CONCRETE TECHNOLOGY

MODULE - 1

Module -1

Portland Cement

In 1984 Joseph Aspdin, a brick layer and mason in Leeds, England, took out a patent on hydraulic cement that he called portland cement because its colour, resembled the stone quarried on the Isle of Portland off the British coast.

* What is cement?

Ans It is a powdery substance made by calcining lime and clay, mixed with water to form mortar or mixed with sand, gravel and water to make concrete.

Types of Cement

* Ordinary Portland cement - 33 grade, 43 grade, 53 grade.
* Rapid hardening Portland Cement
* Portland slag cement
* Portland Pozzolana Cement.
* High-alumina Cement.
* Super-sulphated cement
* Hydrophobic cement
* sulphate resisting portland Cement.

Chemical Composition

Ingredients	Percentage
Lime (CaO)	60% - 65%
Silica (SiO_2)	20% - 25%

Alumina (Al_2O_3)	4% – 8%
Iron oxide (Fe_2O_3)	2% – 4%
Magnesium oxide (MgO)	1% – 3%
Sulphur trioxide (SO_3)	1% – 2%
Alkalies (Soda or Potash $Na_2O + K_2O$)	0.3% – 1%

Hydration

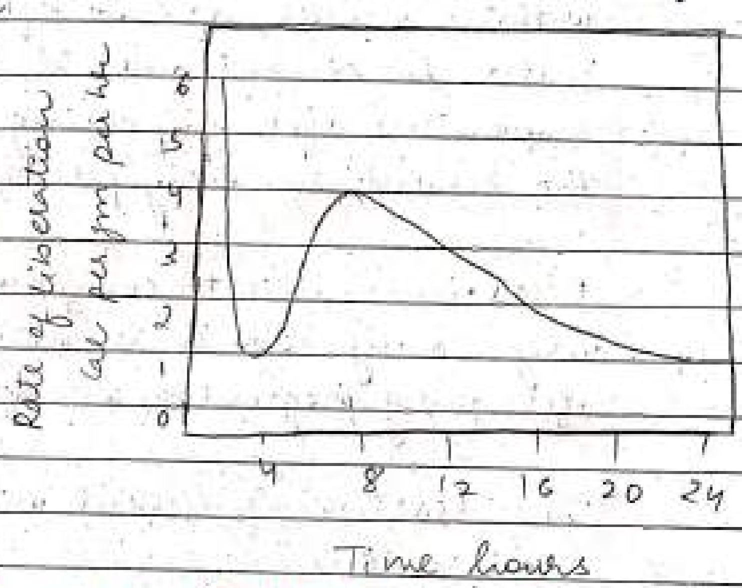
It is the reaction of cement with water to form the binding material.

Chemical Composition of Clinker

	Compound	Formula	Shorthand form	% by weight
1.	Tricalcium aluminate	$Ca_3Al_2O_6$	C_3A	10
2.	Tetra calcium aluminoferrite	$Ca_4Al_2Fe_2O_{10}$	C_4AF	8
3.	Belite or dicalcium silicate	Ca_2SiO_5	C_2S	20
4.	Alite or tricalcium silicate	Ca_3SiO_4	C_3S	55
5.	Sodium oxide	Na_2O	N	
6.	Potassium oxide	K_2O	K	upto 2
7.	Gypsum	$CaSO_4 \cdot 2H_2O$	CSH_2	upto 2 5

Anhydrous cement does not bind fine and coarse agg. It acquires adhesive property only when mixed with water. The chemical reaction that take place between cement and water is referred as hydration of cement.

Heat liberation from a setting cement.



Structure of hydrated cement.

Concrete is considered as a two phase material namely i) Paste phase ii) Aggregate Phase.

When water is added to cement, the ingredients of cement react chemically with water and forms various complicated chemical compounds. The important compounds formed during the setting action of cement are :-

1. Tricalcium aluminate → (C_3A)
2. Tetra-calcium alumino-ferrite (C_4AF)
3. Tricalcium silicate → (C_3S)
4. Dicalcium silicate → (C_2S)

} Bogue's Compound.

Tricalcium aluminate and tetra-calcium alumino ferrite compounds formed within 24 hours after addition of water.

Tricalcium silicate compounds formed within a week or so after addition of water to cement and it is mainly responsible for imparting strength to the cement in early period of setting.

Dicalcium silicate compound is formed very slowly and it is mainly responsible for giving progressive strength to the cement.

