

Chapter - 1

Introduction

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★ Concrete:- → It is a composite and heterogeneous ^{man made} material which is most widely used building material in the construction industry.

→ It consists of binding material like lime or cement, well graded fine and coarse aggregate, water and if required some admixtures.

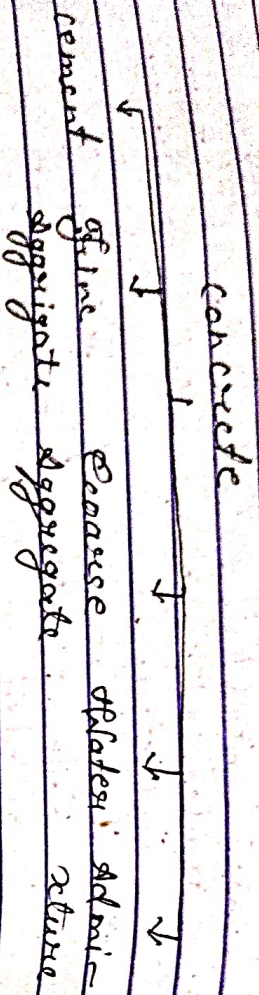
→ This mixture when allowed to set becomes hard as a stone.

→ The strength of concrete depends upon its ingredients, their relative quantities and the manner they are mixed and placed.

→ The main reason for its extensive use is that its properties can be control within a wide range by using appropriate ingredients and by special mechanical physical and chemical processing technique.

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Constituents / Ingredients of concrete:



Functions of ingredients of concrete:

1) Cement -> Cement is an adhesive binding material which is capable of binding together a particle of solid matter into a compact durable mass. The primary function is to bind fine and coarse aggregate particles together. Cement is also used to fill the voids created by the fine aggregate. Cement increases the compressive strength of concrete. It is used in giving shape of the structural elements.

from made by concrete. Cement is used in making concrete, reinforced bricks, tiles and in R.C.C. building.

2) Fine Aggregate (Sand) :-

-> It may be in the form of sand, crushed gravel or any other inert material which passes through 4.75 mm IS sieve and contains not more than 5% of coarse material. Fine aggregate gives body to concrete by increasing its volume in bulk, they also reduce shrinkage in concrete. One of the important purpose of fine aggregate is to effect the economy of concrete by controlling its volume. They do not affect the strength largely but adds to

The volume of concrete, thus affecting its economy, is also called the wastage created by the coarse aggregate.

3) Source of aggregate:-

→ These are mineral aggregate which are either obtained from natural sources or artificially which are obtained from quarries, T.S. mine, granite, limestone, sand stone, granite, marble etc.

→ The main responsibility of coarse aggregate is to increase the impact strength of concrete.

→ If concrete is viewed as two phase material, paste phase and aggregate phase, the paste phase is weaker and more permeable than the aggregate phase. The main objective achieved by aggregate is increased

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economy, higher strength, lower shrinkage and greater durability.

4) Admixture:-

→ Admixture is an important ingredient of concrete as it actively takes part in the chemical reaction with cement. Since it helps to form the strength giving cement gel, the quality and quantity of water, which is required to be added must be done carefully, since it affects the strength.

5) Admixture:-

→ It is defined as a material other than cement, aggregate and water. That is used as an ingredient of concrete and is added to the batch immediately before or during mixing.

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→ Advantages are use to modify the properties of ordinary concrete so that it can be made suitable for any situation. They impart or many desirable characteristics and effect the economy in concrete construction.

★ Grades of concrete (IS code 456-2000)

→ Concrete are generally graded according to its compressive strength (IS code 456-2000).

→ Depending upon its compressive strength in N/mm^2 of concrete cube sample of 150 mm side after 28 days of curing concrete can be classified as given below:-

→ The cement concrete is specified by the proportion of different ingredients for different grades.

→ It is pre-assumed that by following these specifications satisfactory performance will be achieved.

→ Grades of concrete :-

Mix	Grade	Proportion	compressive strength
Nominal mix	M-10	1:3:6	10 N/mm^2
	M-15	1:2:4	15 N/mm^2
	M-20	1:1½:3	20 N/mm^2
	M-25	1:1:2	25 N/mm^2
Design mix	M-30		
	M-35		
	M-40		

★ Types of concrete :-

- 1) Reinforced cement concrete
- 2) Ready mix concrete
- 3) Pure stress concrete
- 4) Fiber reinforced concrete
- 5) Polymer concrete
- 6) Air entrained concrete (Heavy weight)
- 7) Fly ash concrete
- 8) Silica fume concrete
- 9) Self compacting concrete
- 10) Vacuum concrete

★ Types of cement and their properties:-

1) Ordinary Portland cement:-

- Ordinary Portland cement is a high strength cement is suitable for all kinds of construction work.
- The fineness of this cement is $2250 \text{ cm}^2/\text{gm}$.
- The initial setting time of this cement is 30 minutes and final setting time is 10 hours.
- Its compressive strength after 28 days is $430 \text{ kg}/\text{cm}^2$

Office of OPC is:-

- It is normally used for the reinforced concrete buildings, bridges, pavements and where soil conditions are normal.
- It has great resistance to cracking, pure and shrinkage but less resistance to chemical attacks.
- It is used for general construction purposes where special properties are not required.
- It is also used for most of concrete masonry units.

2) Rapid Hardening cement:-

- This cement gains strength at higher rate.
- This cement attains strength at the age of 3 days which is equal to strength of OPC in 7 days.
- The initial and final setting time of this cement is same as OPC.
- The early strength of this cement is because of fine grinding process and due to higher C_3S and lower C_2S .
- The specific surface is greater than

3250 cm^2/gm .

- RHC is lighter than OPC.
- The curing period for RHC is less.

Uses of RHC :-

- In construction of mild pavements.
- In emergency repair work.
- In construction site where fast work is to be removed quickly.
- In cold weather condition.

3) Quick setting cement :-

- This type of cement is manufactured by mixing a small quantity of Al_2SO_4 in cement and reducing the quantity of gypsum.

Uses of Quick setting cement :-

- It is used in construction under running or stagnant water.

4) Low heat cement :-

- This cement is produced by reducing the % of SiO_2 and CaO and increasing the % of C_2S .
- The rate of development of strength is very low because the rate of hydration is decreased.

Uses of Low heat cement :-

- It is used in mass concrete construction work such as dams, pierce, foundation wall etc.

5) Portland slag cement :-

- It is manufactured by mixing cement clinkers with granulated blast furnace slag and gypsum in a pre-determined proportion.

- This cement is a low heat cement which has more resistance against the attack of chlorides, sulphates and acids.

- It gains strength with time.
- It offers less permeability.
- It is cheap and used in many construction works.

c) Pastland pozzolana cement :-

- cell pozzolanic material is essentially a siliceous and aluminous compound which does not passess. cementing property but when finely divided practicals in presence of water forms a cementing material.
- It is in the form of CaOH silica gel.
- Pastland pozzolana cement is manufactured by intergrinding OPC clinkers with 10-25% pozzolanic material.
- ^{advantage} It attains compressive strength with age.
- It can resist the action of sulphates and chlorides.
- It has more water tightness and it is cheap.
- ex:- 1) Volcanic ash, 2) Rice husk, 3) Fly ash, 4) diatomite etc.

Properties:-

- Drying shrinkage should not be more than 0.15%.
- Fineness should not be less than 300

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Advantages:-

- 7 day strength of PPC is less but final strength is equal to the 28 day strength of OPC.
- PPC has lower rate of development of strength than OPC.

Use of PPC:-

- Used in hydraulic structure, marine structures, construction near the sea shore, dam construction etc.
- Used in pre-stressed and post-tensioned concrete members.
- Used in manufacture of precast sewage pipes.
- Used under harsh concreting conditions.
- Used in masonry, masonry and plastering.

