the total load of 40tones and then the load is released.

9. Aggregates including the crushed portion are removed from the cylinder and sieved on a 2.36mm IS sieve, the material which passes this sieve is collected and taken W_2 gms.

Aggregate crushing value $= \frac{W_2}{W_1}$ **X100**

According to Indian road congress & ISI has specified that aggregate crushing value of the coarse aggregate used for cement concrete pavements should not exceed 30% and used for concrete other than wearing surface should not exceed 45%.

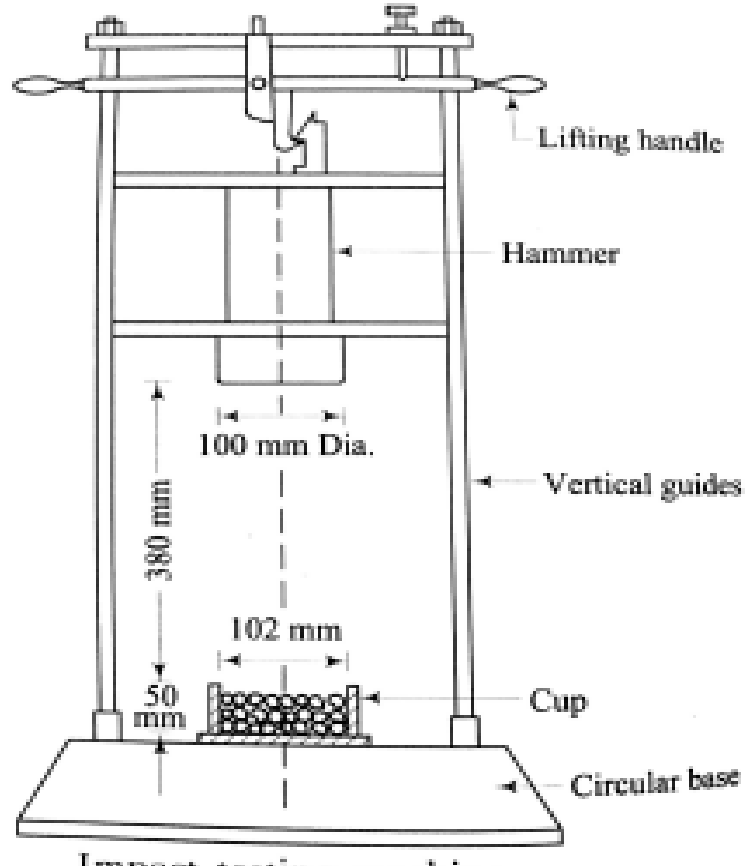
Concrete Ingredients

To determine the aggregate impact value

The aggregate impact value gives the relative measure of the resistance of an aggregate to sudden shock or impact.

Apparatus required for the experiment are as follows

1. Impact testing machine
2. Cylindrical measure
3. Tamping rod
4. Balance



Impact testing machine

Concrete Ingredients

Procedure

1. Oven dry aggregate passing through 12.5mm IS sieve and retained in 10mm IS sieve are selected for the test.

2. The cylindrical measure is filled by the sample aggregates in three layers and each layer being tamped by 25blows with rounded end of the tamping rod.

3. After tamping the third layer, the top surface is leveled using the tamping rod as straight edge. The test sample weight is taken as W1 gms.

4. The cup of the test apparatus is placed in position on the base plate and test sample is transferred to the cup in a single layer and being tamped 25 blows and top surface is leveled.

Concrete Ingredients

Procedure

5. The hammer is raised until its lower face is 38cm above the upper surface of the aggregate in the cup, and allowed to fall freely on aggregate for 15 times at an interval not more than 2 seconds and not less than 1second.

6. The crushed aggregate is then removed from the cup and the whole sample is sieved on 2.36mm IS sieve, the material which passes this sieve is collected and taken W2 gms.

Aggregate impact value $= \frac{W_2}{W_1}$ **X100**

Note: According to IS specification, the aggregate impact value

< 10% → exceptionally strong

10 – 20% → strong

20 – 30% → satisfactory for road surfacing

> 30% → weak for road surfacing

Concrete Ingredients

Test for the determination of aggregate abrasion value

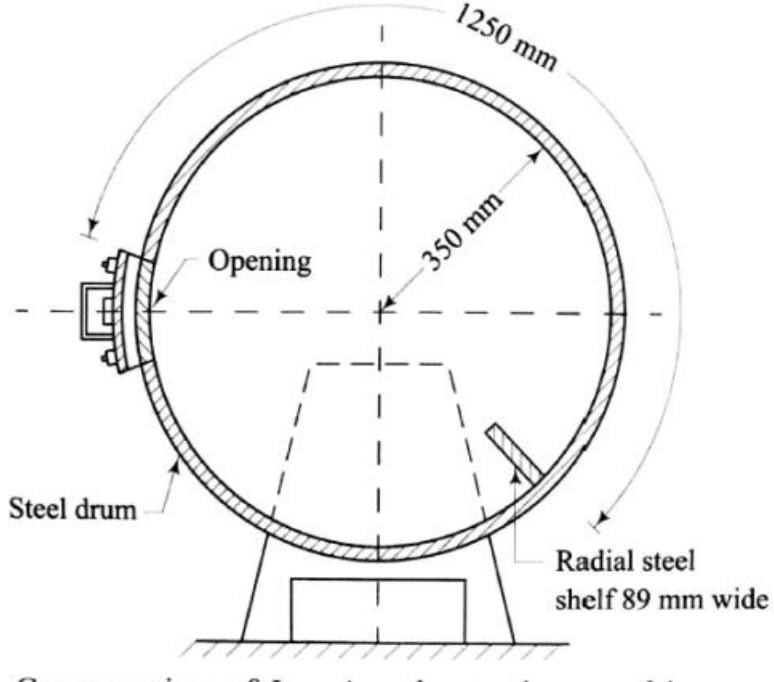
Apparatus required for the experiment are as follows

1. Los-Angeles machine

2. Steel balls (dia - 48cm, weight - 390 to 445g)

3. Balance

4. Sieves



Cross-section of Los Angeles testing machine

Concrete Ingredients

Procedure

1. Clean dry aggregate, confirming to any one of the grading A to G is used for the test. Aggregate weighing 5kg for grading A, B, C or D and 10kg for grading E and for G may be taken as test specimen and placed in the cylinder and is noted as W1 gms.

2. The abrasive charge is also chosen depending upon the aggregate and is placed in the cylinder of the machine; the cover is then fixed dust tight.

3. The machine is rotated for 500 revolutions for grading A, B, C and D & for grading E, F and G it shall be rotated for 1000 revolutions.

4. After the desired number of revolutions, machine is stopped and the material is discharged from the machine taking care to take out entire stone dust.

5. Using 1.7mm IS sieve the material is sieved and the coarser material is retained on the sieve is taken as W2 gms.

Percentage wear $= \frac{W_2}{W_1}$ **X100**

No.	Sieve size		Weight (in gms) and grading of test samples						
	Passing on mm	Retained on mm	A	B	C	D	E	F	G
1	80	63	-	-	-	-	2500	-	-
2	63	50	-	-	-	-	2500	-	-
3	50	40	-	-	-	-	5000	5000	-
4	40	25	1250	-	-	-	-	5000	5000
5	25	20	1250	-	-	-	-	-	-
6	20	12.5	1250	2500	-	-	-	-	-
7	12.5	10	1250	2500	-	-	-	-	-
8	10	6.3	-	-	2500	-	-	-	-
9	6.3	4.75	-	-	2500	-	-	-	-
10	4.75	2.36	-	-	-	5000	-	-	--
Number of spheres to be used			12	11	8	6	12	12	12
Number of revolutions			500				1000		

No.	Type of surface	Maximum abrasion values
1	W.B.M subsurface course	60
2	W.B.M base course with bituminous surfacing	50
3	W.B.M surface course	40
4	Cement concrete surface course	35
5	Bituminous / Asphalt concrete surface course	30

Concrete Ingredients

Test to determine Specific Gravity of coarse aggregate by wire basket method

1. Take about 5kg of coarse aggregates retained on 4.75mm sieve.

2. Wash thoroughly to remove dust, dry to constant mass at a temperature of 105± 5ºC.

3. Immerse the sample in water at 22 to 32ºC for a period of 24±1/2 hours (30min in practice).

4. Remove the aggregates from water & roll the same in a large piece of an absorbent cloth until all visible films of water are removed, although the surface of the particles will still appears to be damp.

5. Now, weigh 3kg of this sample in the in the saturated dry condition and note down the mass as W_1gm.

6. Place the weighed aggregate immediately in the wire basket & dip it water. Weigh this bucket with aggregates, keeping it in water with the help of a balance. Note down the mass as W_3 gm.

Concrete Ingredients

Test to determine Specific Gravity of coarse aggregate by wire basket method

7.Note down the weight of suspended empty wire basket in water without aggregates and note down the mass as W2 gm.

8. Dry the sample to the constant weight at the temperature of 100 to 110ºC for 24±1/2 hours.

9. Cool to room temperature and weigh it & note down the mass as W4 gm.

10. Calculate specific gravity and repeat the procedure for fresh sample of aggregates.

Weight of oven dry aggregate (C) = W4 gm.

Weight of saturated surface dry aggregate (B) = W3 gm.

Weight of basket & aggregates in water (A1) = W2 gm.

Weight of empty basket submerged in water (A2) = W1gm.

Actual Specific gravity =**C**/(**B**−**A**)

Apparent specific gravity =**C**/(**C**−**A**)

Water absorption =**100 X** (**B**−**C**)/**C**

Where A = weight of saturated aggregate in water = A1 – A2.

Concrete Ingredients

Recycled Aggregates

- World is growing and urbanizing at a very fast rate and so is India.
- This effect of rapid urbanization is also seen in construction industry.
- However, with urbanization comes the moral responsibility of sustaining the environment.
- Concrete is the favorite choice as a construction material among civil engineers around the globe for decades.
- It is preferred for its better performance, longer life and low maintenance cost.
- To achieve rapid urbanization every year smaller structures are demolished and newer and bigger ones are constructed.

Concrete Ingredients

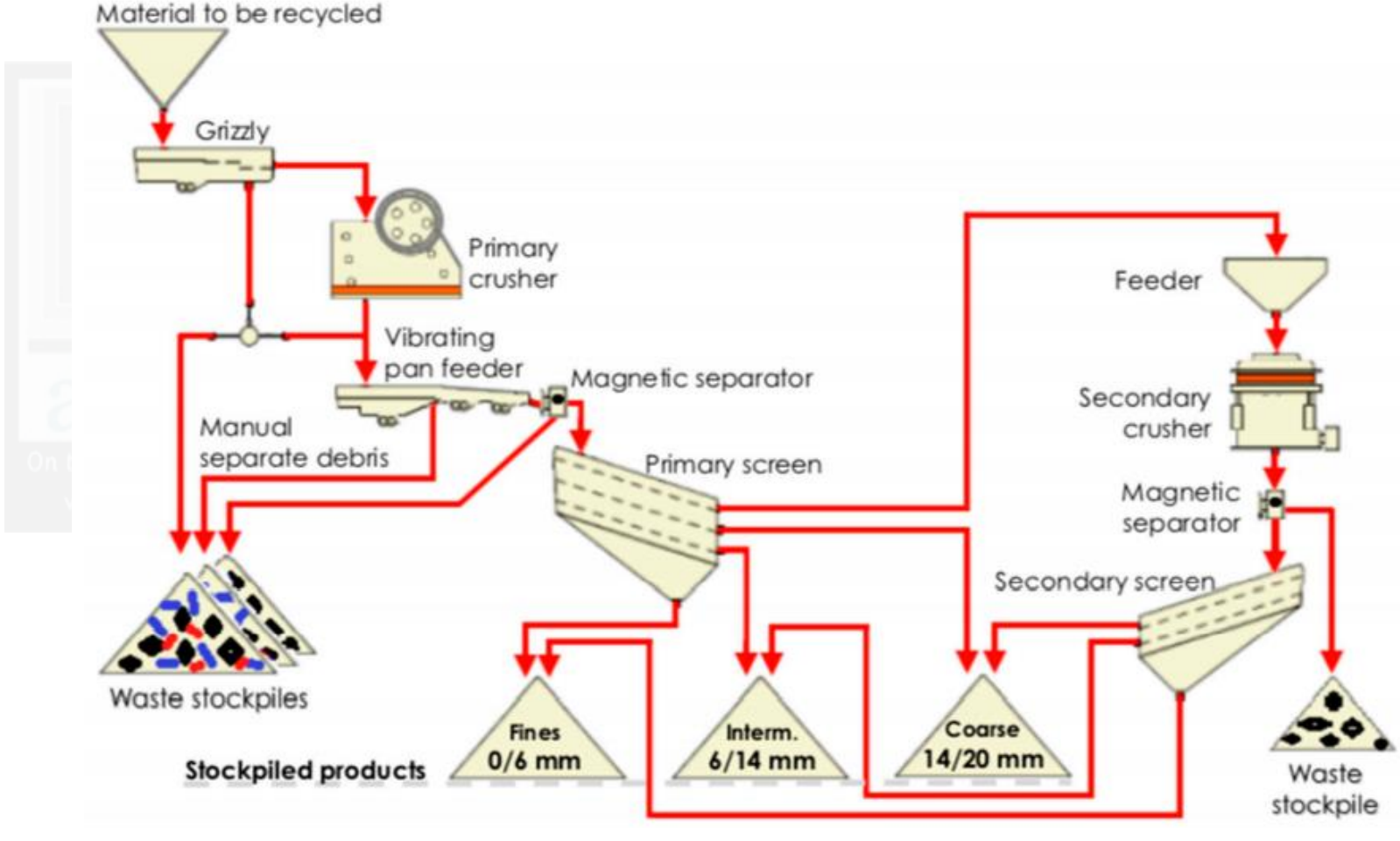
Recycled Aggregates

- These demolished materials (majority of which is usually concrete) are often dumped on land and is not reused for any purpose.
- This practice effects the fertility of land.

- One such material is recycled aggregate concrete.
- Aggregates which are obtained from demolished concrete structures are referred as Recycled aggregates.
- ASTM (American Society for Testing and Materials) has classified these aggregates as Artificial aggregates.
- It has low strength, lower young's modulus, low density, high drying shrinkage, higher porosity and higher absorption capacity.
- It produces a concrete of low density than compared to conventional aggregates.
- It is an added advantage if it is saturated. Because it helps in internal curing.

Concrete Ingredients

Manufacturing of Recycled Aggregates



Concrete Ingredients

Manufacturing of Recycled Aggregates

- **Evaluation of Source concrete:**

The first step in production of RAC is to determine the quality of the source concrete. Properties and records of source concrete like strength, durability and composition are looked into for deciding the proper source concrete.

- **Crushing of demolished concrete:**

The simple process involves crushing concrete into specified size and quality (usually of size 20 mm – 50 mm).

- **Removal of Contaminants:**

Contaminants like reinforcing steel, foundation materials, asphalt concrete shoulders, soil, etc. are removed. It can be achieved by many methods including screening or air separation, demolition, using electromagnets, etc. Some contaminants depending on the use of RCA can also be processed separately

Concrete Ingredients

Advantages of Recycled Aggregates

- Reduces the amount of virgin aggregates to be created, hence less evacuation of natural resources.
- While being crushed into smaller particles a large amount of carbon dioxide is absorbed. This reduces the amount of CO_2 is the atmosphere.
- Cost saving – few research studies have shown a significant reduction in construction costs if RAC is used.
- Conserves landfill space, reduces the need for new landfills and hence saving more costs.
- Creates more employment opportunities is recycling industry.

Concrete Ingredients

Disadvantages of Recycled Aggregates

- Downgrading of quality of concrete.
- Increase in water absorption capacity ranging from 3% to 9%
- Decrease in compressive strength of concrete (10-30%)
- Reduces workability of concrete.
- Lack of specifications and guidelines.
- Less durability of RAC, however few papers have shown an improvement in the durability by mixing it with special materials like fly ash

Concrete Ingredients

Applications of Recycled Aggregates

- Can be used for constructing gutters, pavements etc.
- Large pieces of crushed aggregate can be used for building revetments which in turn is very useful in controlling soil erosion.
- Recycled concrete rubbles can be used as coarse aggregate in concrete.

Concrete Ingredients

Blending of Aggregates

- Sometimes aggregates available at sites may not be of specified or desirable grading.
- In such cases two or more aggregates from different sources may be combined to get the desired grading.
- Often, mixing of available fine aggregate with available coarse aggregate in appropriate percentages may produce desirable grading.
- But sometimes two or more fractions of coarse aggregates is mixed first and then the combined coarse aggregate is mixed with fine aggregate to obtain desirable grading.