The reaction of cement with water is exothermic.

Setting of Cement.

Setting time is influenced by the percentage of water and its temperature and by the temperature and humidity of air.

1. Initial setting time

- Take 300 gm of cement. Prepare a neat cement paste by gauging the cement with 0.85 times the water required to give a paste of standard consistency.

- Pour the paste in vicat mould completely. The mould resting on the non porous plate.
- level the surface of the paste.
- The needle (1mm square) is lowered gently until it comes in contact with surface of the test block and released quickly to penetrate into the test block.
- The penetration of the needle is read on the scale.

2. Final setting time.

Replace the needle of the vicat apparatus used for setting time by the needle with an annular attachment.
- The cement should be considered finally set when upon applying the needle gently to the surface of the test block, the needle makes an impression there on, while the attachments fails to do so.
- The period elapsing between the time when the water added to the cement and the time at which the needle makes an impression on the surface of the test block while the attachment fails to do so shall be the final setting time.

Tests on Physical Properties.

(a) Field testing.
b) laboratory testing.

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(a) Field Testing

→ Open the bag and take a good look at the cement. There should not be any visible lumps.

→ The colour of the cement should normally be greenish grey.

→ Take a pinch of cement and feel between the fingers. It should give a smooth and not a gritty feeling.

→ Thrust your hand into the cement bag it must give you a cool feeling. There should not be any lump inside.

→ Take a handful of cement and throw it on a bucket full of water, the particles should float for some time before they sink.

→ Take about 100 gms of cement and a small quantity of water and make a stiff paste.

→ From the stiff paste, pat a cake with sharp edges. Put it on a glass plate and slowly take it under water in a bucket.

→ See that the shape of the cake is not disturbed while taking it down to the bottom of the bucket.

→ After 24 hrs the cake should retain its original shape and at the same time it should also set and attain some strength.

(b) Laboratory Testing

(a) ~~Fitness~~ Fineness Test
(b) Setting time test

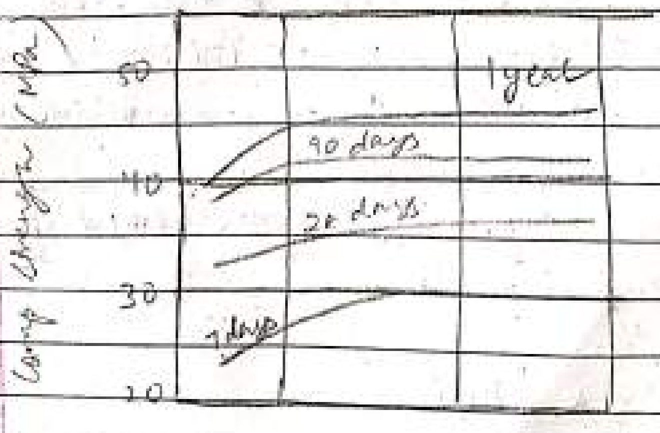
c) Strength test. d) Soundness test.
e) Heat of hydration test
f) Chemical composition test.

FINENESS TEST

i) By seiving
ii) By air permeability method.

→ BY SEIVING

* Break down the air set lumps in the sample with fingers.
* Continuously sieve the sample giving circular and vertical motion for a period of 15 min.
* Weigh the residue left on the sieve. This weight shall not exceed 10% for ordinary cement.
* The disadvantages of fine grinding is that it is susceptible to air-set and early deterioration.



Sp. surface (Wagner) - m²/kg

Relation between strength of concrete at diff ages and fineness of cement.

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BY AIR PERMEABILITY METHOD.

- The principle is based on the relation between the flow of air through the cement bed and the surface area of the particles comprising the cement bed.
- From this, the surface area per unit weight of the body material can be related to the permeability of a bed of a given porosity.
- The cement bed in the permeability cell is 1cm high and 2.5 cm in diameter.
- Knowing the density of cement the weight required to make a cement bed of porosity of 0.475 can be calculated.
- This quantity of cement is placed in the permeability cell in a standard manner.
- slowly pass on air through the cement bed at a constant velocity. Adjust the rate of air flow until the flow meter shows a differentiate in level of 30-50 cm.
- Read the difference in level (h_1) of the manometer and the difference in level (h_2) of the flow-meter. Repeat these observation to ensure that steady condition have been obtained as shown by a constant value of h_1/h_2
- specific surface S_w is calculated from the following formula.

$$S_w = k\sqrt{h_1/h_2}$$

$$K = \frac{14}{d(1-X)}\sqrt{\frac{X^3 A}{CL}}$$

where :

X = Porosity of cement bed i.e, 0.475
A = Area of the cement bed (5.066 cm^2)
L = length (cm) of the cement bed (1cm)
d = Density of cement (g/cm^2)
C = Flowmeter constant :
h_1 = Pressure drop across that bed .
h_2 = Pressure drop across the flow meter capillary .