7) Coloured cement:-

- This cement is just a variety of ordinary cement which is produced by reducing the content of iron and magnesia.

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→ It is quick drying, possesses high strength and has superior aesthetic property.

→ It is used in floor finish, plaster work, painting and ornamental work.

Chromium oxide - green, cobalt - blue, iron oxide

Use of coloured cement:- red, brown, yellow

→ It is used for floor finishing.

→ Magnesium oxide - black and deep brown.

8) High alumina cement:-

→ High alumina cement has manufactured from bauxite and limestone.

→ It attains the high strength in short period.

→ It achieves the strength after 1 day up to 40 MPa.

→ It is resistant to chemical attacks and chemical corrosion.

→ The pH level is low.

→ It has high durability in sulphuric acid.

→ Hardening property of this cement is fast.

Use of HAC:-

→ Due to the property of rapid hardening and strength, it is widely used in marine construction and sewer infrastructure.

→ High alumina cement is also used in refractory concrete where it requires more strength at very high temperature.

9) Sulphate resistant cement:-

→ OPC is prone to the attack of cement which react with $CaOH_2$, CaA to form calcium sulphate aluminate whose volume is 22.7% more than original volume.

→ This cement is produced by reducing the proportion of CaA and $CaAF$.

→ Its fineness is $280 \pm 10 \text{ g m/14g}$.

→ Its initial setting time is 80 min and final setting time is 240 min.

Use of Sulphate resistant cement:-

→ Foundations, piling works.

- Effluent treatment plants.
- Chimney, cooling towers.
- Coastal are protective works, sea as sea walls, breakwaters, tetrapods etc.
- Suitable for underground works where sulphate is present in the soil and water.

10) High ^{early} strength cement:-

- Development of high early strength becomes an important factor, sometimes fast repair and emergency work.
- Research has been carried out in the recent past to develop rapid setting and hardening cement to give materials of very high early strength.
- The fineness is about 3000 sq. cm/gm.

Use High early strength cement:-

- It is use as superplasticizer in combination with a water reducing retarder.
- The most common use of high strength

cement is for construction of high rise buildings.

* Types of concrete:-

1) Fiber reinforced concrete:-

- The reinforcement of certain fibers into concrete generates fiber reinforced concrete.
- They are added to concrete because they influence the properties of concrete and limit them to a certain extent. Like elastic deformation, cracking etc.
- The principal role of fiber is to increase the toughness.
- The behaviour of fibers depends upon its length, concentration and quality of bonds.
- When a crack appears, longer fibers or fibers with low strength would easily break and lead to cover cracking.
- Applications:-

- Fiber reinforced concrete is used

in hydraulic structures, highways, bridges, air field pavement, bridge decks and tunnel lining.

→ Advantages :-

- 1) Strength of concrete increases.
- 2) Fibres help to reducing cracking.
- 3) Ductility, impact resistance and tensile strength of concrete increases.
- 4) Mix becomes cohesive and possibility of segregation reduces.

→ Disadvantages :-

- 1) Fibres reduce the workability of the mix.
- 2) Steel fibres tend to mix or get stuck in mesh and form balls during mixing.

2) Light weight concrete :-

→ For structures such as multi storied building it is desirable to reduce the dead load.

→ Light weight concrete is most suitable for such construction works.

→ Light weight concrete can be produced by using light weight aggregates, by extra entraining air or by using foam.

→ Light weight aggregate concrete is suitable where low density, heat good thermal insulation and fire protection are required.

→ It can be made by following methods :-

- a) By making concrete with cement and coarse aggregate only, such concrete is also known as no fine concrete.

In this type of concrete, natural aggregates are used such as pumice stones, blast furnace slag, clinkers, which are used.
b) By replacing coarse aggregate with cellular aggregate.

→ Uses :-

They are used in multi storied building in construction of ceilings.

partition walls and fire resisting structures.

→ Advantages :-

- Dead load is reduced.
- Low density and fire resistance.
- Better thermal and sound insulation.

→ Disadvantages

- Strength of the structure is reduced.
- Noise and vibration in the room.

3) Heavy weight concrete :-

- The heavy weight concrete is also known as high density concrete and is used in heavy construction works and radiation shielding.
- This concrete is generally produced by using heavy weight aggregate.
- Concrete of this type serves to

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be most economical building material unless it comes to civil logical shielding in nuclear power plants, medical units and atomic research centre.

- The reduction in thickness of the shield is done by heavy weight concrete due to their high density.

4) Ready mix concrete :-

- It is a type of concrete that is manufactured in batching plants.
- Here the concrete mix are prepared according to pre-decided standards and then delivered to the work site by means of truck mounted transit mixers.
- RMC is preferred over site made concrete because of the accuracy of the mixture and the reduced labour at work site.
- RMC is specially manufactured for delivery to the customers.

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and at construction site is plastic

- stage is brought and sold in terms of volume usually expressed in cubic meters.
- RMC is manufactured under computer controlled operation.
- Specific equipment and method are used by ready mix plants so that the mix can easily be delivered at the point of discharge.

→ Advantages :-

- Better quality of concrete is produced
- A Centralised batching plant can secure a huge saving
- Storage space for cement material at the site is not required.
- Reduction in noise and dust pollution at the site.
- It saves labour.

→ Disadvantages :-

- Read and Site should have topography

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may be cause the weight of truck

- Sometimes the construction site are far away from the batching plant which may cause setting of cement in the concrete and will also increase the transportation cost.

5) Polymer Concrete :-

- The strength of concrete is affected by its porosity and it can be reduced by vibration, pressure application or spinning
- The impregnation of monomer and its polymerization reduces the porosity of concrete.

→ The polymers such as :-

- 1) Poly vinyl acetate,
- 2) Mono polymer emulsion
- and 3) vinyl acetate are added to in case the strength absorption, sealer to oil and short grit and also improves the bond between and old polymer.

- It is also used in prefabricated

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structures and pre-stressed concrete.

→ Uses:-

- It is used in production of prefabricated elements, prestressed concrete, marine works, nuclear power plants and in sewage disposal works.
- Due to its high sulphate and acid resistance.

→ Disadvantages:-

- Very brittle.
- Expensive.

B) Pre-cast concrete:-

- The term precast concrete denotes individual concrete members or units of various types that are separately produced before they are joined in the structure.
- They are totally opposite to cast in situ concrete.

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→ Pre cast members are casted at the building site or in a casting yard located at a distance from the site, which are then transported to the construction site. by means of a truck and finally placed in position by cranes and other such devices.

- Hollow concrete blocks are the simplest example of pre-cast unit.
- The reason for its popularity in modern building industry is the low cost at which it is produced and its ability to provide desirable strength, durability etc.

→ Advantages

- Many identical members can be produced using same formwork.
- High speed method.
- Available in diverse shapes.
- Economical.
- Suitable in all types of weather condition.

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→ Disadvantages

- The assembly of different structural elements is a difficult task.
- There are chances of damage of precast units during transportation and handling.
- Skilled labour is required.

7) Precast stressed concrete :-

- It is defined as a concrete in which stresses of suitable magnitude and distribution are introduced to a desired degree in order to counteract the stresses resulting from external loads.
- It is of two types :-
 - 1) Pre-tensioning
 - 2) Post-tensioning

→ Advantages :-

- The size of structural members are reduced.

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- Resistance to impact load, shock and vibrations.
- Smaller deflections.

→ Disadvantages :-

- Extra labour cost.
- Precast stressing is uneconomical for shorter span or smaller loads.