Blending of Aggregates

Material	Agg. #1		Agg. #2		Blend	Target
% Used	50 %		50 %			
U.S. Sieve	% Passing	% Batch	% Passing	% Batch		
3/8 "	100	50	100	50	100	100
No. 4	90	45	100	50	95	80 - 100
No. 8	30	15	100	50	65	65 - 100
No. 16	7	3.5	88	44	47.5	40 - 80
No. 30	3	1.5	47	23.5	25	20 - 65
No. 50	1	0.5	32	16	16.5	7 - 40
No. 100	0	0	24	12	12	3 - 20
No. 200	0	0	10	5	5	2 - 10

Concrete Ingredients

Water

Some of the Qualities of water can used for mixing are

- The use of portable water is generally safe for mixing of concrete.
- Any water with a pH of 6 to 8 which does not taste saline is suitable for use to mix the concrete.
- Sea water contains large quantities of chlorides tends to cause persistent dampness and efflorescence.
- In RCC, sea water increases the risk of corrosion of the reinforcement.
- Water containing less than 2000ppm of dissolved salts can generally be used satisfactory for making concrete.
- Presence of zinc, copper, tin, manganese and lead reduce the concrete strength.
- Sodium phosphate, sodium borate etc., acts as retarders which results in loss of strength.
- Sugar up to 0.05% by weight of water is harmless.
- Sugar up to 0.05% by weight of cement retard the setting time, reduce the early strength and increases 28days strength.
- Sugar up to 0.2% causes quick setting of cement.

Concrete Ingredients

Use of sea water for mixing concrete

- Sea water has a salinity of about 3.5%.
- About 78% is NaCl and 15% is chlorides and sulphates of magnesium.
- Sea water also contains small quantities of sodium and potassium salts.
- This will react with aggregates and cement used for mixing.
- Hence sea water should not be used for mixing concrete.
- It is seen that use of sea water for mixing concrete does not appreciably reduce the strength of concrete but it may lead to corrosion of reinforcement.
- Sea water slightly accelerates the early strength of concrete but it reduces 28days strength of concrete by about 10-15%.

Concrete Ingredients

Admixtures

- Admixtures are chemical or mineral substances other than fine aggregates, coarse aggregates, cement and water, which are added in small amount before or at the mixing stage to the concrete product.
- They can also be blended at the time of grinding of clinker in cement manufacturing process.
- Added only when properties of fresh or hardened concrete need to be modified.

Concrete Ingredients

Most commonly used Chemical admixtures are

- Plasticizers
- Super plasticizers
- Retarders and Retarding plasticizers
- Accelerators and Accelerating plasticizers
- Air-entraining Admixtures
- Damp proofing and Water proofing Admixtures
- Gas forming Admixtures
- Air detraining Admixtures
- Workability Admixtures
- Bonding Admixtures
- Coloring Admixtures

How Chemical Admixtures act?

Reaction of chemical admixtures with cement takes place in three different stages

1. Physico Chemical reaction:-

In this stage, C3S & C3A are formed early when water is added to the cement and because of adhesive property of cement, an intermolecular force of attraction will be created between the cement grains as a result cement floc will be formed in the cement paste.

How Chemical Admixtures act?

Reaction of chemical admixtures with cement takes place in three different stages

2.Chemical adsorption and interaction:-

- When chemical admixtures are added to the cement, it gets adsorbed on cement compounds or cement grains and on the products of hydration (especially on C3A), which stiffens the hydrated compounds.
- But sometimes it also initiates very early stiffening.
- They really combine and never slowdowns the setting but initiates long term hydration.

How Chemical Admixtures act?

Reaction of chemical admixtures with cement takes place in three different stages

3. Deflocculation or Dispersion:-

- Flocculated cement compounds consists of certain amount of water in it.
- But due to the attack of admixtures, it deflocculates or disperses the cement grains by creating an intermolecular repulsion between the cement grains which releases the water in the cement paste as a result, workability of concrete increases.
- The intermolecular repulsion between the cement grains is known as “Zeta Potential”.

Concrete Ingredients

Plasticizers (Water reducers):-

- Workability is the inherent property of concrete. High degree of workability is required in deep beams, thin walls, column-beam junctions and in RMC's.
- Plasticizer helps in providing high workability even in difficult situations.
- Addition of extra water will only improve the fluidity but not workability.
- Addition of plasticizers will improve the plastic properties of concrete.
- It reduces the water-cement ratio for a given workability, which increases strength and durability.
- Used to reduce the cement content and heat of hydration in mass concreting.

Concrete Ingredients

Super plasticizers:-

- These are chemically different form normal plasticizers.
- Reduces water content up to 30% without reducing the workability.
- Used for producing self leveling, flowing, self compacting and high performance concrete.
- Can reduce w/c ratio for a given workability.
- Can reduce cement content for given w/c ratio.
- Provides homogenous cohesive concrete but no tendency of segregation and bleeding.

Concrete Ingredients

Super plasticizers:-

Commonly used as base for super plasticizer are

- Sulphonated Melanie – Formaldehyde condensates (SMF)
- Sulphonated Naphthalene – Formaldehyde condensates (SNF)
- Modified Ligno sulphonate (MLS)
- Poly Carboxylated Ether (PCE)

Concrete Ingredients

Retarders:-

- It is an admixture which slowdowns the hydration process and concrete remains plastic for long time.
- Use to overcome the accelerated effect of high temperature on setting in weather conditions.
- Calcium sulphates are the best retarding admixtures which retards setting of concrete
- Sometimes common sugar is also used to delay setting of concrete.

Concrete Ingredients

Retarding Plasticizers:-

- We know that plasticizers and super plasticizers show certain extent of retardation.
- Retarding plasticizers are mixed in RMC's for retaining slump loss in case of long distance transportation.
- When concrete is being placed or transported under conditions of high ambient temperature.
- In case of large concrete pours d) Concrete construction involving sliding formwork

Concrete Ingredients

Mode of action

- It is thought that retarding admixtures are absorbed on to the C3A phase in cement forming a film around the cement grains and presenting or reducing the reaction with water.
- After a while thus film breaks down and normal hydration proceeds.

Commonly used chemicals

- Unrefined lignosulphonates containing sugar
- Hydroxyl carboxylic acid and their salts
- Carbohydrates including sugar
- Soluble zinc
- Soluble borates etc.

Concrete Ingredients

Accelerators:-

- Added to increase the early strength development in concrete.
- Allows earlier removal of formwork
- Reduce required period of curing
- Used in emergency repair works

Commonly used chemicals are

- Calcium chlorides
- Sulphates
- Aluminates

- But $CaCl_2$ is not desirable for concrete because it leads to corrosion of reinforcement in RCC.

Concrete Ingredients

Accelerating Plasticizers:-

- When accelerated super plasticizers are added to the concrete, it increases the strength.
- Commonly used chemicals are

➢ Tri-ethanolamine chlorides

➢ Nitrates and fluorosilicates

Concrete Ingredients

Air entraining admixtures

- Mixing small quantity of air entraining agents will increases the voids or air bubbles in concrete which improves the plastic and hardened properties and have improved resistance against frost action and permeability.
- Air voids in concrete can be brought into two groups

➢ Entrapped air is due to insufficient compaction of concrete

➢ Entrained air is intentionally added and distributed uniformly.

- Some of the chemical air entraining agents are Natural wood resins, Animal and vegetable fats and oils

Concrete Ingredients

Mineral admixtures

Mineral admixtures are inorganic, finely grained materials having Pozzolanic properties added to the concrete mix in order to improve the properties of concrete.

Source of Mineral Admixtures

a) Raw or calcined natural minerals

b) Industrial by products

Classification of Mineral Admixture

ASIM specification C618 recognizes the following three classes of mineral admixtures.

a) Class N — Raw or calcined natural pozzolanic such as diatomaceous earths, clay and shales, tuffs and volcanic ashes.

b) Class F — Fly ash produced from burning anthracite or bituminous coal.

c) Class C — Ash normally produced from lignite or sub-bituminous coal which may contain analytical CaO higher than 10%.

Concrete Ingredients

Reasons for using mineral admixtures

a) In recent years' considerable efforts have been made by the cement industry world wide to reduce energy consumption in the manufacture of Portland cement. Therefore, a partial replacement of Portland cement by mineral admixtures which can be of the order of 50 – 60% by weight of total cementitious material, represents considerable energy savings.

b) The ability of cement and concrete industries to consume mithions of tons of industrial byproducts containing toxic metal would qualify these industries to be classified as environmentally friendly.

Reasons for using mineral admixtures

Since natural Pozzolana and industrial by products are generally available substantially lower costs than Portland cement, the exploitation of the Pozzolanic and cementitious properties of mineral admixtures are used as a partial replacement of cement can lead to a considerable economic benefit.

Possible technological benefits from the use of mineral admixtures in concrete include entrancement of impermeability and chemical durability, improved resistance to thermal cracking and increase in ultimate strength.

Concrete Ingredients

Types of Mineral admixtures

- Fly Ash
- GGBS
- Silica Fume
- Metakaolin
- Rice Husk Ash

Concrete Ingredients

Fly ash:-

- A by-product of coal fired electric generation plant, used for partially replacing cement up to 60% by mass.
- It is obtained by Electro static precipitator.
- It is produced in large quantity in India.
- In India, Fly ash is classified as Class F because it contains less calcium.
- It contributes strength and durability and enhances workability due to spherical nature.

Concrete Ingredients

Fly ash:-

- There are two types of Fly ash

➢ Low lime Fly ash → produces cementitious property because of lime or cement

➢ High lime fly ash → Exhibit cementitious property by itself

Applications:- Building blocks, Fine aggregate, Blending cements, geotechnical applications etc.

Component	Bituminous Coal	Sub bituminous Coal	Lignite Coal
SiO2 (%)	20-60	40-60	15-45
Al2O3 (%)	5-35	20-30	20-25
Fe2O3 (%)	10-40	4-10	4-15
CaO (%)	1-12	5-30	15-40
LOI (%)	0-15	0-3	0-5

Concrete Ingredients

Effects of Fly Ash on Fresh Concrete:

- Reduction of water demand for desired slump.
- With the reduction of unit water content, bleeding and drying shrinkage will also be reduced.

Effects of Fly Ash on Hardened Concrete:

- Contributes to the strength of concrete due to its pozzolanic reactivity.
- Continued pozzolanic reactivity concrete develops greater strength at later age not at initial stage.
- Resulting in decrease of water permeability

Concrete Ingredients

Ground Granulated Blast Furnace Slag (GGBFS/ GGBS):-

- It is a by-product of steel production
- Used to partially replace cement by 80% by mass.

Typical chemical composition

Calcium oxide:	40%
Silica:	35%
Alumina:	13%
Magnesia:	8%

Typical physical properties

Colour:	off-white
Specific gravity:	2.9
Bulk density:	1000 - 1100 kg/m^3 (loose) 1200 - 1300kg/m^3 (vibrated)
Fineness:	>350m^2/kg

Concrete Ingredients

Effects on fresh concrete:

- It reduces the unit water content necessary to obtain the same slump.
- Water used for mixing is not immediately lost, as the surface hydration of slag is slightly slower than that of cement.
- It reduction of bleeding.

Effects on hardened concrete:

- It Reduced heat of hydration.
- Refinement of pore structures greatly reduced permeability to the external agencies and increased resistance to chemical attack.

Concrete Ingredients

SILICA FUME:

- It is a product resulting from reduction of high purity quartz with coal in an electric arc furnace in the manufacture of silicon or ferrosilicon alloy.
- Contains at least 85% SiO_2 content with Mean particle size between 0.1 and 0.2 micron.
- Minimum specific surface area is 15,000 m^2/kg. Particle shape is Spherical.

Concrete Ingredients

Effect on fresh concrete:

- Fresh concrete sticky in nature and hard to handle.
- Causes large reduction in bleeding and concrete with micro silica could be handled and transported without segregation to plastic shrinkage cracking.

Effect on hardened concrete:

- Modulus of elasticity of micro silica concrete is less.
- It causes improvement in durability of concrete and Resistance against frost damage.

Concrete Ingredients

Application:

- Conserve cement
- Produce ultra high strength concrete of the order of 70 to 120 Mpa.
- Increase early strength of fly concrete.
- Control alkali-aggregate reaction.
- Reduce sulfate attack & chloride associated corrosion.

Concrete Ingredients

RICE HUSK ASH:

- Rice husk ash is obtained by Burning rice husk in a controlled manner.
- Material of future as mineral additives. It is added to 10% by weight of cement.
- It greatly enhances the workability and impermeability of concrete.
- It contains Amorphous silica (90% SiO_2) in very high proportion when burnt in controlled manner, 5% carbon, 2% K_2O.

Concrete Ingredients

Effects:

 It reduces susceptible to acid attack and improves resistance to chloride penetration and reduces large pores and porosity resulting very low permeability and free lime present in the cement paste.

 It Decreases the permeability of the system and Improves overall resistance to CO_2 attack Improves capillary suction and accelerated chloride diffusivity.

 It also Enhances resistance to corrosion of steel in concrete. Reducing micro cracking and improving freeze-thaw resistance.

METAKAOLIN:

Highly reactive Metakaolin is made by water processing to remove unreactive impurities to make 100% reactive pozzolanic Such a product, white or cream in color, purified, thermally activated is called High Reactive Metakaolin (HRM)

Concrete Ingredients

Effects of Metakaolin:

- High reactive Metakaolin shows high pozzolanic reactivity and reduction in Ca(OH)2 even as early as one day.
- The cement paste undergoes distinct densification.
- Densification includes an increase in strength and decrease in permeability.
- The high reactive Metakaolin is having the potential to compete with silica fume.

MODULE – 2

FRESH CONCRETE

Fresh Concrete

Introduction

The cement concrete is a mixture of cement, sand, pebbles or crushed stones and water. When this mixture is placed and allowed to cure, becomes hard like a stone.

Fresh Concrete

Introduction

- The potential strength and durability of concrete of a given mix proportion is very dependent on the degree of its compaction
- It is vital, therefore, that the consistency of the mix be such that the concrete can be transported, placed, and finished sufficiently early enough to attain the expected strength and durability.

Significance

- The first 48 hours are very important for the performance of the concrete structure.
- It controls the long-term behavior, influence f'c (ultimate strength), Ec (elastic modulus), creep, and durability.

Fresh Concrete

Properties of concrete

- Density : *2240 - 2400 kg/m^3*
- Compressive strength: *20 - 40 MPa*
- Flexural strength: *3 - 5 MPa*
- Tensile strength: *2 - 5 MPa*
- Modulus of elasticity : *14000 - 41000 MPa*
- Permeability: *1 X 10^{-10} cm/sec*
- Coefficient of thermal expansion: *10^{-5} ^{o}C*
- Drying shrinkage: *4 - 8 X 10^{-4}*
- Drying shrinkage of reinforced concrete: *2 - 3 X 10^{-4}*
- Poisson's ratio : *0.20 - 0.21*
- Shear strength : *6 - 17 MPa*
- Specific heat capacity : *0.75 kJ/kg K*

Fresh Concrete

Properties of good concrete

- It has high compressive strength.
- It is free from corrosion and less effected by atmospheric agents.
- It hardens with age and process of hardening continues for a long period of time after concrete has attained sufficient strength.
- It is proved to be more economical than steel. This is due to the fact that, the aggregates constitutes about 80 – 90% of volume of concrete and is available at reasonable rates.

Fresh Concrete

- It binds rapidly with steel and as it is weak in tension, the steel reinforcement is placed in cement concrete structure at suitable places to take up tensile stresses. This is termed as Reinforced Cement Concrete (RCC).
- Under the following two conditions, it has a tendency to shrink:

➢ There is an initial shrinkage of cement concrete which is mainly due to the loss of water through forms, absorption by surfaces of forms.

➢ The shrinkage of cement concrete occurs as it hardens. This tendency of cement concrete can be minimized by proper curing of concrete.

Fresh Concrete

- It has a tendency to be porous in nature. This is due to the presence of voids which are formed during and after its placing. The two precautions necessary to avoid this tendency are as follows:

➢ There should be proper grading and consolidation of aggregates.

➢ The minimum water-cement ratio should be adopted.

- It forms a hard surface and offers resistance to abrasion.