BY STANDARD CONSISTENCY TEST

- Take about 500gm of cement and prepare a paste with a weighed quantity of water (say 24% by weight) of cement) for the first trial.
- The paste must be prepared in a standard manner and filled into the vicat mould within 3 – 5 min.
- After completely filled the mould shake the mould to expel air.
- A standard plunger, 10 mm dia, 50 mm long is attached and brought down to touch the surface of the paste in the test block and quickly released allowing it to sink into the paste by its own weight.
- Take the reading by noting the depth of penetration of the plunger.
- Conduct a 2nd trial by increasing water % & find out the depth of penetration of plunger.
- Similarly, conduct trial with higher w/C

ratio till such time the plunger penetrates for a depth of 33 - 35 mm from the top.

CHEMICAL COMPOSITION TEST

Ratio of Percentage of lime to percentage of silica, alumina and iron oxide, when calculated by the formula.

$$\frac{CaO - 0.7SO_3}{2.8SiO_2 + 1.2Al_2O_3 + 0.65Fe_2O_3}$$

The above called lime saturation factor percent.

DIFFERENT GRADES OF CEMENT

Country	Grade
India	33 grade
	43 grade
	53 grade
Germany	30 grade
	35 grade
	40 "
	45 "
	50 "
	55 "

China	—	275	grade
		325	"
		425	"
		525	"
		625	"
		725	"
USSR Union Soviet Socialist Republic	—	400	grade
		500	"
		550	"
		600	"
UK	—	OPC	
USA	—	OPC Type -1.	

ADMIXTURES

Admixture is defined as a material other than cement, water and aggregates that is used as an ingredient of concrete and is added to the batch immediately before or during mixing.

- ~~Admixture~~ Additive is a material which is added at the time of grinding cement clincker at the cement factory.
- Admixture is used to modify the properties of ordinary concrete so as to make it more suitable for any situation, more suitable for the work at hand or for economy.

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TYPES OF ADMIXTURES

- Plasticizers
- Super Plasticizers
- Retarders and Retarding Plasticizers
- Accelerators and Accelerating Plasticizers
- Air - entraining Admixtures.
- Pozzolanic or mineral admixtures
- Damp - Proofing and water Proofing admixtures
- Gas forming Admixtures
- Air - de training Admixtures.
- Alkali - aggregate expansion inhibiting admixtures
- Workability admixtures
- Grouting admixtures
- Corrosion inhibiting admixtures.
- Bonding Admixtures
- Fungicidal, Germicidal, Insecticidal admixtures
- Colouring Admixtures.

CHEMICAL ADMIXTURES

- Superplasticizers are an essential component of SCC to provide necessary workability.
- The new generation super plasticizers termed poly - carboxylated ethers (PCE) is particularly useful for SCC.
- Other types may be incorporated as necessary such as viscosity modifying agents (VMA) for stability, air entraining agents (AEA) to improve freeze - thaw resistance and retarders for control of setting.

MINERAL ADMIXTURES

Fly ash :- Fly ash in appropriate quantity may be added to improve the quality and durability of SCC.

Ground granulated blast furnace slag (GGBFS) :- GGBFS which is both cementitious and pozzolanic material may be added to improve rheological properties.

Silica fume :- Silica fume may be added to improve the mechanical properties of SCC.

Stone Powder - finely crushed lime stone, dolomite or granite may be added to increase the powder content.
The fraction should be less than 125 micron

Fibres - It may be used to enhance the properties of SCC in the same way as for normal concrete

EFFECTS OF ADMIXTURES IN CONCRETE

The following aspects have to be kept in mind

1. A change in quantity and quality of cement used or modification of aggregate grading or change in mix proportions may be advisable.
2. Many admixtures affect more than one

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property of concrete, sometimes affecting property of concrete adversely.
the desirable property of admixtures are modified

3. The effects of some admixtures are modified by the richness or wetness of mix, grading of aggregate and the .
4. The specific effects of some admixtures vary with type, quantity and properties of the cement used.
5. Certain specific effects on an admixture cannot be predicted accurately prior to testing.