8) High strength concrete :-

- High strength concrete have compressive strength more than 40 N/mm^2 .
- It is produced by reducing the content of CGA up to 8% and decreasing the fineness in the range $300 - 400 \text{ m}^2/\text{kg}$.
- Reducing the size of coarse aggregate and the fineness modulus of fine aggregate greater than 3000 also helps in producing high strength concrete.

→ Uses :-

- Multi storey building, bridge decks

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industrial purpose:

→ Advantages:-

- Economical.
- Reducing the size of structural elements.
- high durability in marine conditions.

2) Green Concrete:-

- Green concrete is eco-friendly and saves the environment by utilizing the waste produced by industries in various forms such as rice husk ash, mineral silica etc. to make resource saving concrete structures.

→ Advantages:-

- Saves energy.
- Economical.
- have greater strength and durability than normal concrete.

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* Admixtures:-

Admixtures is a

chemical other than cement, aggregate and water that is used as a ingredients of concrete.

- It is added to the batch before or during mixing.
- They serves various purposes according to the condition in concrete to make it suitable in different condition.

→ Admixtures are used to modify the properties of concrete so as to make it possible its suitable for any situation.

→ Types of admixtures:-

- 1) Plasticizers
- 2) Super plasticizer
- 3) Retarders
- 4) Accelerators
- 5) Air entraining admixture
- 6) Mineral admixture

1) Plasticizers:-

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→ In different condition concrete of workability is different degree of workability is required.

→ In high degree of workability is required in case of deep beams, thin walls, retaining structures with highest percentage of reinforcement pumping concrete and during not weather concreting.

→ The conventional method for obtain high workability is by gradation relatively high percentage of cement and fine aggregate etc.

→ Now a days plasticizers are used and super plasticizers can help in such situations for obtaining highest workability without using excess of water.

ex:-

- i) ligno sulphate
- ii) Polyglycolic esters
- iii) Carboxylic acid
- iv) Carbohydrates

→ Plasticizers are used in the

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amount of 0.1 to 0.4% by weight of cement and at this dose for constant water cement ratio there is a reduction of 5 to 15% of water which is expected with higher workability.

→ The action of plasticizers is cement being in fine state have the tendency to flocculate in wet concrete.

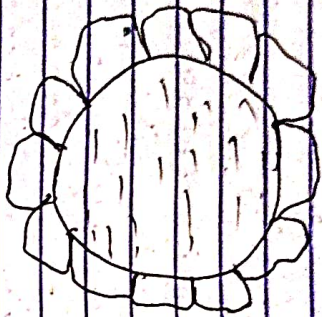
of this flocculation extracts certain amount of water used in the mix and there by all the water is not freely available for fluidity of the mix.

→ When plasticizers are used they get absorbed on the surface of cement particle and induce and similar change among them due to the similarity in charge cement particles generate repulsive force among them and try to move away from each other.

Due to this the water trapped inside gets released and

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→ If water becomes available to the mix.



plasticizer



→ If it is used in production of self compacting concrete, decrease of self and in high strength concrete. Of the mechanism of super plasticizers is more or less same as the plasticizers.

→ They are more powerful and an high water reducing.

→ As a result super plasticizers increased strength, workability with lower water cement ratio.

→ Of the super plasticizers produce homogeneous cohesive concrete without tendency of segregation and bleeding.

ex:-

i) Sulphonate melamine formaldehyde condensate.

ii) Sulphonate naphthalene formaldehyde condensate.

iii) Ceece, linked acrylic polymers.

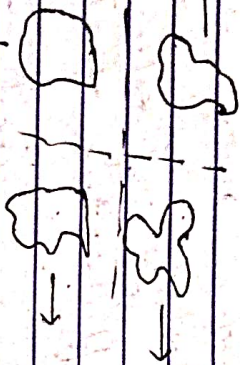
iv) Polycarboxylate ether.

3) Retarders:-

→ A retarder is an admixture

2) Super plasticizers:-

→ Super plasticizers are improved version of plasticizers they are permits the reduction of water upto 30% without of reduction in workability.



that slows down the chemical process of hydration, so that the concrete remains plastic and workable for a longer period of time.

→ Retarder are used to cover come the accelerating effect of high temperature on setting property of concrete. They are generally used in casting and grouting oil wells.

→ The retarder are also spreaded on the surface of formwork to prevent the hardening of mortar at the interface of concrete in the formwork where as the setting concrete is hardened.

ex:-

- i) Calcium sulphate
- ii) Starch
- iii) Sugar
- iv) & old salty

→ addition of retarder's from 0.05 to 0.1% have a little effect on the rate of hydration but if the quantity is increase upto 0.2% the hydration can be retarded to such an extent that the final setting time may not take place upto 72 hours.

4) Accelerator:-

→ It is an admixture that is added to concrete to increase the rate of early strength development in concrete.

→ It is used under
a) To reduce the required period of curing.
b) Permits early removal of formwork
c) In emergency repairing work.

→ One of the most commonly used accelerators is $CaCl_2$ but it is not used now-a-days.

ex:-

- 1) Soluble Carbonate
- 2) Silicates

→ Some of the accelerators are so powerful that it is possible to make the cement set into hard stone in 5 minutes.

→ With the availability of such powerful accelerators the under-water concreting becomes easy, the repair work can be carried out very fast in low temperature.

are seen in tidal areas.

5) Air Entraining Admixtures :-

→ Air entraining admixtures are ~~not~~ incompressible millions of air bubble which act as a flexible ball bearing and will modify the properties of concrete like -

- 1) improved workability
- 2) reduced segregation and bleeding
- 3) improved finishing quality.
- 4) It also modifies the

properties of hardened concrete like resistance to frost action and increased permeability.

→ The air voids can be brought

to in three ways -

- 1) Entrained air
- 2) Entrapped air

→ Entrained air is intentionally incorporated in the form of minute spherical bubbles evenly distributed along the concrete mass.

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The entrapped air in concrete is due to the presence of voids produced because of insufficient compaction.

→ The effect of air entraining admixtures on the properties of concrete -

- a) increased resistance to freezing and thawing
- b) improved workability
- c) reduction in segregation and bleeding
- 4) decreased permeability

EX :-

- 1) Oil and emulsin
- 2) animal and vegetable oil
- 3) sapon soluble soap
- 4) aluminium powder
- 5) Hydrogen peroxide

6) Mineral admixtures OR Pozzolanic admixtures :-

→ Pozzolanic materials are siliceous or still silica aluminous materials which itself does not have any cementing property but in presence of moisture it forms

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Pozzolanic Material

Natural

→ volcanic ash

→ Rice husk

→ Pumice

→ Clay and shales

Artificial

→ Silica fume

→ Fly ash

→ Slag

→ Sunkhi

cement gel like compound.

→ Pozzolana used in appropriate amount is used to modify certain properties of fresh or hardened concrete.

It has following effects on concrete -

- 1) Lowered heat of hydration
- 2) Increased water tightness
- 3) Improved resistance to the chloride (Cl_2) and sulphate (SO_4) attack.

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→ Improves workability and is economical.

★ Heat of Hydration :-

→ Hydration of Portland Cement :-

→ Portland cement is a hydraulic cement, hence it derives its strength from chemical reactions between the cement and water.

→ The process is known as hydration.

→ The cement of average composition requires approximately 25% of water by mass of chemical reaction.

→ In addition, an amount of water is needed to fill the gel pores.

→ The total amount of water, therefore needed for chemical reaction and to fill the gel pores is 42%.