Fresh Concrete

Factors affecting Strength of concrete

- **Water-Cement ratio -** It is water cement ratio that basically governs the property of strength. Lesser the water cement ratio, greater will be strength
- **Type of cementing material –** It affects the hydration process and therefore strength of concrete.
- **Amount of cementing material -** It is the paste that holds or binds all the ingredients. Thus greater amount of cementing material greater will be strength.
- **Type of aggregate -** Rough and angular aggregates are preferable as they provide greater bonding

Fresh Concrete

Air content – The amount of air improves the concrete resistance on freezing and thawing. But in excess lead to failure

Admixtures - Chemical admixtures like plasticizers reduce the water cement ratio and increase the strength of concrete at same water cement ratio. Mineral admixtures affect the strength at later stage and increase the strength by increasing the amount of cementing material.

- Once the mixing was completed the mixture is said to be Fresh concrete which is in plastic state and can be moulded in any forms whereas the Hardened concrete is the one which is fully cured

Fresh Concrete

For fresh concrete to be acceptable, it should:

1. Be easily mixed and transported.

2. Be uniform throughout a given batch and between batches.

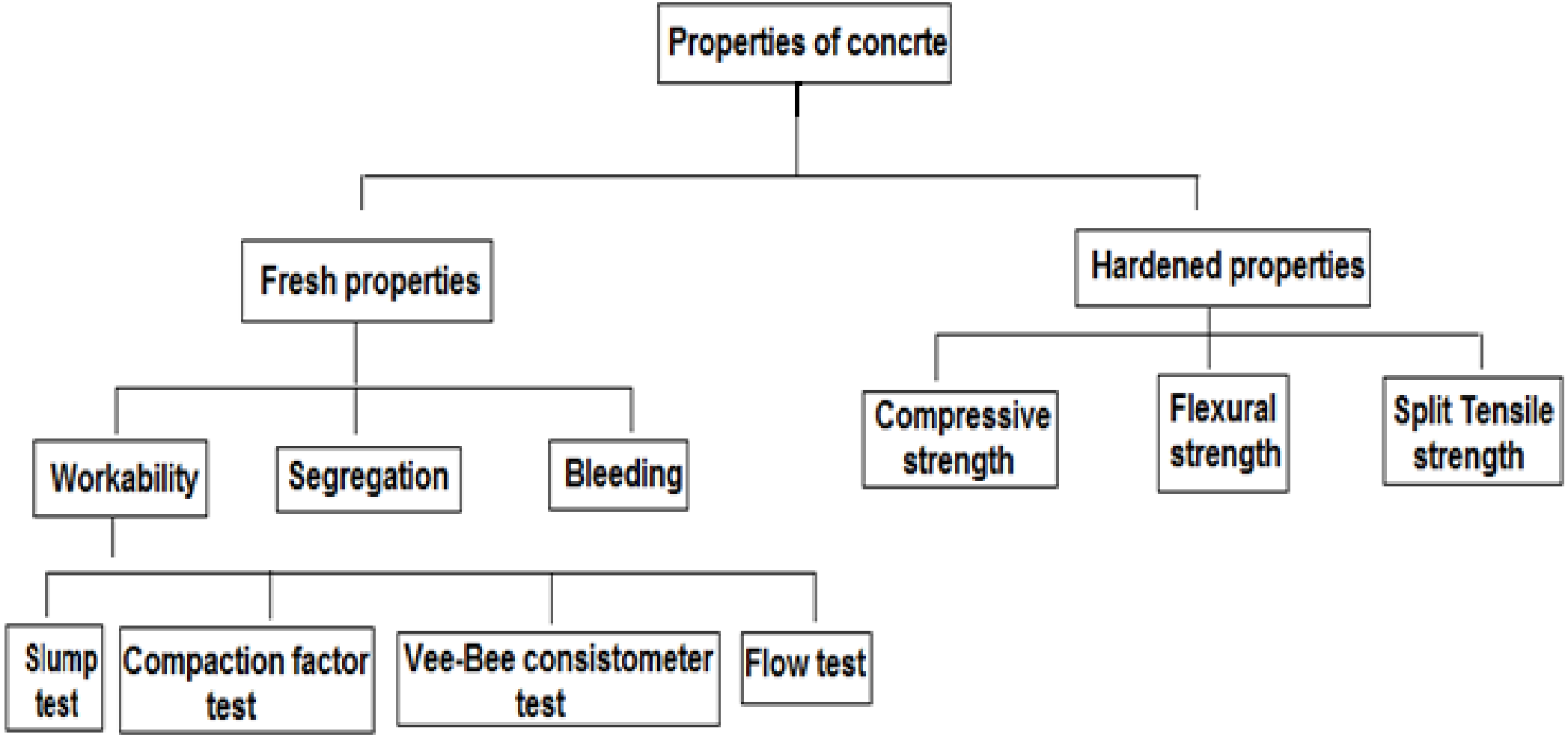
3. Be of a consistency so that it can fill completely the forms for which it was designed.

4. Have the ability to be compacted without excessive loss of energy.

5. Not segregate during placing and consolidation.

6. Have good finishing characteristics.

Fresh Concrete



Fresh Concrete

Workability

- The property of concrete determines the amount of internal work required to produce full compaction.

Or

- It is the ease with which the concrete can be compacted 100% and can be deposited / transported or placed in required position.
- In general; easy to mix, easy to handle and easy to place is referred as workability of concrete

Factors affecting workability

1. Water content:

- The water content in a given volume of concrete will have significant influence on workability of concrete.
- Higher the water content per cubic meter of concrete, higher will be the fluidity.
- It should be noted that from the desirable point of view, increase in water content will be the last resource for improving the workability in case of uncontrolled concrete.
- But for controlled concrete we cannot increase the water content.
- If we want to increase the water content, simultaneously we have to increase the cement in order to maintain water-cement ratio as constant and strength of the concrete remains same.

Factors affecting workability

2. Mix proportion:

- Aggregate to cement ratio is an important ratio influencing workability.
- Higher the aggregate to cement ratio, leaner will be the concrete mix.
- In case of lean concrete less quantity of paste is available for lubricating the surface.
- Hence there is chance of mobility of aggregates.
- On the other hand in case of rich mix with lower aggregate to cement ratio, more paste is available to make the mix cohesive and also gives better workability.

Fresh Concrete

Factors affecting workability

Size of aggregate:

- Bigger the size of particles less will be the surface area and hence less amount of water is required and also less cement paste required for lubricating the surfaces of aggregates.
- So bigger the size, gives higher workability.

Fresh Concrete

Factors affecting workability

Shape of aggregate:

- Angular, elongated or flaky aggregates make the concrete very harsh when compared to rounded or cubical aggregates.
- Contribution to better workability of rounded aggregate will come from the fact that for a given volume or weight.
- It will have a less surface area and lesser voids.
- Not only is that being in rounded in shape, the frictional resistance between the aggregates also reduced.
- Hence the workability will be more in case of rounded than compared to flaky aggregates.
- Hence the strength will be more by using rounded or cubical aggregates.

Fresh Concrete

Factors affecting workability

Surface texture:

- The influence of surface texture on the workability is due to the fact that, total surface area of rough texture aggregate is more than that of surface area of smooth rounded aggregates of same volume.
- Rough textured aggregates will show poor workability and smooth textured aggregates will give better workability because of lesser frictional resistance of inner surface particle.

Fresh Concrete

Factors affecting workability

Grading of aggregates:

- This is one of the factor will have maximum influence on workability.
- A well graded aggregate will give least amount of voids for given volume of aggregates.
- When the voids are less, excess paste will be available to give better workability.
- Better the grading, lesser will be the voids and greater will be the workability.

Use of admixtures:

- Like plasticizers and super plasticizers greatly improves the workability of concrete.

Fresh Concrete

How To improve the workability of concrete

- increase water/cement ratio
- increase size of aggregate
- use well-rounded and smooth aggregate instead of irregular shape
- increase the mixing time
- increase the mixing temperature
- use non-porous and saturated aggregate
- with addition of air-entraining mixtures

Fresh Concrete

Measurement of Workability

The following tests are commonly employed to measure workability.

- Slump Test
- Compacting Factor Test
- Vee-Bee Consistometer Test
- Flow Test

Fresh Concrete

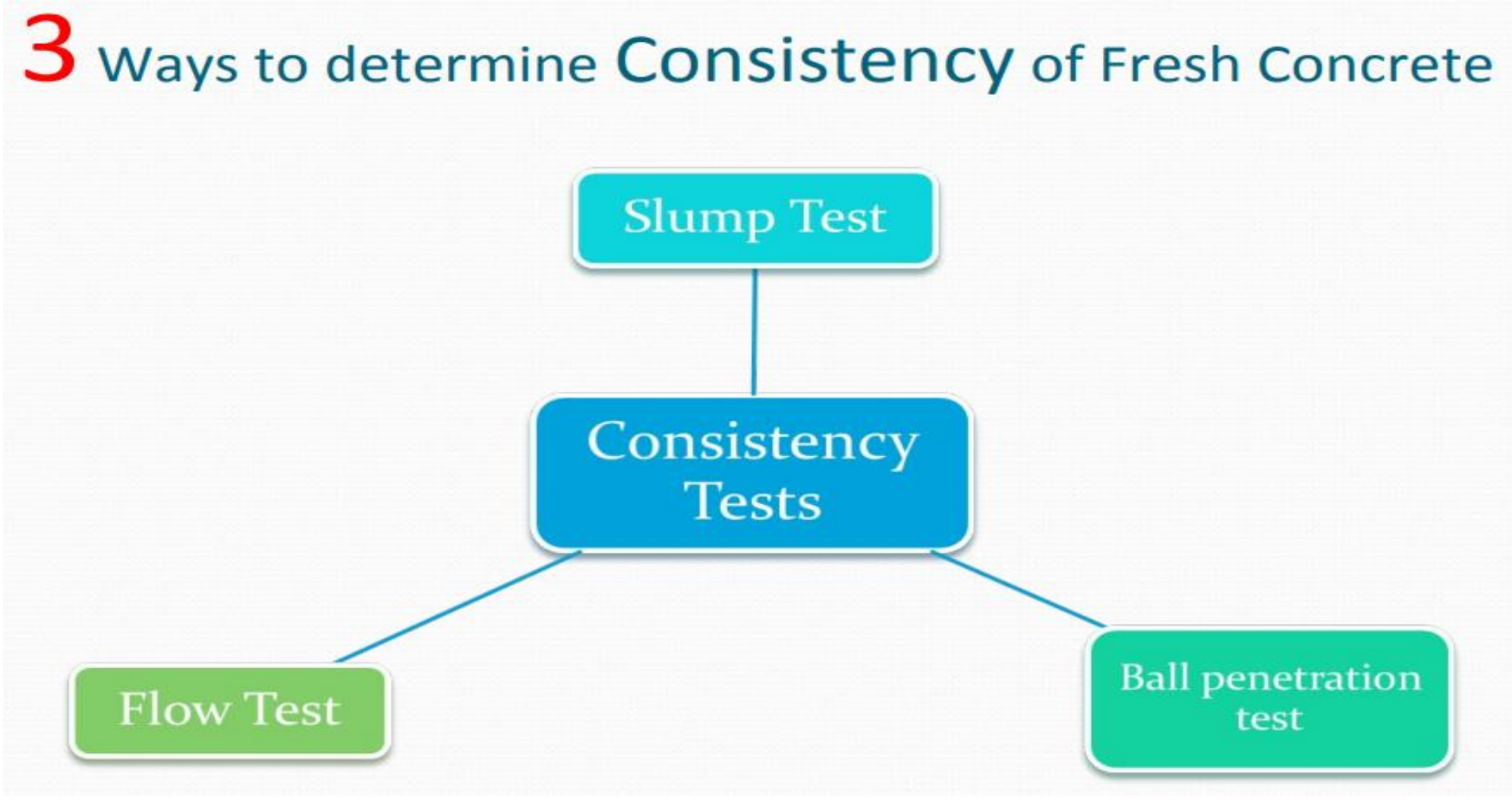
Concrete Consistency

- Consistency or fluidity of concrete is an important component of workability and refers in a way to the wetness of the concrete.
- Wetter the mix the more workable it is. If a mix is too wet, segregation may occur with resulting honeycomb, excessive bleeding, and sand streaking on the formed surfaces

Consistency of concrete

On the other hand, if a mix is too dry it may be difficult to place and compact, and segregation may occur because of lack of cohesiveness and plasticity of the paste.

Fresh Concrete



Fresh Concrete

Slump Test

- A slump test is a method used to determine the consistency of concrete.
- The consistency, or stiffness, indicates how much water has been used in the mix.
- The stiffness of the concrete mix should be matched to the requirements for the finished product quality

➢ Slump is a measurement of concrete's workability, or fluidity.

➢ It's an indirect measurement of concrete consistency or stiffness.

Principle

- The slump test result is a measure of the behavior of a compacted inverted cone of concrete under the action of gravity. It measures the consistency or the wetness of concrete

Fresh Concrete

Tools and apparatus used for slump test (equipment):

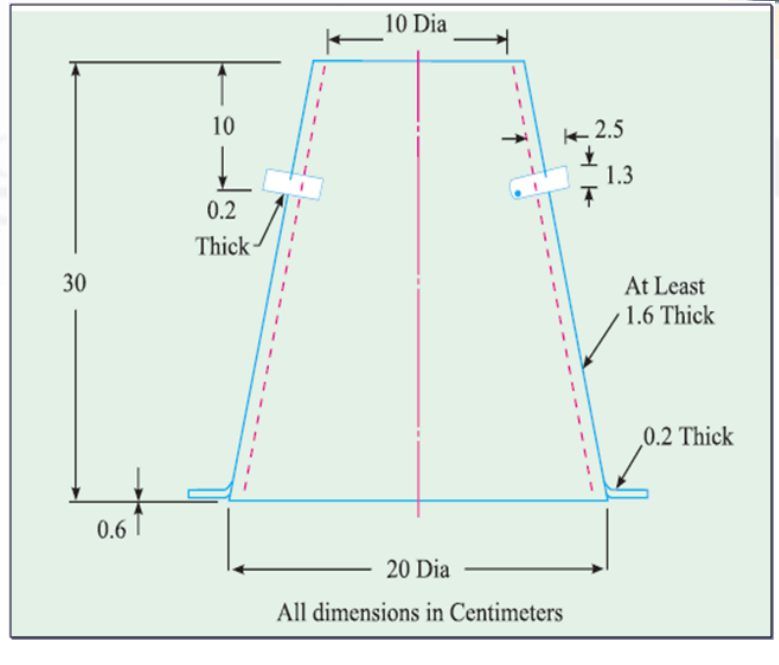
1. Standard slump cone (100 mm top diameter x 200 mm bottom diameter x 300 mm high)

2. Small scoop

3. Bullet-nosed rod (600 mm long x 16 mm diameter)

4. Rule

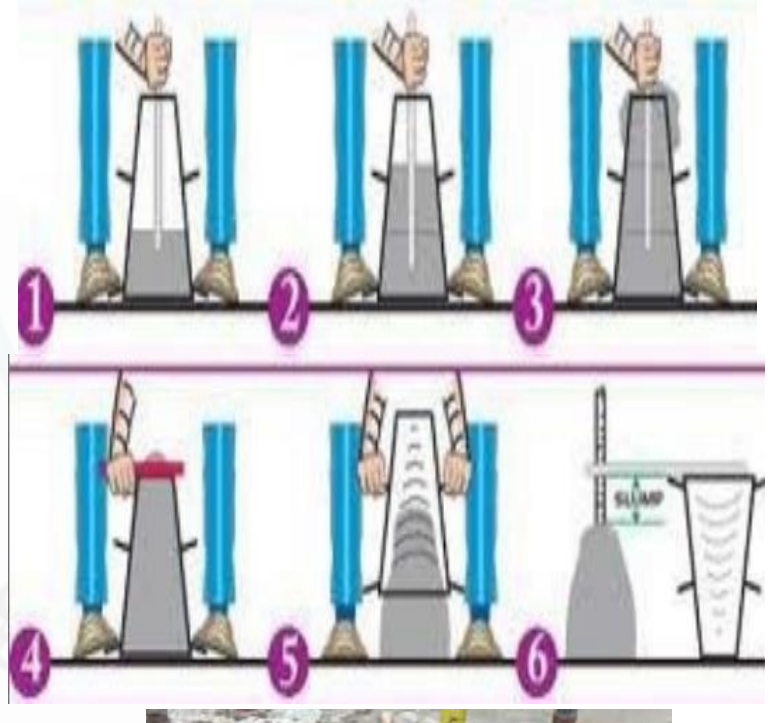
5. Slump plate (500 mm x 500 mm)



Fresh Concrete

Procedure

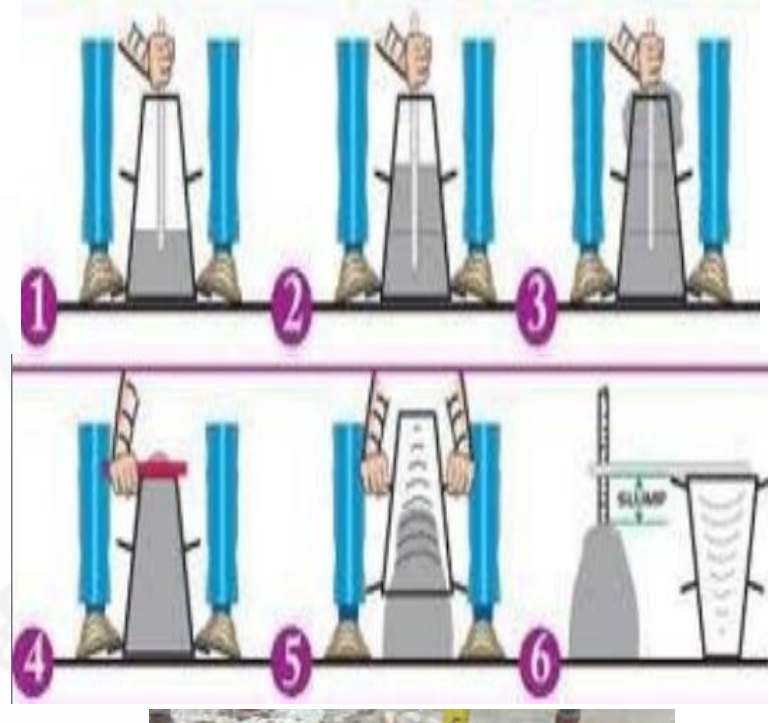
- The base is placed on a smooth surface and the container is filled with concrete in three layers, whose workability is to be tested .
- Each layer is temped 25 times with a standard 16 mm (5/8 in) diameter steel rod, rounded at the end.
- When the mold is completely filled with concrete, the top surface is struck off (leveled with mold top opening) by means of screening and rolling motion of the temping rod.
- The mold must be firmly held against its base during the entire operation so that it could not move due to the pouring of concrete and this can be done by means of handles or foot – rests brazed to the mold.