USES OF ADMIXTURES

* Improving workability without increasing water content.
* Accelerating rate of strength development at early ages
* Increase in strength
* Acceleration or retardation of initial setting.
* Reduction or retardation of heat evolution.
* Modifications in rate of bleeding.
* Increase in resistence to special conditions of exposure.
* Control of alkali - aggregate expansion
* Decrease in permeability.
* Improving pumpability of concrete.
* Increase in bond of concrete to steel and bond between old and new concrete.
* Production of fungicidal and germicidal concrete.
* Corrosion inhibition

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* counteract shrinkage on hydration
* effect overall economy.

DOSAGES

The dosages of superplasticizer influences the viscosity of and the workability of concrete

- In India generally low dosage is adopted for normal concreting operations.
- A dosage more than 2.5 % by weight of cement is rarely used.
- In other countries much higher dosages upto 4 to 5% are used in special situation.
- Dosage of about 3% there are no harmful effect on the hardening properties of concrete.
- Higher dosage is said to have affected the shrinkage and creep properties.

The optimum dosage can be calculated or ascertained from Marsh cone test if brand of cement - Plasticizer and W/C ratio is already fixed.

For Plasticizer Dosage % by wt of cement (2kg) with W/C = 0.45 is varies from 0.1, 0.2, 0.3

For superplasticizer dosage % by wt of cement (2kg) with W/C = 0.45 is 0.5, 0.7, 0.9, 1.1.

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AGGREGATES

Aggregates are defined as inert, granular and inorganic materials that normally consist of stone or stone like solids.

3 main functions of aggregates in concrete

1. To provide a mass of particle which are suitable to resist the action of applied loads and show better durability than cement paste alone.
2. To provide a relatively cheap filler for the cementing material.
3. To reduce volume changes resulting from setting & hardening process and from moisture changes during drying.

The properties of concrete are affected by properties of aggregate.

1. The mineral character of aggregate affects the strength, durability, elasticity of concrete.
2. The surface characteristics of aggregate affects the workability of fresh mass & the bond between the aggregates and cement paste in hardened concrete. If it is rough, workability decreases & bond increases.
3. The grading of aggregate affects the workability, density & economy.

All aggregates are not inert.

The Physical action : Swelling & Shrinkage,
The Chemical action : alkali-agg reaction,
The thermal action : expansion & contraction,

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Classification of aggregates based on unit weight

1. Normal weight aggregates.
2. Light weight aggregates.
3. Heavy weight aggregates.

① Normal Weight aggregates :-

(i) Natural Aggregates - Native deposits with no change in their natural state other than washing, crushing & grinding
- sand
- Gravel
- Crushed Rock (Granite, Basalt, Quartzite)

(ii) Artificial aggregates - They are obtained either as a by-product or special manufacturing process such as heating.
- Broken bricks
- Bloated clay
- Air cooled slag
- fly-ash.

② Light Weight aggregates

(i) Natural aggregates
- Pumice
- Rise husk
- Scoria
- Sawdust

(ii) Artificial aggregates
- Expanded shale
- Bloated Clay
- Foamed slag
- Sintered fly-ash.

③ Heavy weight aggregates
- Barite
- Limonite
- Magnetite
- Haematite

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Classification on the basis of size

① Fine Aggregates

- Size of aggregates : < 4.75 mm
- Bulking is more in fine aggregates.
- Fine aggregate fills the voids between coarse aggregate.
- Grading zone : 4.

Ex :- Natural sand , Crushed gravel
Crushed sand

② Coarse Aggregates

- Size of aggregate > 4.75 mm
- Bulking is very small and neglected.
- Coarse aggregates (C.A) gives strength to the concrete

Ex :- Gravel , crushed stone

Classification on the basis of shape.

① Rounded Aggregate

- Completely shaped by attrition.
- Contains minimum voids ranging from 32 to 33%
- It requires minimum cement paste to make good concrete.
- It gives better workability.
- The interlocking between the particles is less and hence unsuitable for high strength concrete.
- Ex : River or seashore gravels.

② Irregular aggregate

- Partly shaped by attrition, having rounded edges.

- contains higher percentage of voids ranging from 35 to 38 %.
- It requires more cement paste for a given workability.
- The interlocking between the particles is better than that obtained with rounded aggregate.
- Ex: sand and gravels, cuboid rock.