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→ Cement consists of the following

- 1) best compounds :-
of calcium silicate, C_3S ($3CaO \cdot SiO_2$)
- 2) Dicalcium silicate, C_2S ($2CaO \cdot SiO_2$)
- 3) tricalcium aluminate, C_3A ($3CaO \cdot Al_2O_3$)
- 4) tetracalcium aluminoferrite, C_4AF
($4CaO \cdot Al_2O_3 \cdot Fe_2O_3$)
- 5) Gypsum, CSH_2

1) Tricalcium aluminate, (C_3A) :-

- It is formed within 24 hours of the addition of water to cement.
- It is formed about 4-14% by weight.
- Maximum amount of heat is liberated during the formation of this compound.
- Up to 3 days maximum amount of heat liberated is 210 cal/gm.

2) tetracalcium aluminoferrite (C_4AF) :-

- It is also formed within 24 hours of addition of water to cement but after the formation of C_3A .
- It is formed in about 8-10%.

by weight.

- The heat of hydration of C_4AF is $1/3$ of the amount of heat released by C_3A .
- Up to 3 days maximum amount of heat released is 70 cal/gm.

3) Tricalcium silicate (C_3S) :-

- It is formed within a week of addition of water to cement.
- Since it contains lime and silica, these compound impart strength to cement.
- The heat of hydration of this compound is approximately equal to that of C_4AF , i.e. 60 cal/gm.
- It is formed about 45-60% by weight.

4) Dicalcium silicate (C_2S) :-

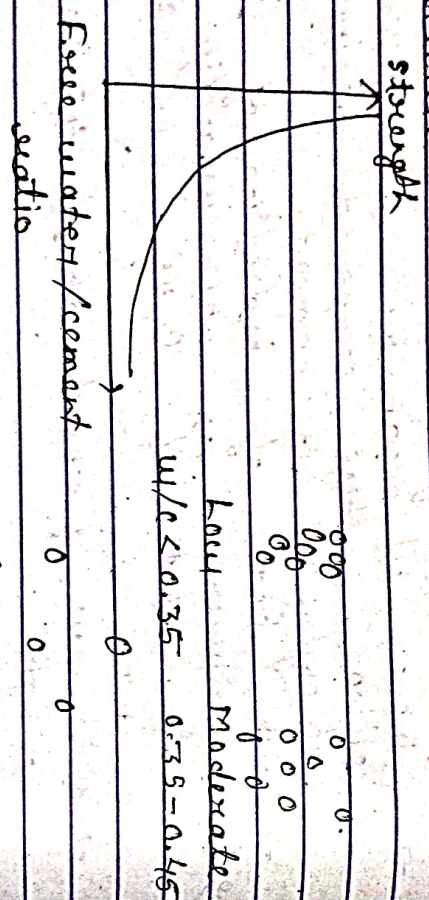
- It is formed within one year of addition of water to cement. Hence it is responsible for long strength of cement.



→ Of the strength of cement is required at later stages the proportion of CS must be increased.

→ Effect of water / cement ratio on the strength of concrete:-

→ The relation between water/cement ratio and strength of concrete is shown in the plot as shown below:



→ Effects of water / cement ratio on the strength:-

→ Of the higher the water/cement ratio, the greater the initial spacing between the cement grains and greater the volume of residual voids not filled by hydration products.

→ The workability of the concrete is reduced if the water/cement ratio is reduced.

→ A lower water/cement ratio may less water, as more cement and lower workability.

→ However if the workability becomes too low the concrete becomes difficult to compact and the strength of the concrete reduces.

For a given set of materials and environment conditions, the strength at any age depends only on the water-cement ratio, providing full compaction can be achieved.

→ The simplest way to think about the w/c ratio is to think that the greater the amount of water in a concrete mix, the more dilute the cement paste will be.



→ This is not only affects the compressive strength, it also affects the tensile and flexural strength, the porosity, the shrinkage and the colour.

→ Effects of Temperature on Hydration:

→ The rate of hydration of the cement phases, however, will increase with increasing temperature, and the setting times will decrease.

→ Above 110°C , the hydration products formed are considerably fewer than obtained at lower temperatures.

→ Temperature plays a vital role in attaining the strength of a concrete mix.

→ Harmful effects occur at both low and high temperature.

→ Gypsum and belite phases hydrate to give crystalline $\alpha\text{-C}_2\text{SH}$ rather than amorphous C-S-H .

→ $\alpha\text{-C}_2\text{SH}$ is a relatively dense crystalline material that is porous

and weak and is deleterious in that it provides high permeability and low compressive strength.

→ Formation of $\alpha\text{-C}_2\text{SH}$ can be prevented or minimized by the addition of finely ground silica, such as silica fume, to the cement.

→ Effect of Maximum size of Aggregate on Strength:

→ The larger maximum size aggregate gives lower surface area per development of gel bonds which is responsible for the lower strength of concrete.

→ Bigger aggregate size causes a more heterogeneity in the concrete which will prevent the uniform distribution of load when stressed.

→ Other large size aggregate is used, due to internal bleeding, the transition zone will become much weaker due to the development of micro cracks which result in lower compressive strength.

→ Generally, high strength concrete or

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which concrete is adversely affected by the use of large size aggregate.

- But in lean mixes or weaker concrete the influence of size of the aggregate gets reduced.
- In lean mixes larger aggregate gives highest strength while in rich mixes it gives the similar aggregate which yields higher strength.

★ Absolute Requirement of Cement :-

- CS requires 24% of water by weight for its complete hydration
- CS requires 21% of water by weight for its complete hydration.
- Cement thus as a whole requires 23% of water by weight for its complete hydration.
- 15% of water is required to fill the voids in cement.

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$$\text{Total} = 23 + 15\% = 38\%$$

Effective water requires for complete hydration of cement is 38% at 40%.

★ Hydration of Cement :-

- Anhydrous cement does not bind and cause aggregate. It acquires adhesive property only when mixed with water.
- The chemical reaction that takes place between cement and water is known as hydration of cement.
- The chemistry of concrete is essentially the chemistry of the reaction between cement and water.
- Products are formed.
- If these products are important because they have cementing or adhesive value.

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→ The quality, quantity and scale of formation of these product are important for it to gain required strength.

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→ Test of cement :-

[Dimension = 10 cm]

1) Field test :-

a) Colour test :- → The colour of cement should be uniform.
→ The typical colour of cement is gray colour with a light greenish shade.

b) Physical test :- → The cement should be

not rubbed when the fingers.

→ If it is felt rough it indicates adulteration with sand.

→ If a small quantity of cement is thrown between in a bucket of water, it should immediately sink and should not float over the surface.

→ A thin paste of cement with water should be sticky when the fingers.

c) Presence of lumps :- → The cement

free from the presence of hard lumps which are formed due to absorption of moisture from the

atmosphere by the cement particles.
→ of the cement paste more than 90 days of life and packaging.

ii) Laboratory test:-

1) Fineness test:-

a) sieving
b) Blain's air permeability test

a) sieving:- → Take 100 gm of cement sample and place it on IS sieve no. 9 of 90 μ .

- sieve the cement sample continuously for 15 minutes and check all the ~~sample~~ lumps present in the sample during sieving.
- Weigh the residue of sample left on the sieve after 15 minutes.
- If the weight of residue should not exceed 10% of initial weight.

ii) Consistency test:-

of Vicat's apparatus is used to find out the consistency, initial setting time and final setting time of cement.

A minimum quantity of water required to initiate the chemical reaction between water and cement to form a paste is known as consistency of cement.

Procedure:-

- 1) Take a sample of dried cement of about 400 gm.
- 2) Mix about 25% water by weight of dry cement and form a uniform paste.
- 3) Now fill the Vicat mould with the cement paste.
- 4) Pressure to compact the paste well after filling the mould.
- 5) Gild the cement paste to the top of the mould. Remove the excess paste by the trowel.

6) Now make the lamin. plunger fixed to

the arrangement to just touch the top surface of cement paste.