Fresh Concrete

Procedure

- Immediately after filling is completed and the concrete is leveled, the cone is slowly and carefully lifted vertically, an unsupported concrete will now slump.
- The decrease in the height of the center of the slumped concrete is called slump.
- The slump is measured by placing the cone just besides the slump concrete and the temping rod is placed over the cone so that it should also come over the area of slumped concrete.
- The decrease in height of concrete to that of mould is noted with scale. (usually measured to the nearest 5 mm (1/4 in).



Fresh Concrete

Precautions

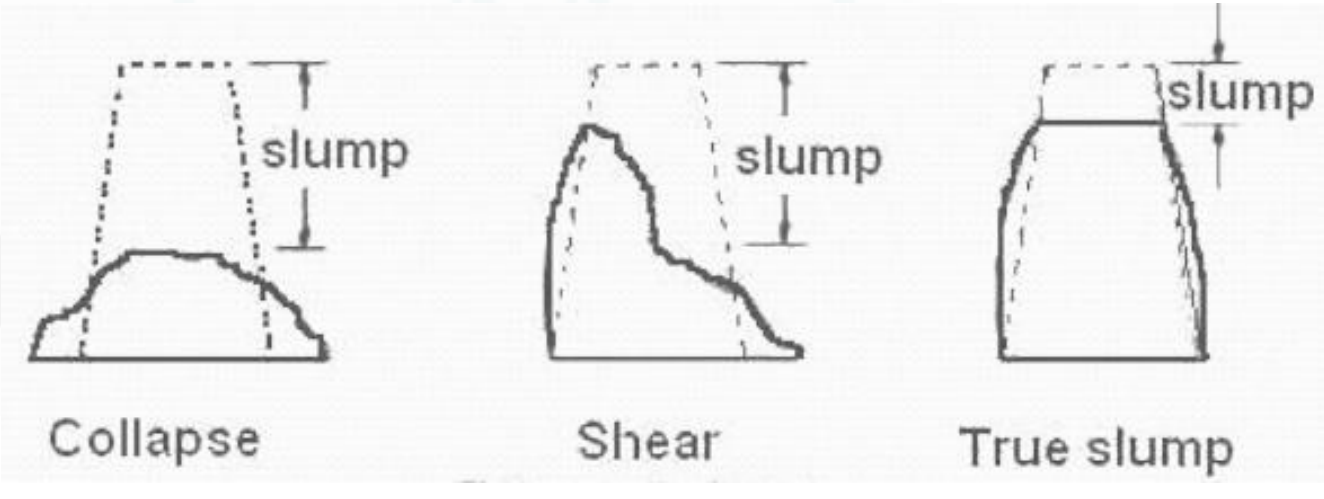
- In order to reduce the influence on slump of the variation in the surface friction, the inside of the mold and its base should be moistened at the beginning of every test, and prior to lifting of the mold the area immediately around the base of the cone should be cleaned from concrete which may have dropped accidentally.

Fresh Concrete

Types Of Slump

The slumped concrete takes various shapes, and according to the profile of slumped concrete, the slump is termed as;

- Collapse Slump
- Shear Slump
- True Slump



Fresh Concrete

Types of slump

Collapse Slump

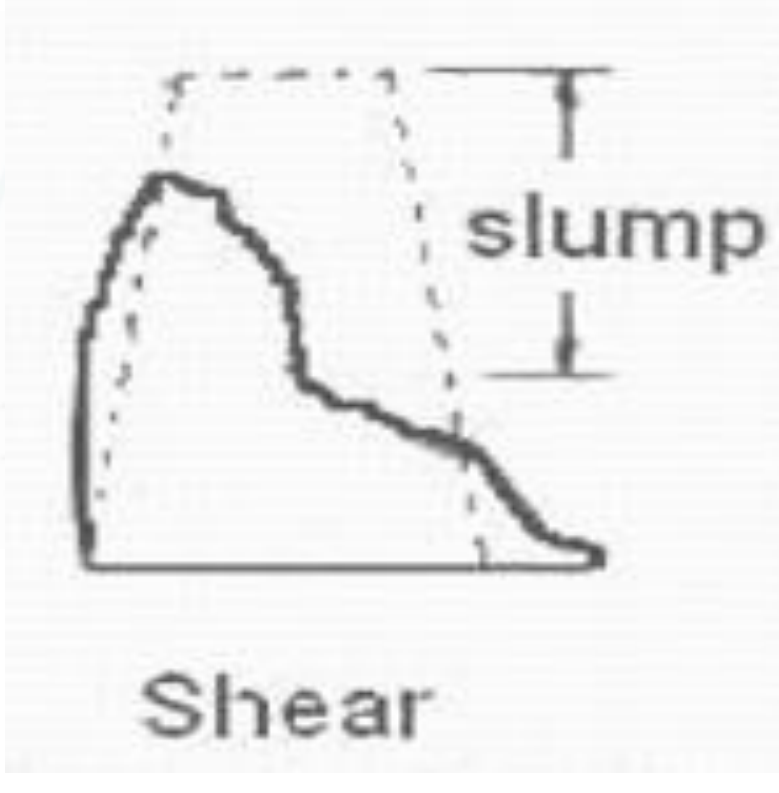
- In a collapse slump the concrete collapses completely.
- A collapse slump will generally mean that the mix is too wet or that it is a high workability mix, for which slump test is not appropriate.

Fresh Concrete

Types of slump

Shear Slump

- In a shear slump the top portion of the concrete shears off and slips sideways. OR If one-half of the cone slides down an inclined plane, the slump is said to be a shear slump.
- If a shear or collapse slump is achieved, a fresh sample should be taken and the test is repeated.
- If the shear slump persists, as may the case with harsh mixes, this is an indication of lack of cohesion of the mix.



Fresh Concrete

Types of slump

True Slump

- In a true slump the concrete simply subsides, keeping more or less to shape
- This is the only slump which is used in various tests.
- Mixes of stiff consistence have a Zero slump, so that in the rather dry range no variation can be detected between mixes of different workability.

Fresh Concrete

Uses

- The slump test is used to ensure uniformity for different batches of similar concrete under field conditions and to ascertain the effects of plasticizers on their introduction.
- This test is very useful on site as a check on the day-to-day or hour- to-hour variation in the materials being fed into the mixer.
- An increase in slump may mean, for instance, that the moisture content of aggregate has unexpectedly increases.
- Other cause would be a change in the grading of the aggregate, such as a deficiency of sand.
- Too high or too low a slump gives immediate warning and enables the mixer operator to remedy the situation.
- This application of slump test as well as its simplicity, is responsible for its widespread use.

Slump Test

Degree of workability	Slump (mm)	Compacting Factor	Use for which concrete is suitable
Very low	0 - 25	0.78	Very dry mixes; used in road making. Roads vibrated by power operated machines
Low	25 - 50	0.85	Low workability mixes; used for foundations with light reinforcement. Roads vibrated by hand operated Machines
Medium	50 - 100	0.92	Medium workability mixes; manually compacted flat slabs using crushed aggregates. Normal reinforced concrete manually compacted and heavily reinforced sections with vibrations
High	100 - 175	0.95	High workability concrete; for sections with congested reinforcement. Not normally suitable for vibration

Slump Test

Slump (mm)	0 - 20	20 - 40	40 - 120	120 - 200	200 - 220
Consistency	Dry	Stiff	Plastic	Wet	Sloppy

Fresh Concrete

Compaction Factor Test

- This test measure the degree of compaction.
- The test require measurement of the weight of the partially and fully compacted concrete and the ratio the partially compacted weight to the fully compacted weight, which is always less than one, is known as compacted factor .
- For the normal range of concrete the compacting factor lies between 0.8 - 0.92

Fresh Concrete

Compaction Factor Test

Apparatus

- Trowels
- Hand Scoop (15.2 cm long)
- Rod of steel or other suitable material (1.6 cm diameter, 61 cm long rounded at one end).
- Balance.

Fresh Concrete

Procedure

1) Ensure the apparatus and associated equipment are clean before test and free from hardened concrete and superfluous water .
2) Weigh the bottom cylinder to nearest 10gm , put it back on the stand and cover it up with a pair of floats .
3) Gently fill the upper hopper with the sampled concrete to the level of the rim with use of a scoop .
4) Immediately open the trap door of the upper hopper and allow the sampled concrete to fall into the middle hopper .
5) Remove the floats on top of the bottom cylinder and open the trap door of the middle hopper allowing the sampled concrete to fall into the bottom cylinder .
6) Remove the surplus concrete above the top of the bottom cylinder by holding a float in each hand and move towards each other to cut off the concrete across the top of cylinder

Fresh Concrete

Procedure

1) Wipe clean the outside of cylinder of concrete and weigh to nearest 10gm .
2) Subtract the weight of empty cylinder from the weight of cylinder plus concrete to obtain the weight of partially compacted concrete
3) Remove the concrete from the cylinder and refill with sampled concrete in layers .
4) Compact each layer thoroughly with the standard Compacting Bar to achieve full compaction .
5) Float off the surplus concrete to top of cylinder and wipe it clean .
6) Weigh the cylinder to nearest 10gm and subtract the weight of empty cylinder from the weight of cylinder plus concrete to obtain the weight of fully compacted concrete

$$\text{The Compacting Factor } (CF) = \frac{\text{weight of partially compacted concrete}}{\text{weight of fully compacted concrete}}$$

Workability	Slump (mm)	C.F	Uses
Very Low	0 - 25	0.78	Roads - Pavements
Low	25 - 50	0.85	Foundations Concrete
Medium	25 - 100	0.92	Reinforced Concrete
High	100 - 175	0.95	Reinforced Concrete (High Reinforcement)

Fresh Concrete

Vee-Be Time Test

It is based on measuring the time (Called VEBE time) needed to transfer the shape of a concrete mix from a frustum cone to a cylinder (these shapes are standardized by the apparatus of this test), by vibrating and compacting the mix. The more VEBE time needed the less workable the mix is. This method is very useful for stiff mixes.

Fresh Concrete

Vee-Be Time Test

Apparatus

- Cylindrical container with diameter = 240 mm, and height = 200 mm
- Mould: the same mould used in the slump test.
- Disc : A transparent horizontal disc attached to a rod which slides vertically
- Vibrating Table : 380*260 mm, supported by four rubber shock absorbers
- Tamping Rod
- Stop watch

Fresh Concrete

Procedure

- Slump test as described earlier is performed, placing the slump cone inside the sheet metal cylindrical pot of the consist meter.
- The glass disc attached to the swivel arm is turn and place on the top of the concrete in the pot.
- The electrical vibrator is then switched on and simultaneously a stop watch started.
- The vibration is continued till such time as the conical shape of the concrete disappears and the concrete assume a cylindrical shape.
- This can be judge by observing the glass disc from the top disappearance of transparency.
- Immediately when the concrete fully assume a cylindrical shape, the stop watch is switched off

Fresh Concrete

- The time required for the shape of concrete to change from slump cone shape to cylindrical shape in second is known as Vibe Degree.
- This method is very suitable for very dry concrete whose slump value cannot be measure by slump test, but the vibration is too vigorous for concrete with slump greater than about 50m.
- The test fails if Vee-Be Time is less than 5 seconds .. And the test must be repeated when no collapse or shears slump in concrete

Fresh Concrete

Flow Test

The flow table test or flow test is a method to determine the consistence of fresh concrete.

Application

- When fresh concrete is delivered to a site by a truck mixer it is sometimes necessary to check its consistence before pouring it into formwork.
- If the consistence is not correct, the concrete will not have the desired qualities once it has set, particularly the desired strength. If the concrete is too pasty, it may result in cavities within the concrete which leads to corrosion of the rebar, eventually leading to the formation of cracks (as the rebar expands as it corrodes) which will accelerate the whole process, rather like insufficient concrete cover.
- Cavities will also lower the stress the concrete is able to support.

Fresh Concrete

Flow Test

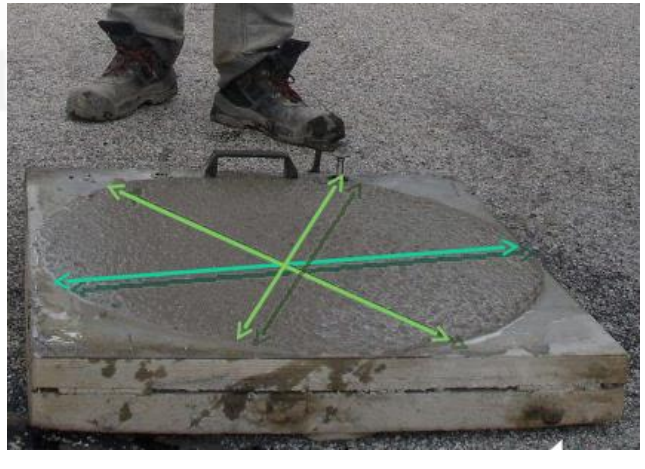
Equipment

- Flow table with a grip and a hinge, 70 cm x 70 cm.
- Abrams cone, open at the top and at the bottom - 30 cm high, 17 cm top diameter, 25 cm base diameter
- Water bucket and broom for wetting the flow table.
- Tamping rod, 60 cm height
- Scale for measurement

Fresh Concrete

Procedure

- The flow table is wetted.
- The cone is placed on the flow table and filled with fresh concrete in two layers, each layer 25 times tamp with tamping rod.
- The cone is lifted, allowing the concrete to flow.
- The flow table is then lifted up about 12.5mm and then dropped for 15 times in 15 seconds, causing the concrete flow a little bit further.
- After this the diameter of the concrete is measured in a 6 different direction and take the average.