③ Angular aggregate
- Possessing well defined edges formed at the intersection of roughly planer faces.
- contains a maximum percentage of voids ranging from 38 to 40 %.
- It requires more cement paste to make workable concrete.
- The interlocking between the particles is good thereby providing a good bond.
- The angular aggregates are suitable for high strength concrete and pavement subjected to tension.
- Ex: crushed rocks of all types.

④ Flaky aggregate
- The aggregate whose least dimension is less than 3/5th (0.6) of its mean dimension is termed as Flaky aggregates.
- The mean dimension of the aggregate is the average of the sieve size through which particle pass and retained respectively.
- They reduce the workability of concrete.
- The flaky particles also adversely affect the

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durability of concrete and reduces the strength of concrete.
— The presence of these particles should not be more than 15% in the mass of aggregates.
Ex: laminated Rocks.

(5) Elongated Aggregates
— The aggregate whose greatest dimension (length) is greater than 9/5 th (1.8) of its mean dimension is called the elongated aggregate.
— They reduces the workability of concrete.
— The presence of these particles should not be more than 15% in the mass of aggregates.
Ex: laminated Rocks.

Classification on the basis of texture

1. Glassy — Eg - Black flint.
2. Smooth — Eg - Chert, slate, marble
3. Granular — Eg - Sand stone
4. Crystalline — Basalt, dolerite, granite
5. Honeycomb and porous — Eg Pumice.

STRENGTH

Strength is dependent on the bond between the cement paste and the aggregate.
— If the strength of the paste or the bond between the paste and aggregate is low, a concrete of poor quality will be obtained

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irrespective of the strength of the rock or aggregate.

— When cement paste of good quality is provided and its bond, with the agg is satisfactory, then the mechanical properties of the rock or aggregate will influence the strength of concrete.

The test for strength of aggregate is required to be made in the following

(i) For production of high strength & ultra strength concrete.
(ii) When contemplating to use aggregate manufactured from weathered rocks.
(iii) Aggregate manufactured by industrial Process.

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Mechanical Properties of Aggregate

The mechanical properties of aggregates are:-

(i) Toughness
(ii) Hardness
(iii) Specific gravity
(iv) Porosity and absorption of water by aggregate.
(v) Bulking of sand.

1. Test for determination of aggregate crushing value.

2. Test for determination of Ten per cent fines value
3. Test for determination of aggregate impact value.
4. Test for determination of aggregate abrasion value.

SPECIFIC GRAVITY

specific gravity is the ratio of the weight of a given volume of aggregate to the weight of an equal volume of water.

* sp gravity of aggregate is also required in calculating the compacting factor in connection with the workability measurements.

* Similarly specific gravity of aggregate is required to be considered when we deal with light wt and heavy weight concrete.

BULK DENSITY

It is the mass of aggregates required to fill the container to a unit volume after aggregates are batched based on volume.

* For a given specific gravity the angular aggregate shows a lower bulk density.
* The bulk density of aggregate is measured by filling a container in a known volume in a standard manner and weighing it.
* Bulk density shows how densely the aggregate

is packed when filled in a standard manner. It depends on the particle size distribution and the shape of particles.

$$\% \text{ voids} = \frac{G_s - \gamma}{G_s} \times 100$$

G_s = specific gravity
γ = Bulk density in kg/lit.

ABSORPTION AND MOISTURE CONTENT

* Porosity and absorption of aggregate will affect w/c ratio and hence the workability of concrete.
* The porosity of aggregate will also affect the durability of concrete when the concrete is subjected to freezing and thawing and also when concrete is subjected to thawing, and also when the concrete is subjected to chemically aggressive liquids.
* The water absorption of aggregate is determined by measuring the increase in weight of an oven dry sample when immersed in water for 24 hours.
* The ratio of the increase in weight to the weight of the dry sample expressed as percentage is known as absorption of aggregate.