- 3) Make the freely fall and note the amount of penetration.
- 4) often the penetration is of about 40 to 45 mm to get when the reading on the vertical graduation is about 5 mm to 7 mm from the bottom of the oil cast mould is of normal consistency.

Generally the water required to form a paste of normal consistency is 30%.

iii) Initial setting time :-

Initial setting time is regarded as the time elapsed between the moments that the water is added to the cement to the time that the paste starts losing its plasticity.

Procedure :-

- 1) Prepare a neat cement paste by gauging the cement with 0.85 times

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0.85p

the water required to give a paste of standard consistency.

- 2) Stand a stop watch at the instant when water is added to the cement.
- 3) Fill the oil cast mould with a cement paste, the mould is setting on a non-porous plate.
- 4) Fill the mould completely and smooth off the surface of the paste making it level with the top of the mould.
- 5) Now place the mould under the bearing the needle, and allowing it to penetrate into the cement surface of the mould.
- 6) Repeat this procedure until the needle fails to pierce the block beyond 5.0 to 0.5 mm measured from the bottom of the mould.
- 7) The period lapsing between the time when water is added to cement and the time at which the needle fails to pierce the test block to a point 5.0 to 0.5 mm measured from the bottom of the mould shall be the initial setting time.

Generally the initial setting time of

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method to an aerial load.

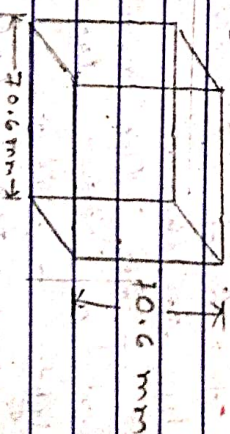
Procedure:- (Size of cube - 70.6 mm or 70 mm)

- 1) Take 200 gm of cement and 600 gm of standard sand in the mix ratio.
- 2) Mix the cement and sand in dry condition with a trowel for one minute and then add water. The quantity of water shall be $(CP/4 + 3\%)$ of combined weight of cement and sand, where P is the % of water required to produce a paste of standard consistency.
- 3) Add cement and mix it until the mixture is of uniform colour. The time of mixing shall not be less than 4 minutes.
- 4) Immediately after filling the mould place the mould in the cube mould and feed with the help of rod.
- 5) The mould shall be preloaded 20 times in about 8 sec to ensure elimination of entrained air.
- 6) If vibrator is used, the period

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of vibration shall be 2 minutes at the specified speed of 1200 rpm. Vibration

- 7) After place the cube mould in temperature of $27 \pm 2^\circ\text{C}$ and 90% relative humidity for 24 hours.
- 8) After 24 hours remove the cube from the mould and immediately immerse in clean water till testing.
- 9) The cube of loading should be 350 kg/cm² and uniform.
- 10) The test should be conducted for 3 cubes and report the average value as the test result for 7 day and 28 day compressive strength.



vi) Soundness test:- Soundness is defined as the volume

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stability of a cement paste.

Procedure is

- 1) Before conducting the test lightly oil the apparatus such as le-chamber, liey mould, glass plates (2).
- 2) of the required amount of cement.
- 3) ^{200 gm.} Prepare a cement paste by adding 0.78 times the water required for standard consistency.
- 4) Mix the cement paste well using the trowel.
- 5) Now place lightly oiled le-chamber mould on the glass panel.
- 6) fill the mould with the prepared cement paste up to the top. while placing the cement hold the mould edges gently together.
- 7) Now place the another glass plate on the top and put weight on it.
- 8) submerge the whole assembly into the water pot at a room temperature and keep it

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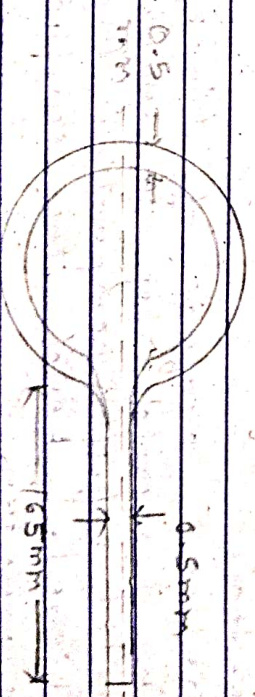
undisturbed for 24 hours.

- 9) Now remove the whole assembly from water and measure the distance between the mould edges. Note that distance L_1 of the measuring platens should indicate to the nearest 0.5 mm.

- 10) submerge the mould again into the water and bring it to the boiling point and cool down it to room temperature. Now again measure the mould edges distance as L_2 .

Roundness of cement = $L_1 - L_2$

- 2) The cement paste should not undergo large changes in volume after it has set.



le chamber apparatus

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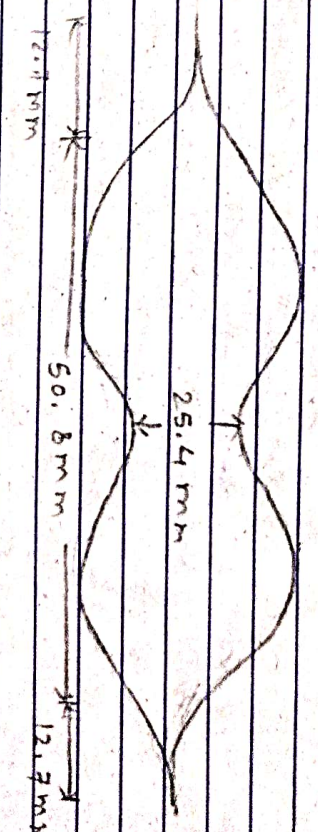
vii) offensile strength :- offensile strength should be high enough to resist cracking from shrinkage and temperature changes.

Procedure :-

- 1) Prepare cement sand mortar with a mix proportion 1:3 and create to both weights of cement and sand ratio of 18%. Use 50 gms of cement.
- 2) Mixing cement and sand at dry condition for one minute then add water and continue the mixing for 4 minutes.
- 3) Filling the internal faces of the mould.
- 4) Place the mould on the sheet of glass and fill it with a mortar.
- 5) Strike surface of the paste in a mould by a spatula until full compaction has achieved. Level the surface of the mortar.
- 6) Place mould in dry room temperature about 20 $\pm$ 1 $^{\circ}$ C and

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- 7) Open the mould and take out specimen.
- 8) Section the specimens using direct tension testing machine.
- 9) Apply the load until the failure of specimen and record the failure load.



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Aggregate Chapter - 4

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Chapter 4 Aggregate

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★ Aggregate

Aggregate materials are the fillers with a binding material in production of mortar and concrete.

→ They occupy 70-80% of the volume and have considerable influence on the properties of concrete. Therefore, it is very essential to obtain right type and quality aggregate at the site.

→ They should be clean, hard, strong, durable and graded in size in order to achieve economy from the point.

★ Classification of Aggregate :-

a) On the basis of origin :-

1) Natural aggregate :- → These are

obtained from igneous, sedimentary and metamorphic rocks.

→ They require saving and crushing

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before they can be used in concrete is sorted and gravel.

2) Artificial aggregate :- $\rightarrow$ Broken bricks, blast furnace slag and synthetic aggregate are obtained as artificial aggregate.

$\rightarrow$ Broken bricks are suitable for mass concrete.
 $\rightarrow$ Blast furnace slag aggregate is obtained from slag cooling of slag followed by its crushing and is used to make precast concrete products.

4) On the basis of size :-

1) Coarse Aggregate :- $\rightarrow$ Aggregates obtained on

4.75 mm IS sieve are identified as coarse aggregates.
 $\rightarrow$ The maximum size of coarse aggregate can be 60 mm.

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$\rightarrow$ For reinforced section the maximum size of aggregate should be atleast 5 mm less than the clear spacing b/w the reinforcement.
 $\rightarrow$ Aggregates more than 20 mm size are rarely used for R.C.C members.