Flow Test

$$\textbf{Flow \%} = \frac{Diameter\ of\ flow\ (cm) - 25}{25} \times 100$$

Percent of Flow	0 – 20 %	20 – 60 %	60 – 100 %	100 – 120 %	120 – 150 %
Consistency	Dry	Stiff	Plastic	Wet	Sloppy

Segregation

Segregation is when the coarse and fine aggregate, and cement paste, become separated. Segregation may happen when the concrete is mixed, transported, placed or compacted

Segregation makes the concrete

- Weaker,
- Less durable,
- and will leave a poor surface finish

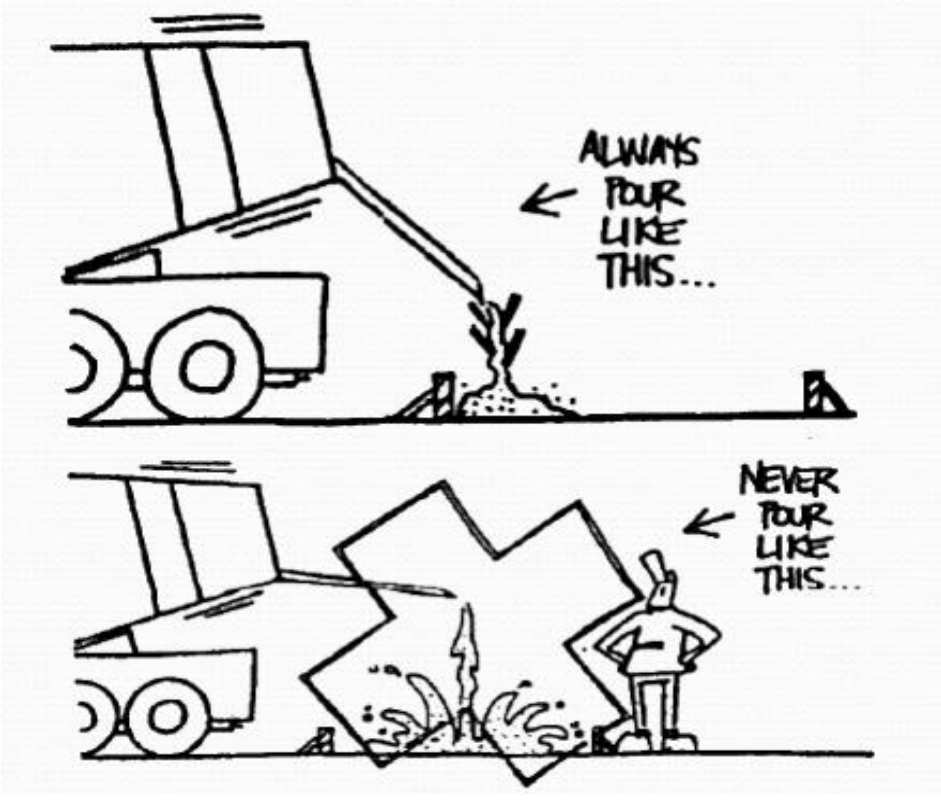
Segregation

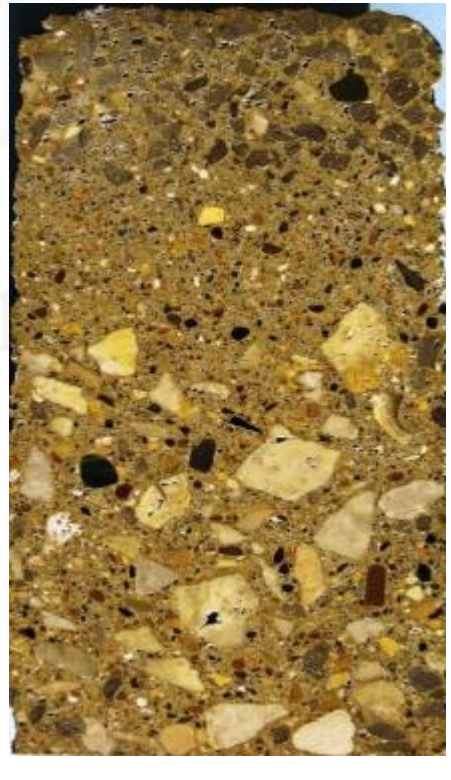
Segregation may be of three types

- firstly, the coarse aggregate separating out or settling down from the rest of the mixing
- Secondly, the paste or matrix separating away from coarse aggregate and
- thirdly, water separating out from the rest of the material being a material of lowest specific gravity.

To Avoid Segregation

- If placing concrete straight from a truck, pour vertically and never let the concrete fall more than one-and-a-half meters.





Fresh Concrete

Concrete Bleeding

- This refers to the appearance of water along with cement particles on the surface of the freshly laid concrete.
- This happens when there is excessive quantity of water in the mix or due to excessive compaction.
- Bleeding causes the formation of pores and renders the concrete weak.
- Bleeding can be avoided by suitably controlling the quantity of water in the concrete and using finer grading of aggregates.

Fresh Concrete

The effects of water gain:

- The water gain which causes voids and reduces the bond between the cement and aggregates.
- Water gain below the reinforcement especially at cranked portion reduces the bond between reinforcement and concrete.
- Water while traversing from bottom to top make a channel and if water-cement ratio greater than 0.7 is used, channel becomes continuous and responsible for permeability of concrete.

Fresh Concrete

Water gain can be avoided by

1. Proper mix proportion

2. Proper mixing

3. By using finely divided pozzolanic material

4. By using finer cement or cement with less alkali content

5. By re-vibration of concrete

6. By using air entraining agents

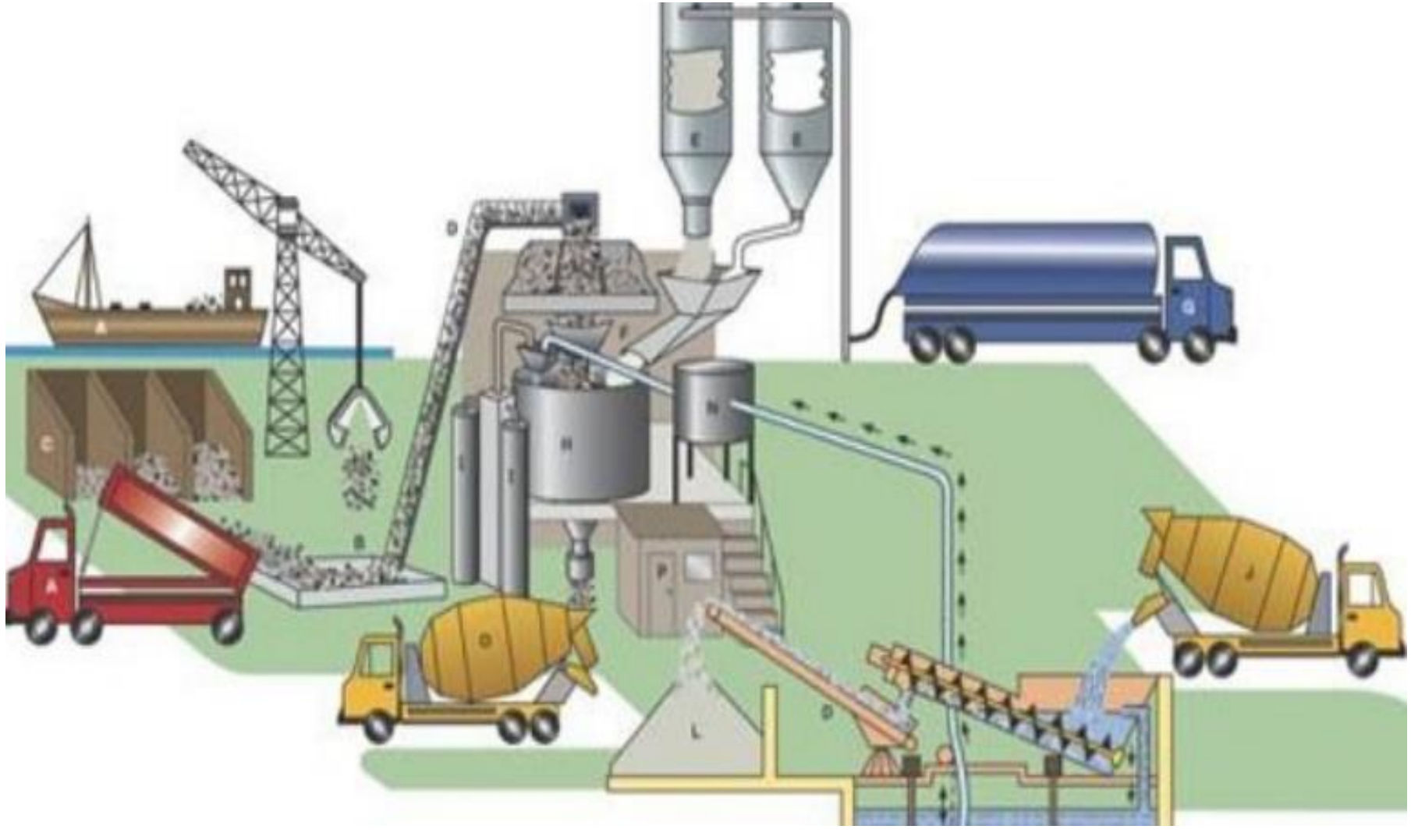
Fresh Concrete

Process of Manufacture of Concrete

- It is interesting to note that the ingredients of good concrete and bad concrete are the same.
- If meticulous care is not exercised, and good rules are not observed, the resultant concrete is going to be of bad quality.
- With the same material if intense care is taken to exercise control at every stage, it will result in good concrete.

Good Concrete

Bad Concrete



Fresh Concrete

Process of Manufacture of Concrete

The various stages of manufacture of concrete are:

(a) Batching

(b) Mixing

(c) Transporting

(d) Placing

(e) Compacting

(f) Curing

(g) Finishing

Fresh Concrete

Batching

The measurement of materials for making concrete is known as batching. There are two methods of batching:

- Volume batching
- Weigh batching

Fresh Concrete

Batching

Volume Batching:

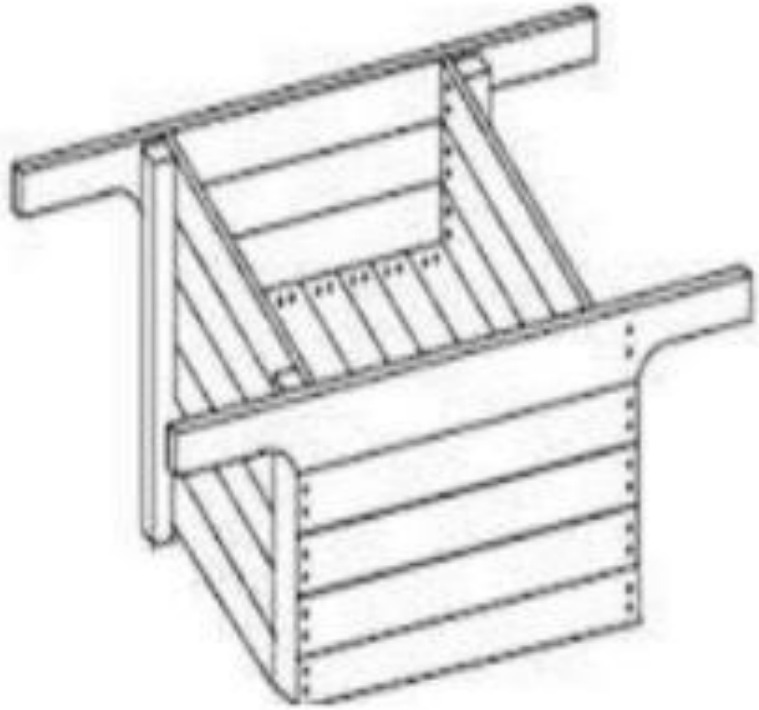
• Volume batching is not a good method for proportioning the material because of the difficulty it offers to measure granular material in terms of volume.

•Volume of moist sand in a loose condition weighs much less than the same volume of dry compacted sand.

•The effect of bulking should be consider for moist fine aggregate.

•For unimportant concrete or for any small job, concrete may be batched by volume.

Volume Batchers (Farma)



Fresh Concrete

Batching

Weigh Batching:

•Weigh batching is the correct method of measuring the materials.

•Use of weight system in batching, facilitates, accuracy, flexibility and simplicity.

•Large weigh batching plants have automatic weighing equipment.

•On large work sites, the weigh bucket type of weighing equipment's are used.

ATME

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Fresh Concrete

Batching

- Cement is always measured by weight.
- It is never measured in volume.
- Generally, for each batch mix, one bag of cement is used.
- The volume of one bag of cement (50kgs) is taken as thirty five (35) liters.

Measurement of water:

- when weigh batching is adopted, the measurement of water must be done accurately.
- Addition of water by graduated bucket in terms of liters will not be accurate for the reason of spillage of water.
- It is usual to have water measured in a horizontal or vertical tank
- These tanks are filled up often every batch.

Fresh Concrete

Mixing

- Thorough mixing of the materials production of uniform concrete.
- The mixing should ensure that is essential for the mass becomes homogeneous, uniform in colour and consistency.
- There are two methods adopted for mixing concrete:

(i) Hand mixing (ii)Machine mixing

Fresh Concrete

Mixing

Hand mixing

- Hand mixing is practiced for small scale unimportant concrete works.
- As the mixing cannot be thorough and efficient, it is desirable to add 10 per cent more cement to cater for the inferior concrete produced by this method.
- Hand mixing should be done over an impervious concrete or brick floor of sufficiently large size to take one bag of cement.
- Spread out the measured quantity of coarse aggregate and fine aggregate in alternate layers.

Fresh Concrete

Mixing

Hand mixing

- Pour the cement on the top of it, and mix them dry by shovel, turning the mixture over and over again until uniformity of colour is achieved.
- Water is taken in a water-can fitted with a rose-head and sprinkled over the mixture and simultaneously turned over.
- This operation is continued till such time a good uniform, homogeneous concrete is obtained.

Fresh Concrete

Mixing

Machine Mixing

- Mixing of concrete is almost invariably carried out by machine, for reinforced concrete work and for medium or large scale mass concrete work.
- Machine mixing is not only efficient, but also economical, when the quantity of concrete to be produced is large.
- They can be classified as batch-mixers and continuous mixers.
- Batch mixers produce concrete, batch by batch with time interval, whereas continuous mixers produce concrete continuously without stoppage till such time the plant is working.

Fresh Concrete

Mixing

Machine Mixing

- In normal concrete work, it is the batch mixers that are used. Batch mixer may be of pan type or drum type.
- The drum type may be further classified as tilting, non-tilting, reversing or forced action type.
- As per I.S. 1791–1985, concrete mixers are designated by a number representing its nominal mixed batch capacity in litres.

The following are the standardized sizes of three types:

- a. Tilting: 85 T, 100 T, 140 T, 200 T
- b. Non-Tilting: 200 NT, 280 NT, 375 NT, 500 NT, 1000 NT
- c. Reversing: 200 R, 280 R, 375 R, 500 R and 1000 R

Fresh Concrete

Mixing

How do we mix concrete in a mixer?

- Firstly about half the quantity of coarse aggregate is placed into the mixer.
- Over this about half quantity of fine aggregate is poured.
- On this mixture, 1 bag of cement is poured and over this remaining half quantity of coarse and fine aggregates is placed. This prevents the blowing away of cement in windy weather.
- Before the loading skip is placed into the drum, about 25% of water is added to the drum in order to avoid the sticking of cement to the surface / deposition at the bottom. After loading skip is placed, remaining 75% of water is added. If the mixer is having an independent feeding of water, it is desirable that remaining 75% of water is added simultaneously along with the loading skip.

Fresh Concrete

- **Mixing Time:**
- Concrete mixers are generally designed to run at a speed of 15 to 20 revolutions per minute.
- For proper mixing, it is seen that about 25 to 30 revolutions are required in a well designed mixer.
- In the site, the normal tendency is to speed up the outturn of concrete by reducing the mixing time. This results in poor quality of concrete.
- On the other hand, if the concrete is mixed for a comparatively longer time, it is uneconomical from the point of view of rate of production of concrete and fuel consumption.
- Therefore, it is of importance to mix the concrete for such a duration which will accrue optimum benefit.

Fresh Concrete

Transporting of Concrete:

- Concrete can be transported by a variety of methods and equipment's. The precaution to be taken while transporting concrete is that the homogeneity obtained at the time of mixing should be maintained while being transported to the final place of deposition.