MOISTURE CONTENT

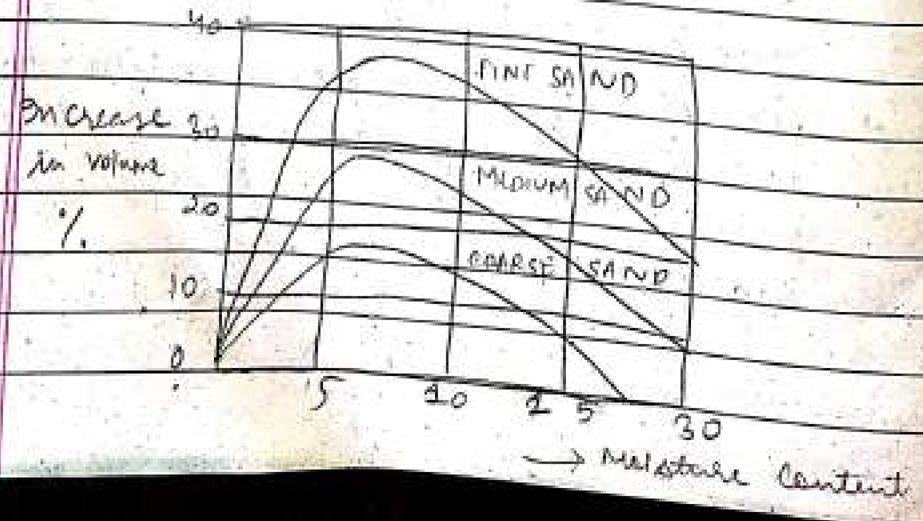
The surface moisture expressed as a % of the weight of the saturated surface dry aggregate is termed as moisture content

* Since, the absorption represents the water contained in the aggregate in the saturated surface dry condition and the moisture content is the water in excess of that, the total water content of a moist aggregate is equal to the sum of absorption and moisture content.

BULKING OF AGGREGATE

The increase in the volume of a given mass of fine aggregate caused by the presence of water is known as bulking.

* The bulking of aggregate is caused by the films of water which push the particles apart. The extent of bulking depends upon the % of moisture present in the sand and its fineness.
* In ordinary sands the bulking usually varies between 15 & 30%.



SOUNDNESS OF AGGREGATE

It refers to the ability of aggregate to resist excessive changes in volume as a result of changes in physical condition.

- The physical condition that affect the soundness of aggregate are the freezing and the thawing, variation in temperature, alternate wetting and drying under normal condition and wetting and drying in salt water.
- Aggregates which undergo more than the specified amount of volume change is said to be unsound aggregate.

ALKALI - AGGREGATE REACTION

Normally aggregates used in concrete are considered as inert materials.

→ But some of the aggregates contains reactive type of silica which reacts with alkalies present in cement i.e sodium oxide (Na_2O) and Potassium oxide (K_2O)

→ As a result, the alkali silicate gets of unlimited swelling type are formed. This reaction is known as alkali-Aggregate reaction.

→ The alkali silicate gel formed by alkali aggregate reaction is confined by the surrounding cement paste and internal pressure is developed leading to expansion, cracking and disruption of cement paste.

FACTORS AFFECTING ALKALI-AGGREGATE REACTION.

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i) Reactive type of aggregate
ii) High alkali content in cement
iii) Availability of moisture
iv) Finess of cement particles.

Measures to control Alkali-Aggregate Reaction

i) selection of non-reactive type of aggregate
ii) By restricting alkali content in cement below 0.6%.
iii) By controlling temperature
iv) By controlling moisture condition
v) By the use of Pozzolanas.

THERMAL PROPERTIES

The principal thermal properties of the aggregate are i) coefficient of thermal expansion ii) Specific heat (iii) Thermal conductivity

For majority of aggregate the coefficient of thermal expansion lies between 5.4×10^{-6} and 12.6×10^{-6} per °C.

* The specific gravity of aggregate is a measure of its heat capacity, whereas thermal conductivity is the ability of the aggregate to conduct the heat.

FINENESS MODULUS

The fineness modulus is a numerical index of fineness giving some idea of the mean size of the particles present in the entire body of the aggregate.

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The determination of the fineness modulus consists in dividing a sample of aggregate into fractions of different sizes by sieving through a set of standard test .

→ The value of finess modulus is higher for coarse aggregate.

DELETERIOUS SUBSTANCES IN AGGREGATES

The materials whose presence may adversely affect the strength, workability and long term performance of concrete is known as deleterious materials.

→ These are considered undesirable as constituent because of their intrinsic weakness, softness, fineness or other physical or chemical characteristics harmful to the concrete behaviour.

→ Deleterious substances is divided into 3 broad categories.

i) Impurities interfering with the process of hydration of cements.

ii) Coatings preventing the development of good bond between aggregate and the cement paste.

iii) Unsound particles which are weak or bring about chemical reaction between the aggrege and cement paste.