2) Well in me aggregate :-

$\rightarrow$ Naturally available aggregates are cft. diff. extent fraction of fine and coarse sizes are known as all in me aggregate.
 $\rightarrow$ The efficiency of any particular fraction can be corrected but such aggregates are not recommended for quality concrete.

3) Graded Aggregate :- $\rightarrow$ Aggregate, most

through a particular size of IS sieve are known as graded aggregates.
For example :- a graded aggregate

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sample of nominal size ratio means most of the aggregate from the sample passes through 20 mm size.

4) Strive aggregate :-

→ Aggregates passing through 4.75 mm sieve are known as fine aggregate. They may be natural sand deposited by river, crushed stone or obtained by crushing of gravels. The smallest size of fine aggregate is 0.075 mm.

C) On the basis of shape :-

i) Rounded aggregate :-

→ These are generally obtained from ~~crushed~~ river or sea shore and produce minimum voids (about 32%). They have minimum gratio surface to volume and they also

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require minimum cement paste. → Poor interlocking bond. makes it unsuitable for high strength concrete.

ii) Irregular aggregate :-

→ They have about 25% of voids and require more cement paste as compared to rounded aggregates. But because of irregularity in shape they develop good bond and it is suitable for making ordinary concrete.

iii) Angular aggregate :-

→ They are sharp, angular and rough particles having maximum voids (about 40%).

→ Angular aggregates provide very good bond and are most suitable for making high strength concrete but it requires relatively more cement paste.

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iv) Flakky aggregate :-

→ The aggregate whose least lateral dimension is less than one times ($\frac{3}{4}$) of the mean dimension are known as flakky aggregate.

v) Elongated aggregate :-

→ Elongated aggregates are those aggregates whose greatest dimension is more than 1.8 times ($\frac{3}{5}$) its mean dimension.

★ Properties of aggregate :-

i) Strength :- The strength of aggregate should be at least equal to that of concrete.
 → Rocks commonly used as aggregate are concrete have much higher compressive strength than the usual strength of concrete.
 → The toughness of aggregate is measured by impact

Test and the impact value should not exceed 30% for wearing surface and 45% for remaining concrete.

The abrasion value should be upto 30% for wearing surface and 50% for remaining concrete.

ii) Bond strength :- → Due to

co-efficient of thermal expansion (α) of paste of aggregate and shrinkage of cement paste during hardening of concrete leads to internal stresses even if no external force is present.

→ These stresses create minute cracks even if concrete is never being loaded.

→ Under increasing load these cracks spread along the surface.

→ Angular aggregate would enable greater adhesion than rounded aggregate.

ii) Shape & texture:-

- The shape influence the property of fresh concrete more than the hardened concrete.
- Rounded aggregates are highly workable but produce low strength concrete.
- Ideally aggregate require more cement paste, produce maximum voids and are undesirable.
- angular aggregates are the most suitable.

Note:- angularity number:- → The angularity of the

- aggregate is expressed in terms of angularity number
- which represent the % of voids in it.

→ If the % of voids in aggregate is 33%, the angularity no. will be 0.

→ If the % voids in of the aggregate is 44%, the angularity no. is taken as 11.

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→ For good concrete angularity no. lies b/w 0 to 11.

iv) Specific Gravity:-

- SG is the ratio of density of any substance to the density of standard fluid (water).
- The specific gravity of natural aggregates lies b/w 2.6-2.7.
- A low specific gravity indicates higher porosity and therefore lower strength and durability.

Note:-

Cement	- 3.15
Granite	- 2.80
Quartz	- 2.65
Quartz sand	- 2.63

v) Bulk density:-

→ Bulk density of aggregate depends upon packing, particle shape and size and moisture content.

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→ For the proper aggregate higher bulk density results fewer voids.

★ Grading of aggregate:-

- The particle size distribution of an aggregate sample is determined by sieve analysis.
 - The aggregate sample is said to be graded if it contains different proportions.
 - The grading should be such that the voids of larger particles are filled by next smaller size particles and so on and the voids of fine aggregate are filled by coarse.
 - This result in most economical use of cement paste for filling the voids.
- Types of grading:-

i) Well graded:- Well graded

aggregate sample contains all sizes of particles, thus leading to a dense and compact mass of concrete.

ii) Gap graded:- The aggregate sample is said to be gap graded when there is gap or lack of some sizes that is certain size of aggregate are missing.

→ In such a case most of the crushed are single size crushed three produce single size aggregate.

iii) Poorly graded:- It is a type of grading in which the proportion of or some intermediate size particles are in excess or deficient are known as poorly graded or irregularly graded aggregate.

ix) Continuous graded It is the grading

in which particles of same range in continuity are termed as such grading are termed as coarser and finer depending upon the higher proportion of coarser or finer particles.

→ Effect of grading on concrete

- 1) Strength
- 2) ~~Segregation~~ Segregation
- 3) Bleeding
- 4) Voidage
- 5) Workability

★ Sieve Analysis :-

→ The operation of dividing a sample of aggregate into various fractions, each consisting of particles of same size. using some standard I.S. sieve is termed as sieve analysis.

→ The sieve analysis is done to determine the particle size distribution in a sample of aggregate.

→ It is done by sieving the known amount of sample successively through all the sieves mounted one over another in the order such that larger sieves are on top.

→ The sieves that are generally used are :-

80 mm	
63 mm	
40 mm	
25 mm	
20 mm	
12.5 mm	
10 mm	
7.5 mm	
4.75 mm	
3.36 mm	
1.18 mm	
600 micron	
300 micron	
150 micron	

sieve sizes

→ Sieving can be done either manually or mechanically.

→ The material retained on each sieve after sieving is measured separately and noted.

→ From sieve analysis only the particle size distribution is a sample of aggregate is found out. In this reference a term "fineness modulus" is used, which gives information about coarseness or fineness.

★ Fineness Modulus:- It is a ready index of coarseness and fineness of material.

→ The sum of the cumulative percentage retained on the sieve divided by 100 is termed as fineness modulus.

→ Fineness modulus varies b/w 2-3.5 for fine aggregate and 5.5-8.0 for coarse aggregate.

★ Grading Curve:- The graphical representation of the

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result of sieve analysis is called as grading curve.

→ It is plotted b/w sieve sizes on one axis and percentage retained on each sieve on the other. → Grading curve the pattern of grading can be easily determined.

★ Absorption and Moisture Content:-

→ Absorption:- All aggregate particles have pores within its body.

→ The size of pores in aggregate varies over a wide range, some being very large and some small, the water in this pores leads to absorption.

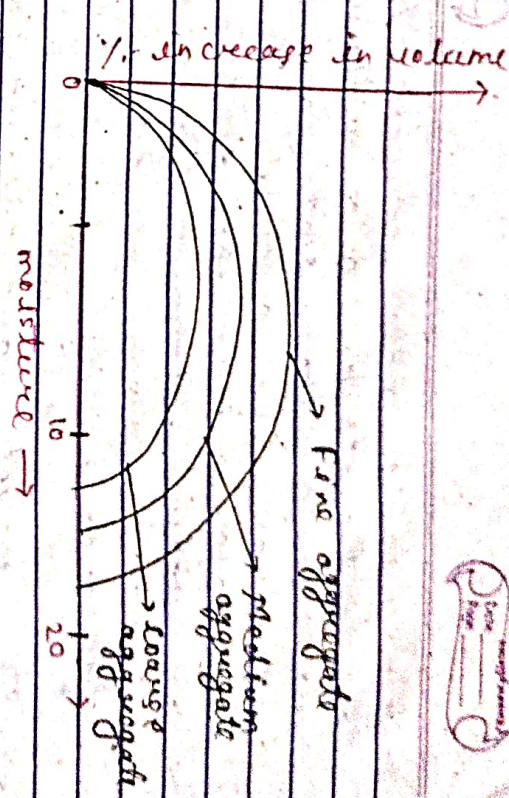
→ Moisture Content:- The surface moisture expressed as a percentage of the weight of standard saturated surface dry aggregates is known as moisture content.