- Mortar Pan
- Wheel Barrow, Hand Cart,
- Crane, Bucket and Rope way ,
- Truck Mixer and Dumpers,
- Chute,
- Skip and Hoist ,
- Tansit Mixer,
- Pump and Pipe Line,
- Helicoptor

Fresh Concrete

Transporting of Concrete:

Mortar Pan

- Use of mortar pan for transportation of concrete is one of the common methods adopted in this country.
- In this case, concrete is carried in small quantities.
- While this method nullifies the segregation to some extent, particularly in thick members Greater loss of water, particularly, in hot weather concreting

Fresh Concrete

Transporting of Concrete:

Wheel Barrows

- Wheel barrows are normally used for transporting concrete to be placed at ground level.
- This method is employed for hauling concrete for comparatively longer distance as in the case of concrete road construction.
- If concrete is conveyed by wheel barrow over a long distance, on rough ground, it is likely that the concrete gets segregated due to vibration

Fresh Concrete

Transporting of Concrete:

Crane, Bucket and Rope way

- A crane and bucket is one of the right equipment for transporting concrete above ground level.
- Crane can handle concrete in high rise construction projects and are becoming a familiar sites in big cities.
- Cranes are fast and versatile to move concrete horizontally as well as vertically along the boom and allows the placement of concrete at the exact point.
- Cranes carry skips or buckets containing concrete. Skips have discharge door at the bottom, whereas buckets are tilted for emptying.
- For a medium scale job the bucket capacity may be 0.5 m^3 .

Fresh Concrete

Transporting of Concrete:

Truck Mixer and Dumpers

- For large concrete works particularly for concrete to be placed at ground level, trucks and dumpers or ordinary open steel-body tipping lorries can be used.
- As they can travel to any part of the work, they have much advantage over the jubilee wagons, which require rail tracks.
- Dumpers are of usually 2 to 3 cubic metre capacity, whereas the capacity of truck may be 4 cubic metre or more

Fresh Concrete

Transporting of Concrete:

Belt Conveyors

- Belt conveyors have very limited applications in concrete construction.
- The principal objection is the tendency of the concrete to segregate on steep inclines, at transfer points or change of direction, and at the points where the belt passes over the rollers.
- Conveyors can place large volumes of concrete quickly where access is limited

Fresh Concrete

Transporting of Concrete:

Chute

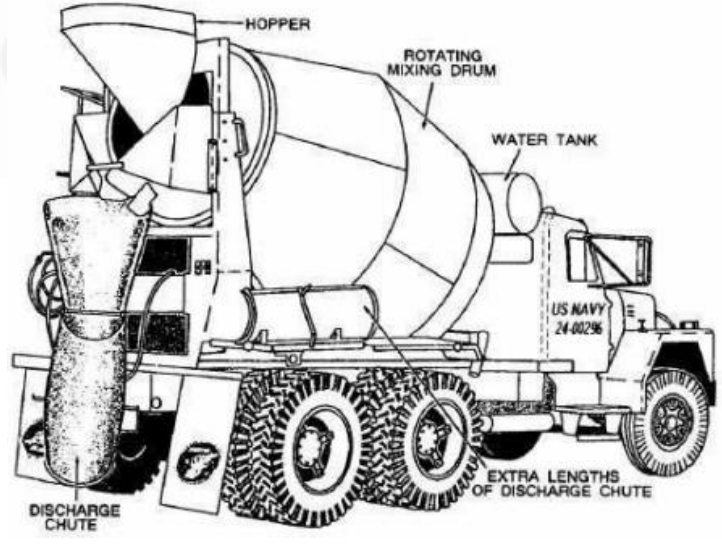
- Chutes are generally provided for transporting concrete from ground level to a lower level.
- The sections of chute should be made of or lined with metal and all runs shall have approximately the same slope, not flatter than 1 vertical to 2 1/2 horizontal.
- The lay-out is made in such a way that the concrete will slide evenly in a compact mass without any separation or segregation

Fresh Concrete

Transporting of Concrete:

Transit Mixer

- Transit mixer is one of the most popular equipment's for transporting concrete over a long distance particularly in Ready Mixed Concrete plant (RMC).
- In India, today (2000 AD) there are about 35 RMC plants and a number of central batching plants are working. They are truck mounted having a capacity of 4 to 7 m3 .
- In one, mixed concrete is transported to the site by keeping it agitated all along at a speed varying between 2 to 6 revolutions per minute.
- In the other category, the concrete is batched at the central batching plant and mixing is done in the truck mixer either in transit or immediately prior to discharging the concrete at site.



Fresh Concrete

Transporting of Concrete:

Pipelines & coupling

- Generally almost all pumped concrete is conveyed 125 mm pipeline.
- General rule is that the pipe diameter should be between 3 to 4 times the largest size of aggregate.
- Concrete has been pumped to a height 400m and to a distance of 2000m

Fresh Concrete

Pumpable Concrete

- A concrete which can be pushed through a pipeline is called a pumpable concrete.
- It is made in such a manner that its friction at the inner wall of the pipeline does not become very high and that it does not wedge while flowing through the pipeline.
- Pumpable concrete emerging from a pipeline flows in the form of a plug which is separated from the pipe wall by a thin lubricating layer consisting of cement paste.
- For continuous plug movement, the pressure generated by the flow resistance must not be greater than the pump pressure rating.

Fresh Concrete

Placing of Concrete

- It is not enough that the concrete is properly mixed, correctly batched and transported, but also it has to be placed in a sequential manner to obtain better results.
- Placing concrete within earth mould (example foundation concrete for wall or a column)
- Placing concrete within large earth mould or timber plank formwork (example: Road slab and Airfield slab).
- Placing concrete in layers within timber or steel shutters (example: Mass concrete in dam construction or construction of concrete abutment or pier).
- Placing concrete within usual from work. (example: Columns, beams and floors).
- Placing concrete under water.

Fresh Concrete

Placing concrete within earth mould (example foundation concrete for wall or a column)

- Concrete is invariably laid as foundation bed below the walls or columns.
- Before placing the concrete in the foundation, all the loose earth must be removed from the bed.
- Any root of trees passing through the foundation must be cut and burnt effectively to prevent its further growth and piercing the concrete at a later date.
- The surface of the earth, if dry, must be just made damp so that the earth does not absorb water from concrete.
- If there is any seepage of water taking place into the foundation trench, effective method for diverting the flow of water must be adopted before concrete is placed in the trench or pit.

Fresh Concrete

Placing concrete within large earth mould or timber plank formwork:

- For the construction of road slabs, airfield slabs and ground floor slabs in buildings, concrete is placed in bays.
- The ground surface on which the concrete is placed must be free from loose earth, pool of water and other organic matters like grass, roots, leaves etc.
- The earth must be properly compacted and made sufficiently damp to prevent the absorption of water from concrete.
- If this is not done, bottom portion of concrete becomes weak.
- Sometimes, in order to prevent the absorption of moisture from concrete, a polyethylene film is placed between concrete and ground surface gives enough scope for the concrete to undergo sufficient shrinkage.

Fresh Concrete

Placing concrete in layers within timber or steel shutters:

- When concrete is laid in great thickness, as in the case of concrete raft for a high rise building or in the construction of concrete pier or abutment or in the construction of mass concrete dam, concrete is placed in layers.
- The thickness of layers depends upon the mode of compaction.
- In reinforced concrete, it is a good practice to place concrete in layers of about 15 to 30 cm thick and in mass concrete, the thickness of layer may vary anything between 35 to 45 cm.
- Before placing the concrete, the surface of the previous lift is cleaned thoroughly with water jet and scrubbing by wire brush.
- Sometimes cement slurry or a very thin layer of rich mortar is placed on the old surface and then the fresh concrete is laid.
- This is done in order to avoid formation of cold joints. So it is better to leave the top surface as rough, which gives better binding between the two layers.

Fresh Concrete

Placing of concrete within usual from work. (example: Columns, beams and floors):

Form work:

- Form work shall be designed and constructed so as to remain sufficiently rigid during placing and compaction of concrete.
- The joints are plugged to prevent the loss of slurry from concrete.
- Reinforcement should be cleaned and free from oils. When reinforcement is placed in congestion, concrete must be placed very carefully. While casting columns, dropping of concrete from greater height causes segregation. In order to avoid this, concrete is placed with tremie, drop chute or by any other means within the reinforcement and ties.
- When the formwork is narrow, a small opening is made on the sides of the formwork and concrete is placed.

Fresh Concrete

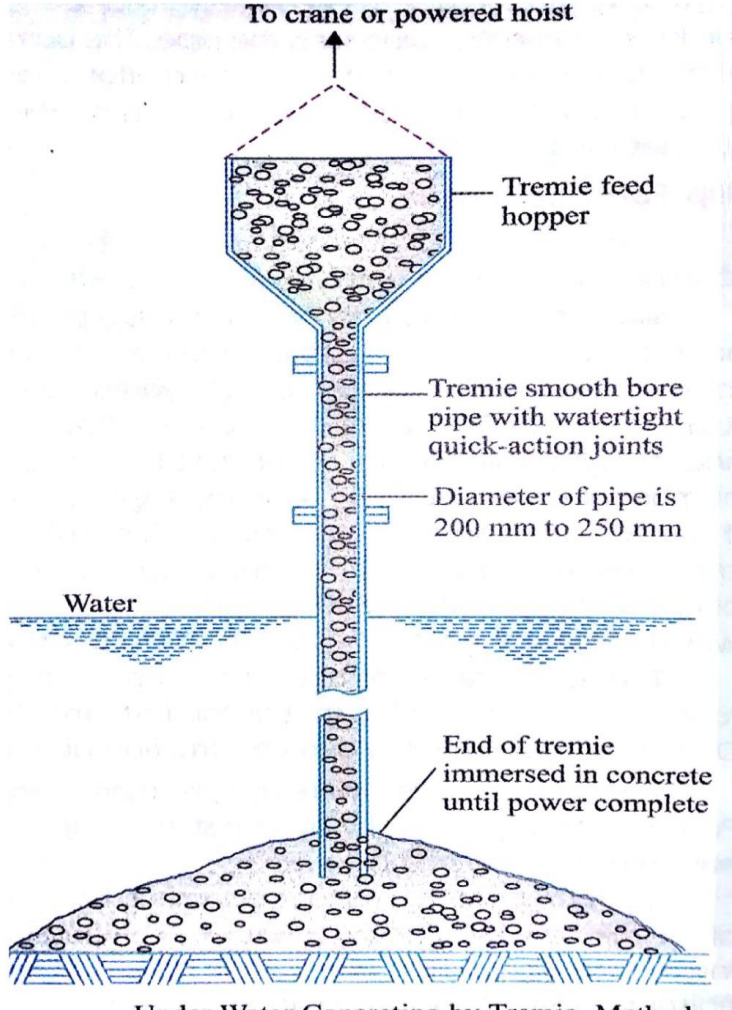
Stripping Time:

Formwork should not be removed until the concrete has developed strength of at least twice the stress to which concrete may be subjected at the time of removal of formwork.

Fresh Concrete

Placing concrete under water:

- In such cases, use of bottom dump bucket or tremie pipe is made use of.
- In the bottom dump bucket concrete is taken through the water in a water-tight box or bucket and on reaching the final place of deposition the bottom is made to open by some mechanism and the whole concrete is dumped slowly.
- A tremie pipe is a pipe having a diameter of about 20 cm capable of easy coupling for increase or decrease of length.
- A funnel is fitted to the top end to facilitate pouring of concrete.
- The bottom end is closed with a plug or thick polyethylene sheet or such other material and taken below the water and made to rest at the point where the concrete is going to be placed.

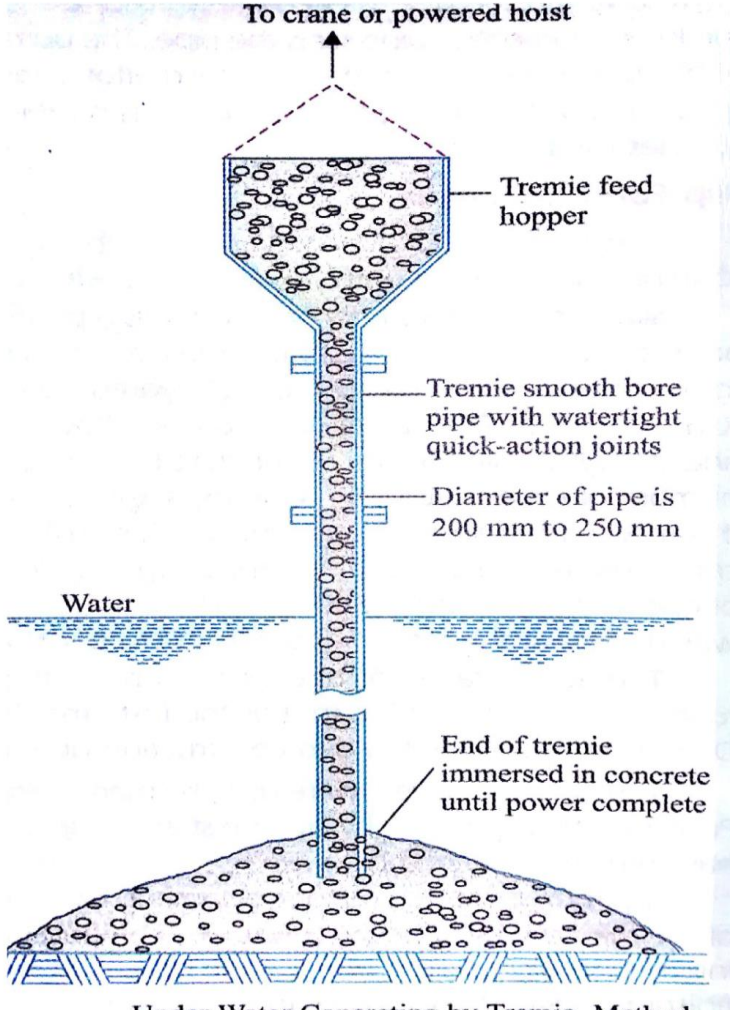


Under Water Concreting by Tremie Method.

Fresh Concrete

Placing concrete under water:

- Since the end is blocked, no water will enter from the bottom of the pipe.
- The concrete having a very high slump of about 15 to 20 cm is poured into the funnel. When the whole length of pipe is filled up with the concrete, the tremie pipe is lifted up and a slight jerk is given by a winch and pulley arrangement.
- When the pipe is raised and given a jerk, due to the weight of concrete, the bottom plug falls and the concrete gets discharged.
- Particular care must be taken at this stage to see that the end of the tremie pipe remains inside the concrete, so that no water enters into the pipe from the bottom.
- In this way, concrete work is progressed without stopping till the concrete level comes above the water level.

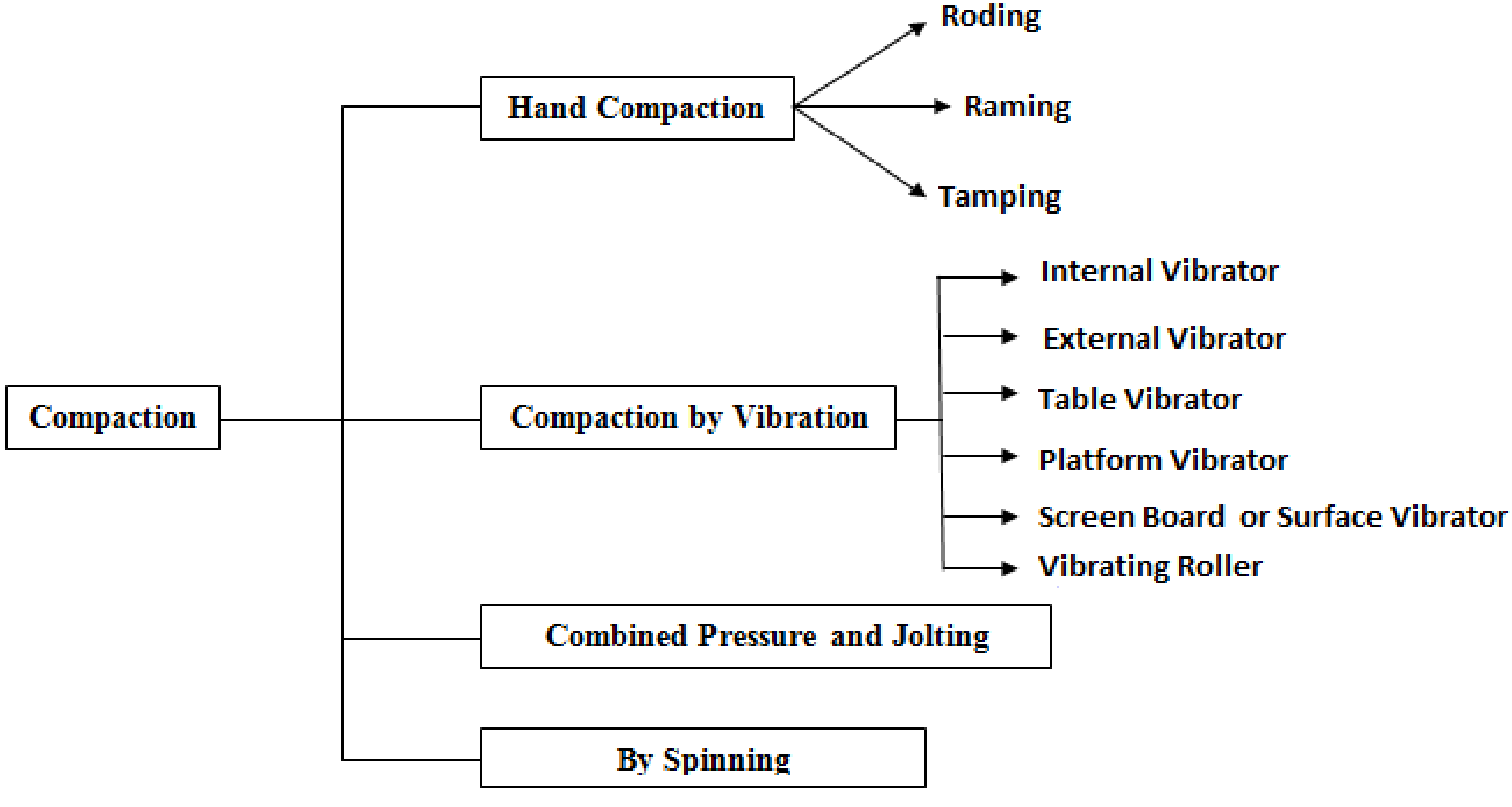


Under Water Concreting by Tremie Method.