GAP - GRADED AGGREGATE

Gap graded is defined as a grading in which one or more intermediate size fractions are absent.

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some important features are :-

1. For the given aggregate- cement and water-cement ratio the highest workability is obtained with lower sand content in the case of gap graded agg. rather than when continuously graded agg is used.
2. Gap graded ~~concrete do~~ aggregate does not affect compressive or tensile strengths.
3. specific surface area of gap graded agg is lower because of higher percentage of coarse aggregate.
4. Gap graded aggregate requires lesser cement and lower water-cement ratio.

MAXIMUM SIZE OF AGGREGATE

In general larger the maximum size of the aggregate smaller is the cement requirement for a particular w/c ratio.

* Due to smaller surface area of the large size aggregate, the w/c ratio can be decreased which increases the strength.
* The maximum size of aggregate also influences the compressive strength of concrete in that for a particular volume of aggregate the compressive strength tends to increase with the decrease in the size of the coarse aggregate.

→ For high strength concrete a 10 or 20 mm size of aggregate is preferable.
→ For strength up to 20 MPa agg upto 40mm may be used.

→ For strength above 30 MPa agg upto 20mm may be used...

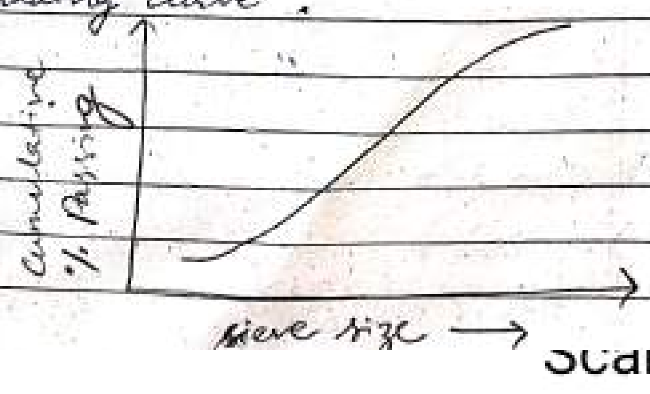
GRADING OF AGGREGATE

The particle size distribution of an aggregate is determined by sieve analysis known as grading of aggregate.

For coarse Aggregate — 80mm
40 mm
20 mm
10 mm
4.75 mm

For Fine Aggregate — 10 mm
4.75 mm
2.36 mm
1.18 mm
600 μ
300 μ
150 μ.

The results of the sieve analysis are plotted with sieve sizes on horizontal (logarithmic scale) and cumulative percentage passing on vertical axis (ordinary scale). The curve obtained is called 'grading curve'.



Informations from the Curve.

(i) If the actual grading curve is below the specified grading curve, the aggregate is coarse and seggregation of mixture takes place.

(ii) If the actual grading curve lies well above the specified grading curve, the aggregate is finer and more water is required

(iii) If the actual grading curve is steeper than the specified grading curve it indicates an excess of medium size particles.

(iv) If the actual grading curve is flatter than the specified grading curve, it indicates the deficiency of medium size particles.

$\frac{W}{C}$ → Water to Cement Ratio

Manufacturing Process of Cement

The manufacturing procedures of Portland cement is described below :-

1) Mixing of raw material
2) Burning
3) Grinding
4) storage and Packaging

1) MIXING OF RAW MATERIAL

The major materials used in the manufacture of cement are calcium, silicon, iron and aluminium. The mixing procedure is done in 2 methods.

- Dry Process
- Wet Process.

(a) Dry Process – The both calcareous and argillaceous raw material are firstly crushed in the gyratory crusher to get 2.5 cm size pieces separately. The crushed material are again grinded to get fine particles into ball or tube mill. Each finely grinded material is stored in the hopper after screening. Now these powdered minerals are mixed in required proportion to get dry raw mix which is then stored in silos and kept ready to be sent into rotary kiln. Now the raw materials are mixed in specific proportions so that the average composition of the final product is maintained properly.