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→ higher moisture content increases the effective water cement ratio to a certain amount.

* Bulking of sand in fine aggregate :-

- The moisture present in fine aggregate causes increase in volume which is known as bulking of sand.
- Due to moisture in each particle of sand gets a coating of water keeps the particles apart, these causes an increase in volume.
- Bulking (curdling) takes place more in fine aggregate (sand) than in coarse aggregate.
- The extent of bulking depends upon percentage of moisture and its fineness.
- The effect of bulking can be reduced by weight batching.



* Effect of aggregate :-

- (1) Determination of specific gravity and water absorption test - (strength)
 - About 2kg of aggregate sample is weighed thoroughly to remove fines, dried and placed in wire basket and immersed in distilled water at a temperature between 22-32°C and a cover of at least 5cm of water above the top of basket.
 - Immediately after immersion the entrapped air is removed from the sample by lifting the basket.

containing it soon above the base of the tank and allowing it to drip at the rate of about one drop per second. The basket and aggregate should remain completely ~~even~~ immersed in water for a period of 24 hours afterwards.

→ The basket and the sample are weighed while suspended in water at a temperature of 23°C - 32°C . The weight while suspended in water is noted as W_2 .

→ The basket and aggregates are removed from the water and allowed to drain for a few minutes, after which the aggregates are transferred to the dry absorbent clothes. The empty basket is then returned to the tank of water for 25 times and weighed in water = W_3 .

→ The aggregate placed on the absorbent clothes are sun-dried till no

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further moisture could be removed by this cloth. Then the aggregate are transferred to the second dry cloth spread in single layer and allowed to dry for at least 10 minutes until the aggregates are completely sun-dry. The surface dried aggregate is then weighed = W_3 .

→ The aggregate is placed in a shallow tray and kept in an oven maintained at a temperature of 110°C for 24 hrs. It is then removed from the oven, cooled in an airtight container and weighed - dry.

→ 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.

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

→ The specific gravity of aggregate

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usually used in road construction ranges from about 2.5 to 3.0 with an average of about 2.68.

→ Absorption:- The increase in the weight of aggregate due to water in the pores of the material, but not including water adhering to the outside surface of the particles, is expressed as a percentage of the dry weight.

The aggregate is considered "dry" when it has been maintained at a temperature of $110 \pm 5^\circ\text{C}$ for sufficient time to remove all uncombined water.

$$\text{Water absorption} = \left(\frac{W_3 - W_4}{W_4} \right) \times 100$$

Water absorption shall not be more than one per cent by weight.

(2) Crushing Value Test:-

→ This test is performed to find the compressive strength of

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aggregate under the action of guided loading.

→ In this test surface dried aggregate sample (A) are taken that passes through 2.5 mm IS sieve and is retained on 10 mm IS sieve.

→ The test cylinder is then filled with the aggregate sample in three layers with 25 strokes of tamping after each layer. The surface is levelled and the apparatus is placed over the turn plates of the machine.

→ A load is further subjected to a gradual load which reaches 200 kN (40 tonnes) in 10 minutes.

→ After this the load is released and the material is removed from the apparatus and is sieved on 2.36 mm IS sieve.

→ The sample passing through the sieve (B) is measured.

→ The weight of the particles passing through the sieve is

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expressed in terms of original weight of aggregate, then it is known as aggregate crushing value.

$$\text{Aggregate crushing value} = \frac{B}{A} \times 100$$

Aggregate to be used for the preparation of concrete pavements should not have value higher than 30%.

→ For other construction works not more than 45%.

(3) Aggregate impact value test:-

→ This test is performed to find the toughness of the given aggregate sample.

→ In this test surface dried aggregate sample (A) are taken that passes through 12.5 mm IS sieve and is retained on 10 mm IS sieve.

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→ The test cylinder is filled with the aggregate sample in three layers with 25 strokes of tapping after each layer. The surface is levelled and operating is placed when the two plates of the machine.

→ Now, in the machine the operating containing the sample is subjected to 15 no. of blows with the help of hammer of having weight of 14 kg and height of free fall 38 cm.

→ The crushed sample is further passed through 2.36 mm IS sieve and the weight of the particles passing through is noted (B).
→ Aggregate impact value is expressed as weight of particles passing through 2.36 mm IS sieve to the total weight of sample.

$$\text{Aggregate impact value} = \frac{B}{A} \times 100$$

→ For pavement construction - ATV not greater than 30%

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→ For other construction - ATV should not be greater than 45%.

(4) Flakiness and Elongation Index Test :-

→ Because of large number of flaky particles in the coarse aggregate more voids are formed. The concrete consequently made is weaker, resulting in uneconomy. Also durability of concrete will be affected.

→ For flatness index (F.T.) and elongation index (E.T.) sufficient quantity of aggregate is taken as as pieces of aggregate at least 30 pieces of any fraction to be tested. The sample is sieved through IS sieves as given in table.

Dimensions of thickness and length gauges :-

Size of aggregate	Thickness	Length
Passing through IS sieve	Retained on IS sieve	gauge (mm)
63 mm	50 mm	33.90

50 mm	40 mm	25 mm	10 mm	7.5 mm	4.75 mm
40 mm	25 mm	25 mm	16 mm	12.5 mm	10 mm
31.5 mm	25 mm	25 mm	16 mm	12.5 mm	10 mm
25 mm	25 mm	25 mm	16 mm	12.5 mm	10 mm
20 mm	16 mm	16 mm	12.5 mm	10 mm	10 mm
16 mm	12.5 mm	12.5 mm	10 mm	10 mm	10 mm
12.5 mm	10 mm	10 mm	10 mm	10 mm	10 mm
10 mm	10 mm	10 mm	10 mm	10 mm	10 mm
7.5 mm	7.5 mm	7.5 mm	7.5 mm	7.5 mm	7.5 mm
4.75 mm	4.75 mm	4.75 mm	4.75 mm	4.75 mm	4.75 mm

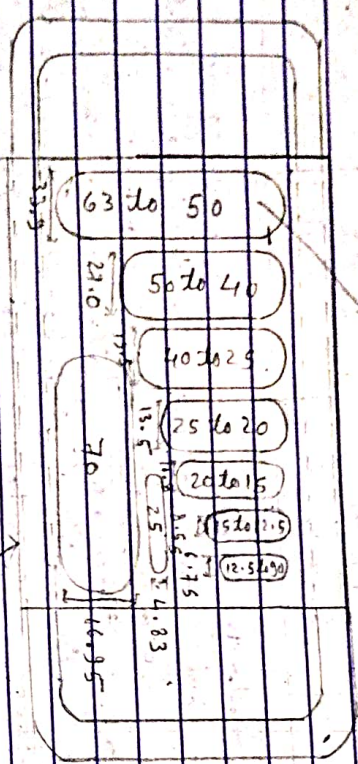
→ For determining F.T. the aggregate retained on sieves are separated. Now, each aggregate piece is passed through the corresponding slot in the thickness gauge. Flakiness index is given by

F.T. = $\frac{\text{Height of aggregate passing through the slot of the thickness gauge}}{\text{Total weight of sample}}$

→ For determining E.T. the aggregate are sieved through the corresponding sieves. Aggregate retained on each sieve are separated. Then each aggregate piece is passed through the corresponding slot of length gauge.