Compaction of Concrete

- Compaction of concrete is the process adopted for expelling the entrapped air from the concrete.
- In the process of mixing, transporting and placing of concrete air is likely to get entrapped in the concrete.
- In other words, stiff concrete mix has high percentage of entrapped air and, therefore would need higher compacting efforts than high workable mixes.
- In order to achieve full compaction and maximum density, with reasonable compacting efforts available at site, it is necessary to use a mix with adequate workability.

Fresh Concrete



Fresh Concrete

Hand Compaction

- Hand compaction of concrete is adopted in case of unimportant concrete work of small magnitude.
- Rodding is done continuously over the complete area to effectively pack the concrete and drive away entrapped air.
- Light ramming can be permitted in unreinforced foundation concrete or in ground floor construction.
- Tamping is one of the usual methods adopted in compacting roof or floor slab or road pavements where the thickness of concrete is comparatively less and the surface to be finished smooth and level.
- Tamping consists of beating the top surface by wooden cross beam

Fresh Concrete

Compaction by Vibration:

- It is pointed out that the compaction by hand, if properly carried out on concrete with sufficient workability, gives satisfactory results, but the strength of the hand compacted concrete will be necessarily low because of higher water cement ratio required for full compaction.
- Where high strength is required, it is necessary that stiff concrete, with low water/cement ratio be used.
- To compact such concrete, mechanically operated vibratory equipment, must be used.
- The vibrated concrete with low water/cement ratio will have many advantages over the hand compacted concrete with higher water/cement ratio.

Fresh Concrete

Compaction by Vibration:

➢ Internal vibrator (Needle vibrator):

- The internal vibrator is most commonly used.
- This is also called, “Needle Vibrator”, “Immersion Vibrator”.
- This essentially consists of a power unit, a flexible shaft and a needle.
- The power unit may be electrically driven or operated by petrol engine or air compressor.
- The vibrations are caused by eccentric weights attached to the shaft or the motor or to the rotor of a vibrating element.
- The frequency of vibration varies up to 12,000 cycles of vibration per minute.
- The needle diameter varies from 20 mm to 75 mm and its length varies from 25 cm to 90 cm.
- The bigger needle is used in the construction of mass concrete dam.

Fresh Concrete

Compaction by Vibration:

- **Formwork vibrator (External vibrator):**
- Formwork vibrators are used for concreting columns, thin walls or in the casting of precast units.
- The machine is clamped on to the external wall surface of the formwork.
- The vibration is given to the formwork so that the concrete in the vicinity of the shutter gets vibrated.
- This method of vibrating concrete is particularly useful and adopted where reinforcement, lateral ties and spacers interfere too much with the internal vibrator.
- Use of formwork vibrator will produce a good finish to the concrete surface.

Fresh Concrete

Compaction by Vibration:

➢ Table vibrator:

- This is the special case of formwork vibrator, where the vibrator is clamped to the table. or table is mounted on springs which are vibrated transferring the vibration to the table.
- They are commonly used for vibrating concrete cubes.

Fresh Concrete

Compaction by Vibration:

➢ Platform vibrator:

- Platform vibrator is nothing but a table vibrator, but it is larger in size.
- This is used in the manufacture of large prefabricated concrete elements such as electric poles, railway sleepers, prefabricated roofing elements etc.
- Sometimes, the platform vibrator is also coupled with jerking or shock giving arrangements such that a through compaction is given to the concrete.

Fresh Concrete

Compaction by Vibration:

➢ **Surface vibrator (Screed vibrator):**

- Surface vibrators are sometimes knows as, “Screed Board Vibrators”.
- A small vibrator placed on the Screed board gives an effective method of compacting and Leveling of thin concrete members, such as floor slabs, roof slabs and road surface.
- Mostly, floor slabs and roof slabs are so thin that internal vibrator or any other type of vibrator cannot be easily employed.
- In such cases, the surface vibrator can be effectively used. In general, surface vibrators are not effective beyond about 15 cm.

Fresh Concrete

Compaction by Vibration:

- **Compaction by Pressure and Jolting:**

- This is one of the effective methods of compacting very dry concrete.
- This method is often used for compacting hollow blocks, cavity blocks and solid concrete blocks.
- The stiff concrete is vibrated, pressed and also given jolts.
- With the combined action of the jolts vibrations and pressure, the stiff concrete gets compacted to a dense form to give good strength and volume stability

Fresh Concrete

Compaction by Vibration:

- **Compaction by Spinning:**

- Spinning is one of the recent methods of compaction of concrete.
- This method of compaction is adopted for the fabrication of concrete pipes.
- The plastic concrete when spinned at a very high speed gets well compacted because of centrifugal force.

Fresh Concrete

Compaction by Vibration:

➢ **Vibratory Roller:**

- One of the recent developments of compacting very dry and lean concrete is the use of Vibratory Roller.
- Such concrete is known as Roller Compacted Concrete

Fresh Concrete

Curing of Concrete

- Concrete derives its strength by the hydration of cement particles.
- The hydration of cement is not a momentary action but a process continuing for long time.
- The quantity of the product of hydration and consequently the amount of gel formed depends upon the extent of hydration.
- Cement requires a water/cement ratio about 0.23 for hydration and a water/cement ratio of 0.15 for filling the voids in the gel pores.
- In other words, a water/cement ratio of about 0.38 would be required to hydrate all the particles of cement and also to occupy the space in the gel pores.

Fresh Concrete

Curing of Concrete

- Curing is the process of controlling the rate and extent of moisture loss from concrete during cement hydration
- Curing can also be described as keeping the concrete moist, so that the hydration of cement can continue.
- Curing methods may be divided broadly into four categories:

(a) Water curing

(b) Membrane curing

(c) Application of heat

(d) Miscellaneous

Fresh Concrete

Purpose of curing:

- In the field though enough water is used for mixing the concrete, some part of water gets evaporated and the water available for hydration process becomes insufficient.
- If the hydration has to be progressed, then extra water is added which replenishes the loss of water due to evaporation.
- Hydration process must continue to attain the desirable properties of concrete.

Fresh Concrete

Water curing:

- This is the best method of curing as it satisfies all the requirements of curing, namely, promotion of hydration, elimination of shrinkage and absorption of the heat of hydration.
- Water curing can be done in the following ways:

➢ Immersion

➢ Ponding

➢ Spraying or Fogging

➢ Wet covering

Fresh Concrete

- The precast concrete items are normally immersed in curing tanks for a certain duration.
- Pavement slabs, roof slab etc. are covered under water by making small ponds.
- Vertical retaining wall or plastered surfaces or concrete columns etc. are cured by spraying water.
- In some cases, wet coverings such as wet gunny bags, hessian cloth, etc., are wrapped to vertical surface for keeping the concrete wet.
- For horizontal surfaces saw dust, earth or sand are used as wet covering to keep the concrete in wet condition for a longer time so that the concrete is not unduly dried to prevent hydration.




Membrane curing:

It is adopted in the following conditions

- When there is scarcity of water for curing
- When the building is located in remote areas
- When the curing of concrete cannot be properly supervised
- When the workman does not understand the importance of curing

Fresh Concrete

- Curing has to be done to promote hydration of concrete by not allowing the water present in the concrete to get evaporated.
- This can be done by providing a membrane or sealant on the surface of concrete.
- This idea of sealing is to obtain a continuous cover to the top surface of concrete by means of impervious film to prevent the escape of moisture content due to evaporation and at the same time it is placed in between the ground and concrete to avoid the absorption of moisture from the concrete.
- For this purpose bituminous compounds like polyethylene or polyester, water proofing paper and rubber compounds are used.

Fresh Concrete

Application of heat

- The development of strength is a function of not only time also that of temperature.
- When concrete is subjected to higher temperature, it accelerates the hydration process resulting in faster development of strength.
- Concrete cannot be subjected to dry heat to accelerate the hydration process as the presence of moisture is also essential.
- Hence subjecting the concrete to higher temperature and maintaining the required moisture can be achieved by stream curing.

Fresh Concrete

Advantages of faster attainment of strength

- Concrete member can be handled very quickly
- Less space will be sufficient during casting
- A small curing tank will be sufficient
- The pre-stressing bed can be released early for further casting

Fresh Concrete

The exposure of concrete to higher temperature is done by following ways:

- Steam curing at ordinary pressure
- Steam curing at higher pressure
- Curing by infrared radiation
- Electrical curing

Fresh Concrete

- **Steam curing at ordinary pressure**

➢ This method of curing is adopted for prefabricated concrete elements.

➢ Steam curing @ ordinary pressure is applied on a prefabricated elements stored in a chamber.

➢ The chamber should be big enough to hold a day's production.

➢ The door of the chamber is closed and then steam is applied.

➢ The steam may be applied either continuously or intermittently.

➢ An accelerated hydration takes place at this high temperature and concrete products attain the 28days strength of normal concrete in about 3days.

Fresh Concrete

- **Steam curing at high pressure**
- This is similar to the above method but the only difference is that high pressure and temperature is applied on the concrete. This process is also called as **Autoclaving.**

Following are the advantages of this method

- High pressure steam cured concrete develops in one day, or less the strength as much as the 28days strength of normally cured concrete.

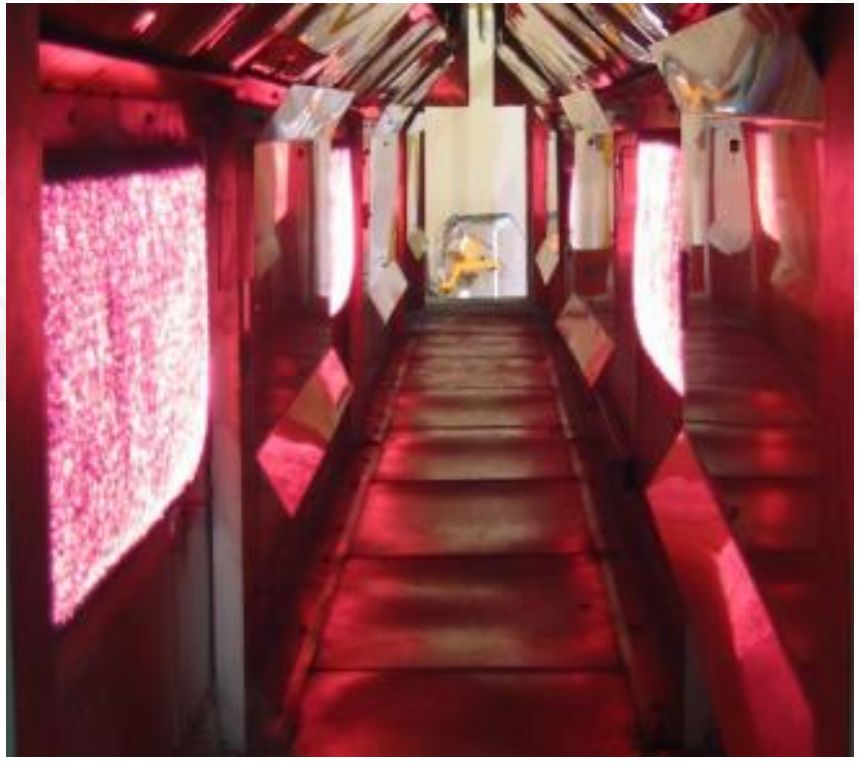
Fresh Concrete

- **Steam curing at high pressure**
- High pressure steam cured concrete exhibits higher resistance to sulphate attack, freezing and thawing action. It also shows less efflorescence.
- High pressure steam cured concrete exhibits lesser shrinkage and less moisture movement
- Improvement in durability is more for the concrete made with higher water-cement ratio than for concrete made with low water-cement ratio.

- **Curing by infrared radiation**

This method is practiced in very cold climate region. This system is adopted for curing of hallow concrete blocks.

The normal operative temperature is around 90ºC.



Fresh Concrete

- **Electric curing**

➢ This method is applied to very cold climate regions.

➢ Concrete can be cured electrically by passing alternative current through the concrete between the electrodes either burreid in concrete or applied to the surface of concrete.

➢ Care must be taken to prevent the moisture to evaporates which makes the concrete completely dry.

Fresh Concrete

- **Accelerated Curing**

- By adopting this method, concrete achieves high early strength.
- Adopted for prefabricated concrete elements.
- Formwork can be removed within 24hrs.
- It reduces the time interval between successive casting
- Cost saving benefits.
- Commonly used methods are steam curing, warm water curing, boiling water curing and autoclave method.

Fresh Concrete

- **Self curing or internal curing**

➢ The ACI-308 Code states that "internal curing refers to the process by which the hydration of cement occurs because of the availability of additional internal water that is not part of the mixing Water."

➢ Conventionally, curing concrete means creating conditions such that water is not lost from the surface i.e., curing is taken to happen 'from the outside to inside'.

➢ In contrast, 'internal curing' is allowing for curing 'from the inside to outside' through the internal reservoirs (in the form of saturated lightweight fine aggregates, superabsorbent polymers, or saturated wood fibers)

➢ 'Internal curing' is often also referred as 'Self–curing'.

Fresh Concrete

- **Need for Self–curing**

➢ When the mineral admixtures react completely in a blended cement system, their demand for curing water (external or internal) can be much greater than that in a conventional ordinary Portland cement concrete.

➢ When this water is not readily available, due to de-percolation of the capillary porosity, for example, significant autogenous deformation and (early-age) cracking may result.

Fresh Concrete

- **Potential Materials for IC**

- Lightweight Aggregate (natural and synthetic, expanded shale),
- LWS Sand (Water absorption =17 %)
- LWA 19mm Coarse (Water absorption = 20%)
- Super-absorbent Polymers (SAP) (60-300 mm size)
- SRA (Shrinkage Reducing Admixture) (propylene glycol type i.e. polyethylene-glycol)
- Wood powder

Fresh Concrete

- **Miscellaneous Methods:**

➢ Calcium chloride is used either as a surface coating or an admixture.

➢ It has been used satisfactory as curing medium.

➢ Both these methods are based on the fact that calcium chloride being a salt, shows affinity for moisture.

➢ The salt not only absorbs moisture from atmosphere but also retains it at the surface.

➢ This moisture held at the surface prevents the mixing water from evaporation and thereby keeps the concrete wet for a long time to promote hydration.

Fresh Concrete

- **Miscellaneous Methods:**

➢ Formwork prevents escaping of moisture from the concrete, particularly in the case of beams and columns.

➢ Keeping the formwork intact and sealing the joint with wax or any other sealing compound prevents the evaporation of moisture from the concrete.

➢ This procedure of promoting hydration can be considered as one of the miscellaneous methods of curing.

Fresh Concrete

- **Finishing**

➢ Finishing operation is the last operation in making concrete.

➢ Finishing in real sense does not apply to all concrete operations.

➢ For a beam concreting, finishing may not be applicable, whereas for the concrete road pavement, airfield pavement or for the flooring of a domestic building, careful finishing is of great importance.

➢ Particularly, many types of prefabricated concrete panels used as floor slab or wall unit are made in such a way as to give very attractive architectural affect.

Fresh Concrete

- **Finishing**

➢ **Formwork Finishes**

✓ Concrete obeys the shape of formwork.

✓ By judiciously assembling the formwork either in plane surface or in undulated fashion or having, a pleasing surface finish can be given to concrete.