Calcareous materials → Jaw crusher → Bin

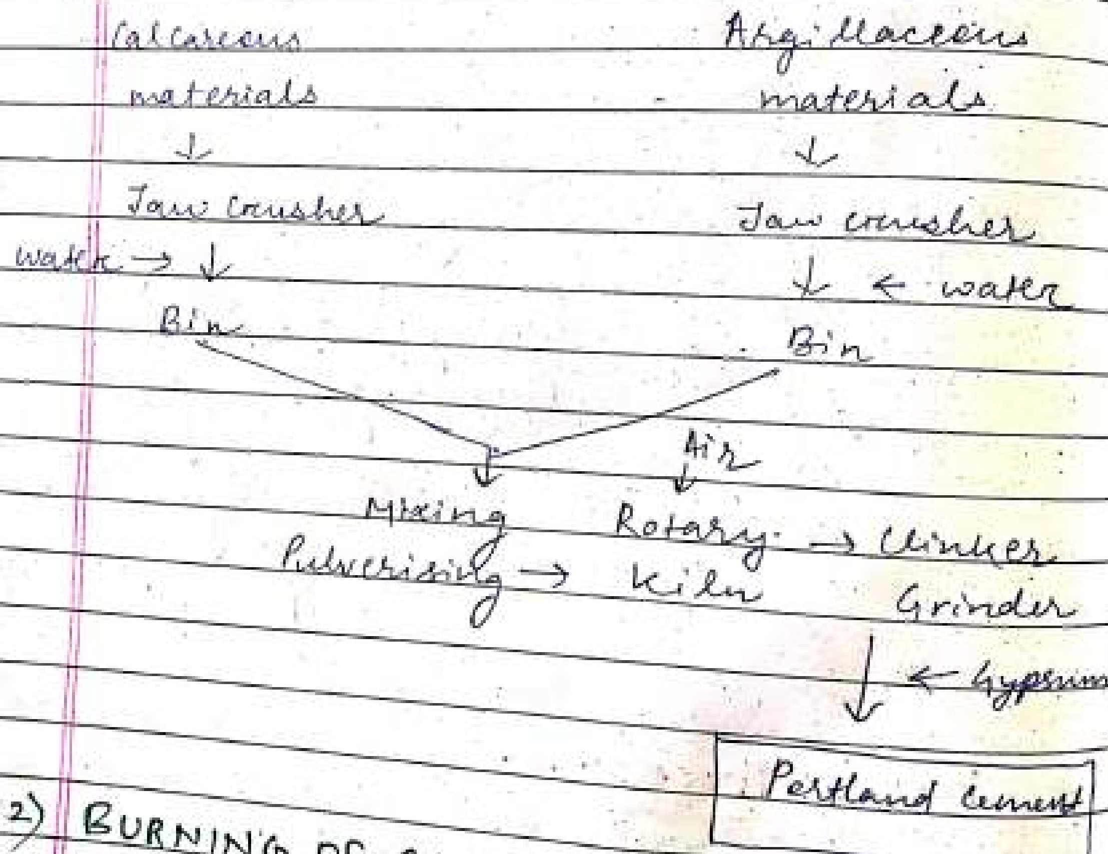
Argillaceous material → Jaw crusher → Bin

Bin + Bin → Mixing Pulverising → Rotary kiln (← Air) → Clinker Grinder (← Gypsum) → **Portland Cement**

b) **Wet Process** — The raw materials are firstly crushed and made into powdered form and stored in silos. The clay is then washed in washing mill to remove adhering organic matters found in clay.

The powdered limestone and water washed clay are sent to flow in the channels are transfer to grinding mills where they are completely mixed and paste is formed known as slurry.

The grinding process can be done in ball or tube mill or even both. Then the slurry is led into collecting basin where composition can be adjusted. The slurry contains about 30-40% water that is stored in storage tanks and kept ready for the rotary kiln



2) BURNING OF RAW MATERIAL

The burning process is carried out in the rotary kilns where the raw materials are rotated at 1-2 rpm at its longitudinal axis. The raw mix of dry process or corrected slurry of wet process is injected into the kiln from the upper end. In the upper part, water or moisture in the material is evaporated at 400°c temperature so, this process is known as drying zone.

The central part i.e calcination zone, the decomposition of limestone takes place. The remaining material is in the form of small lumps known as nodules after the CO_2 is released. The lower part is known as clinkering zone. In this region lime and clay reacts to yield calcium aluminates and calcium silicates. This products of aluminium and silica of calcium fuses together to form hard and small stones known as clinkers.

3) GRINDING OF CLINKERS

The clinkers are grinded finely into powder in ball mill or tube mill. Powdered gypsum is around 2-3% as retarding agent during final grinding.

4) STORAGE AND PACKAGING

The grinded cement is stored in silos from which it is marketed either in container loaded or 50 Kg bags.