✓ A pre-fabricated wall unit cast between steel formwork having very smooth surface using right proportioning of materials can give such a nice surface which can never be obtained by the best masons.

Fresh Concrete

- **Finishing**

➢ **Surface treatment**

✓ This is one of the widely used methods for surface finishing.

✓ The concrete pavement slab is required to be plane but rough to exhibit skid resistance, so is the air-field pavements and road slabs.

✓ Concrete having been brought to the plane level surface, is raked lightly or broomed or textured or scratched to make the surface rough.

Fresh Concrete

- **Finishing**

➢ **Applied finish**

✓ The term applied finish is used to denote the application of rendering to the exteriors of concrete structures.

✓ The concrete surface is cleaned and roughened and kept wet for sufficiently long time.

✓ Over this a mortar of proportion of about 1:3 is applied.

✓ This mortar rendering can be given by any required pleasant finish, such as cement stippling either fine or coarse, keying, renderings etc.

Fresh Concrete

- **Special Surface Finishes**

  - Pattern and Textures
  - Exposed Aggregate Concrete
  - Colored Finishes
  - Rough-form finishes
  - Smooth off-the-form finish
  - Sand-floated finish

Fresh Concrete

- **Good and Bad Practices**

✓ Concrete is a complex construction material consisting of different ingredients, which have different functions.

✓ The properties of concrete depend on the particular mixture of constituents.

✓ The basic constituents used to make concrete are cement, lime, water, aggregates, and admixtures.

✓ Your concreting work can be successful if it involves a good planning and right practices.

✓ Most of the repair and maintenance problems may occur in the building due to bad practices in concrete construction.

Fresh Concrete

- **Do's**

✓ Do hire an experienced Concrete contractor for successful concreting operation.

✓ Also, see that the main/general contractor hire good skilled sub/labour contractor for concreting.

✓ See that concreting is done under skilled supervision. Never leave it to labour on site.

✓ Always wear suitable PPE (Personal Protective Equipment)before casting concrete.

✓ Start placement of concrete with adequate manpower, proper equipment and tools.

✓ Always choose right cement for the particular job.

✓ If you have confusion, ask the technical person.

Fresh Concrete

- **Do's**

✓ Always pour the concrete when the weather conditions are favourable.

✓ Suitable mix design should be used for particular specifications (i.e. M25, M30 etc.).

✓ Choose right concrete mix as per specifications.

✓ First mix the dry concrete uniformly i.e. cement, coarse aggregates, fine aggregates (either manually or in transit mixture) as per predetermined quantity (i.e. batching of concrete materials).

✓ A good concrete contractor will always mix the dry concrete first.

✓ Add water as per predetermined quantity only.

✓ Always measure the water with measuring container before adding in concrete.

✓ Mix the wet concrete thoroughly for around 2 minutes to get the consistent concrete.

Fresh Concrete

- **Do's**

✓ Do slump test before placing the concrete.

✓ Concrete must be placed within 15 to 20 minutes of pouring water. If delayed add fresh cement or concern the consultant.

✓ Do the proper compaction to the concrete with a vibrator or wooden tamp to remove air from the concrete.

✓ If compaction is not well, it will create voids/honeycomb in concrete resulting in leakages from the concrete structure, thereby causing corrosion and also reducing the strength. This also affects the life of the structure.

✓ Pour the concrete throughout in an even thickness.

✓ Always keep on checking the stability of props/ supports of formwork below.

✓ See that the covers insert doesn't get displaced.

Fresh Concrete

- **Do's**

✓ Do proper finishing at joints during concrete construction.

✓ Give attention towards the bleeding in concrete. Water should not evaporate rapidly.

✓ Calculate the number of cement bags concreted per hour. If more than 25 to 30 bags are used per hour, then mixing time allowed is less and it should not be permitted (For 1 bag mixture machine).

✓ See that no one walks on the concrete surface till the concrete gets hardened.

✓ Do proper curing when the concrete has hardened initially.

✓ Start curing after 6 to 10 hours.

Fresh Concrete

- **Don'ts**

✓ Don’t use damaged formwork. It affects the concrete resulting in the honeycomb.

✓ Don’t use unwashed aggregates in concrete; it may result in a weak concrete and substantial cost of maintenance.

✓ Don’t start concreting before casting of a concrete cube. The Strength of the concrete should be as per predetermined mix design.

✓ Don’t go for volumetric batching. Never allow the use of gamellas.

✓ Don’t use high concrete slump, excessively high air content, or excessive fines.

✓ Don’t run concrete mixer more than two minutes resulting in segregation of concrete constituents.

Fresh Concrete

- **Don'ts**

✓ Don’t add more water for ease of placement during the making of concrete.

✓ Don’t use semi-dry concrete in pouring. There will be chances of honeycomb inside the concrete.

✓ Don’t drop concrete form greater height as this will cause segregation.

✓ Don’t allow heaping of concrete at one place during pouring.

✓ Don’t vibrate the concrete after the initial setting has taken place. (i.e. after 30 minutes)

✓ Don’t finish the concrete while bleeding is present on the surface of the concrete.

Fresh Concrete

- **Don'ts**

✓ Unless must and unavoidable, never do concreting at night.

✓ The lighting arrangements are never adequate at all work places and hence some errors can always happen somewhere.

✓ Don’t remove formwork until the concrete has gained sufficient strength.

✓ When finishing of the concrete is carried out, never throw or sprinkle the water on to the concrete surface.

✓ Don’t try to finish the dried concrete.

✓ Don’t do concreting if it is raining heavily

✓ Never allow child labour on site. You will land in jail for violence of law.

Fresh Concrete

- **Effect of Heat of hydration in case of mass concreting works**

✓ Mass concrete is defined by ACI "Any volume of concrete with dimensions large enough to require that measures be taken to cope with generation of heat from hydration of the cement and attendant volume change to minimize cracking.

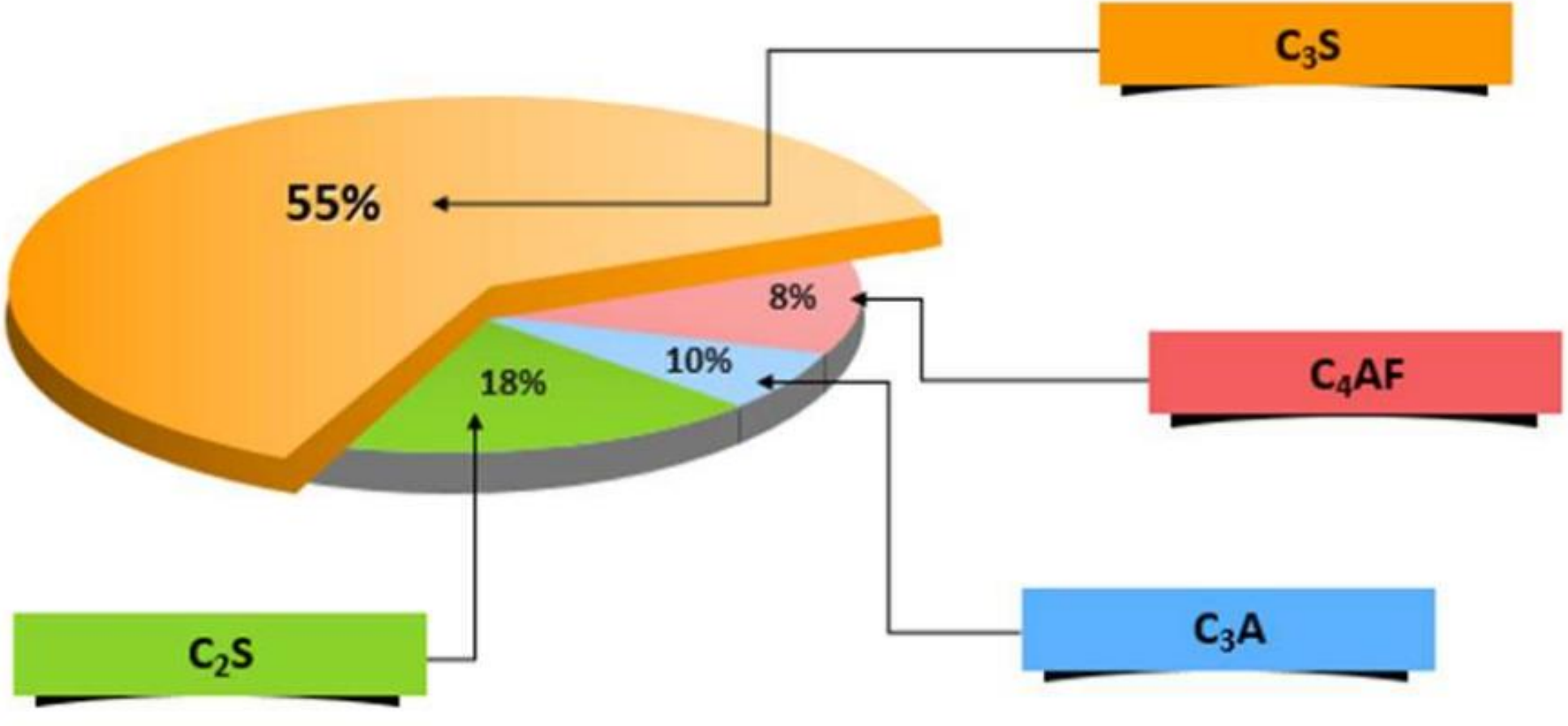
✓ Mass concrete is defined by some agencies as "any concrete element having a least dimension greater than 3 ft (0.9 m).

Examples:

- Dam
- Raft Foundation
- Pile Cap.
- Thick Wall.
- Thick column.
- Deep Slap.

Fresh Concrete

Cement Composition “Type I - OPC”



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Main Chemical Cement Reactions with Water

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HOH generated from cement main ingredients

Reaction	Enthalpy of hydration kJ/kg pure clinker material
$2C_3S+6H \rightarrow 3CH+C_3S_2H_3$	520
$2C_2S+4H \rightarrow CH+C_3S_2H_3$	260
$C_3A+6H \rightarrow C_3AH_6$	910
$C_3A+CH+18H \rightarrow C_4AH_{19}$	1160
$C_3A+3C\bar{S}H_2+26H \rightarrow C_6A\bar{S}_3H_{32}$	1670
$C_3A+C\bar{S}H_2+10H \rightarrow C_4A\bar{S}H_{12}$	1140
$C_4AF+2CH+4H \rightarrow 2C_3(A,F)H_6$	420

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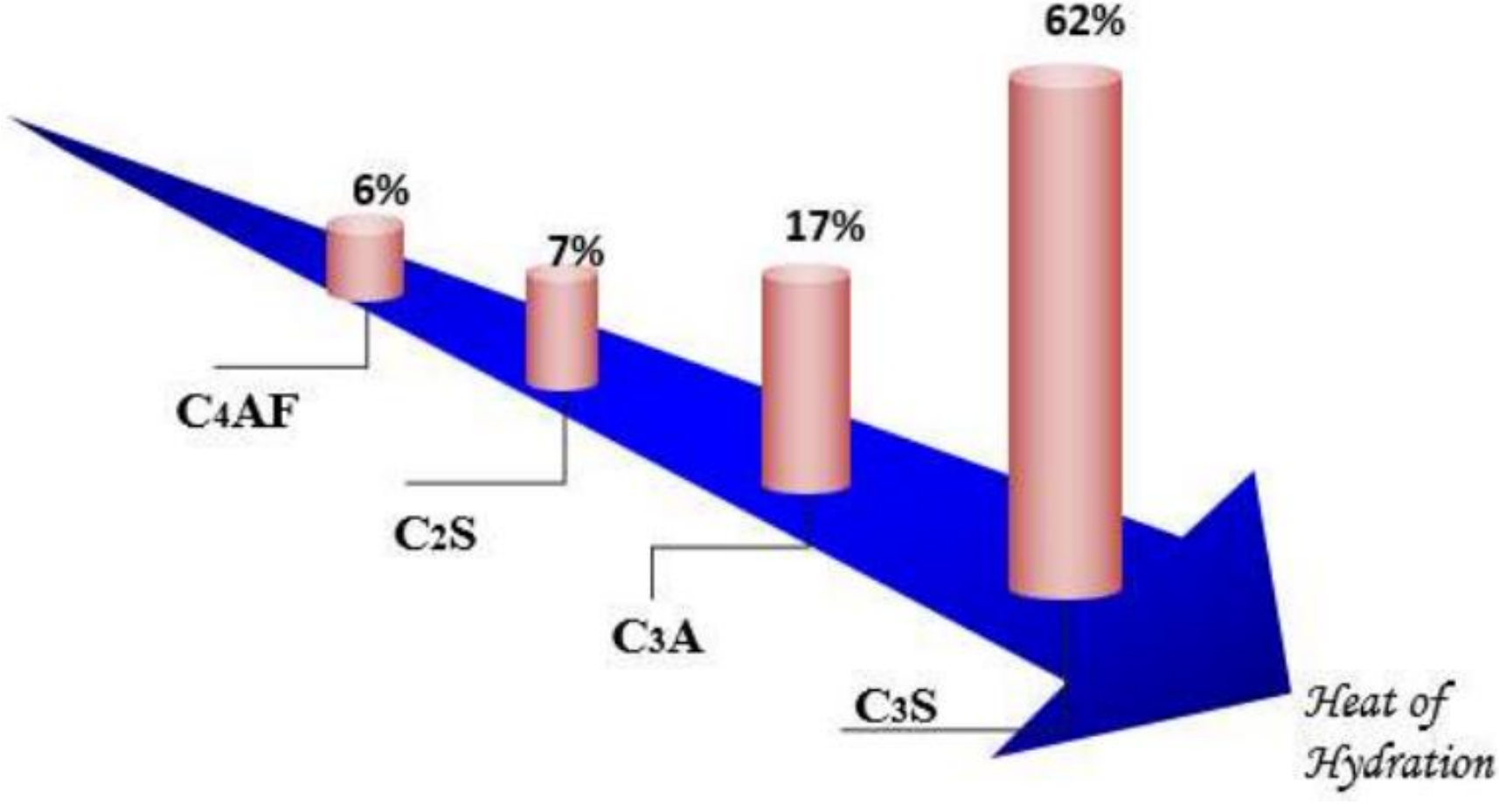
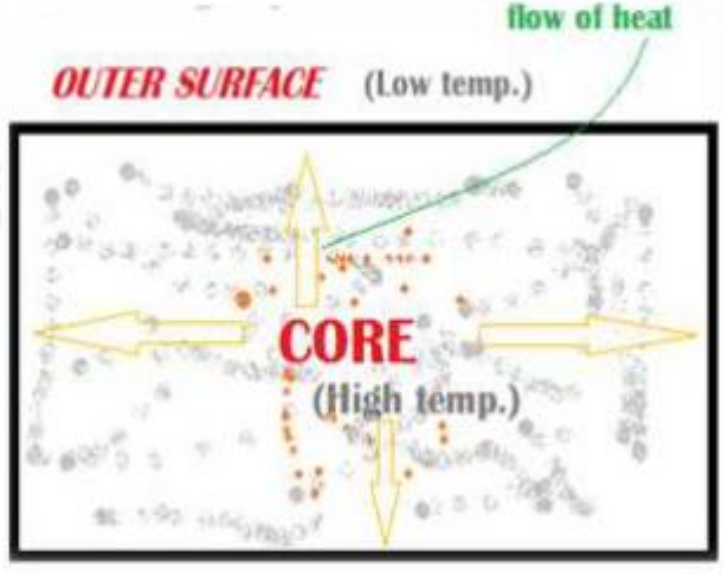
% of HOH generated from cement main ingredients



Fresh Concrete

Why is temperature control necessary?

- Concrete is thermally very poor conductor.
- Heat transfer (heat of hydration) results in unequal thermal expansion
- Tensile stress at the free surface due to expansion of core exceeds the tensile strength
- Then surface cracking will develop
- Temp. difference between interior & outer surface of more than 20^0 C cause cracks.



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Cracks may cause

- Cracks generated due to thermal gradients may cause
- loss of structural integrity
- loss in monolithic action
- excessive shrinkage
- loss in durability
- aesthetically objectionable

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Methods of temperature control

- Methods of controlling mass concrete temperatures range from relatively simple to complex, and from inexpensive to costly.
- Depending on a particular situation, it may be advantageous to use one or more methods over another.
- Low-heat material - GGBFS, Fly ash, Silica fume, large size aggregates
- Pre cooling of concrete – Use chilled mix water, Liquid nitrogen
- Post-cooling of concrete
- Surface insulation – Insulating formwork