Height of the aggregate
retained on length gauge
Total weight of aggregate $\times 100$

These sizes marked on gauge



Addition in mm sheet rolled over 8mm layer

5) Aggregate abrasion value test
→ Los Angeles Test

- This test is performed to find the resistance against wear and tear.
- In order to perform this test Los Angeles Abrasion Testing machine is used.

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A known weight of dried aggregate (A) sample is used in this test.

- The machine is made of cast iron cylinder which consist of charges, cast iron ball and each weighing 600 390-445 gm.

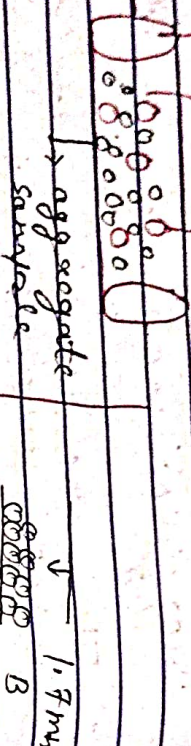
- In order to perform this test the sample of aggregate is taken into iron cylinder and by rotating each of the scale of 20-30 revolution/min. 500 revolution are given.

After this the sample is taken out of the machine and sieved through 1.75mm sieve and the weight of fraction passing through the sieve is noted (B).

$$A \cdot AV = \frac{B}{A} \times 100$$

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cylinder
N
charge



→ For aggregate to be used in pavement construction the aggregate absorption value should not be greater than 30%.

→ And for other construction work not greater than 50%.

6) Specific Surface and Surface Index

→ Specific Surface - The surface area of the material per unit weight as specific surface.

→ This is an indirect measure of grading of aggregate.

→ Specific surface increases with

the reduction in the size of aggregate particles, so that fine aggregate contributes more than the coarse aggregate.

→ Greater the surface area, more water is required for lubricating the mix to give workability.

→ Therefore, the workability of any mix is influenced more by fine aggregate than coarse aggregate.

→ Surface Index -

→ Surface Index - The total surface area of aggregate is calculated by multiplying the percentage of material retained on each sieve to its corresponding surface index and the result is added and the 330 is added and the result is divided by 100.

7) Measurement of moisture content of aggregates by :-

- 1) Drying Method :- 1. Fill the container with water upto the mark and note the weight.
2. Empty the container.
3. pour fill aggregate sample to be tested (not less than 300gms) in container water.
4. Tap up water upto the mark, remove entrained air and weight it again.

$$\text{moisture surface \%} = \frac{\text{weight of water displaced}}{\text{weight of sample}} \times 100$$

- ii) Drying Method :- 1. Place about 1kg containing moisture in the heating tray and weight it.
2. Now place the tray on the heater and heat the sample till

- dry.
3. Weigh the dried aggregate with tray.
4. Empty the tray of dried aggregate and weight the tray.

weight of tray and moist sample = W_1
 weight of tray and dry sample = W_2
 weight of tray = W_3

$$\text{moisture content \%} = \frac{W_1 - W_2}{W_2 - W_3} \times 100$$

8) Clearness, Soundness of aggregates :-

→ Clearness :- Aggregates must be relatively clear when used in HMA (Hot Mix Asphalt) or P.C.C.

→ If vegetation, soft particles, clay lumps, excess dust and vegetable matter are not desirable because they generally affect performance by quickly degrading, which causes loss of structural strength.

→ The concrete should be free from impurities which are likely to interfere with the process of hydration. prevention of effective bond between the aggregates and matrix. The impurities sometimes reduce the durability of the aggregate.

Procedure:- 1. Of the sample of sand is mixed with a liquid containing 3% solution of sodium hydroxide in water.
2. It is kept for 24 hours and the colour developed is compared with a standard colour card.
3. If the colour of the sample is darker than the standard colour card then the impurities in the sand is more than the permissible limit. In that case either the sand is rejected or is used after washing.

1. To test for clay or fine particles, a sample is first washed and dried to remove material passing the 0.075mm sieve.

2. The remaining sample is separated into different sizes and each size is weighed and soaked in water for 24 hours.
3. Particles that can be broken down into fines with fingers are classified as fine or fine material.
4. The amount of the material is calculated by percentage of total sample weight. Specifications usually limit clay and fine to a maximum of one percent.

→ Soundness:- → The soundness test on aggregate is carried out to learn the resistance of aggregate to weathering actions like freezing, thawing, etc.

→ If the resistance against weathering action is good for aggregate then it will have high durability.

Procedure:- 1. Carefully graded and weighed test sample of aggregates is soaked in either sodium sulphate or magnesium sulphate solution and oven dried if it under specified conditions.

2. The growth of salt crystals in the pores of the test sample is considered to produce disruptive internal forces similar to the action of freezing of water on crystallization of salt. After specified number of cycles, loss in weight is measured.

3. As a general guide, after 10 cycles the average loss of weight should not exceed 10% to 15% when tested with sodium sulphate and magnesium sulphate respectively.

9) Open Pore Stress Value Test

→ The sample of aggregate for this test is the same as that of the sample used of aggregate crushing value test.

→ The sample is prepared in the way as described earlier.

→ The cylinder of the test apparatus is placed in position on the base plate and test sample added in

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blinds, each blind being subjected to 25 strokes by tamping rod.

→ The surface of the aggregate is carefully tumbled and the plunger inserted so that it seats horizontally on this surface.

→ The apparatus with the test sample and plunger in position is placed in the compression testing machine. The load is applied at a uniform rate so as to cause a total penetration of the plunger in 10 minutes of about:-

15 mm for rounded or partially rounded aggregate (for ex. crushed gravel)

20 mm for normal crushed aggregates, and.

24 mm for honeycombed aggregate (for ex. expanded shales and slates.)

These figs may be varied according to the extent of the sounding or honeycombing.

→ After sounding the required maximum

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penetration: the load is released and the whole of the material removed from the cylinder and sieved on a 75µm IS sieve.

→ The fines and passing the sieve is weighed and the weight is expressed as a percentage of the weight of the test sample.

→ This percentage will fall within the range 7.5 to 12.5, but if it does not, a further test shall be made at a adjusted as seems appropriate to bring the percentage fines within the range of 7.5 to 12.5 percent.

→ Repeat test is made and the load is found out which gives a percentage of fines within the range of 7.5 to 12.5.

Load required for 10 percent fines = ~~14xx~~

~~14xx~~
Y 44

where, X = load in tons, causing 7.5 to 12.5 percent fines.

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Y = mean percent fines from three tests at X tons load.

*** Suitability of different aggregate for different concrete purpose:-**

i) Granite Aggregate:- → Granite aggregates are crushed aggregate used for hard work of granular structure being the most common in South India. It is the aggregate for high grade concrete.

→ It comes variety of shades, like grey, red and pink.

→ It can also be used for decorative feature.

ii) Gravel Aggregate:- → Gravel aggregates are

aggregates acquired as the result of examining mined rocks and by crushing natural stone rocks.

→ Gravel aggregates are used for foundations and concrete.

→ Gravel aggregates don't possess as much strength as their granite counterparts, but they are often

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cheaper to purchase.
offshore are stone types of gravel

aggregates -
a) crushed stone - regular, natural
or crushed

b) Gravel - rounded pebbles usually
from river or sea origin

iii) fine stone aggregates - $\rightarrow$ limestone
is one of

the main types of aggregates
that besides the gravel and
the granite types is used in
road construction and in
production of reinforced concrete
objects.

$\rightarrow$ lightweight aggregates are creating
through the crushing of
sedimentary rocks.

iv) Secondary aggregates - $\rightarrow$ secondary
aggregate

comes from recycling of construction
waste - concrete, bricks, and
asphalt.

$\rightarrow$ These aggregates are used
as a large-scale filler of
asphalt.

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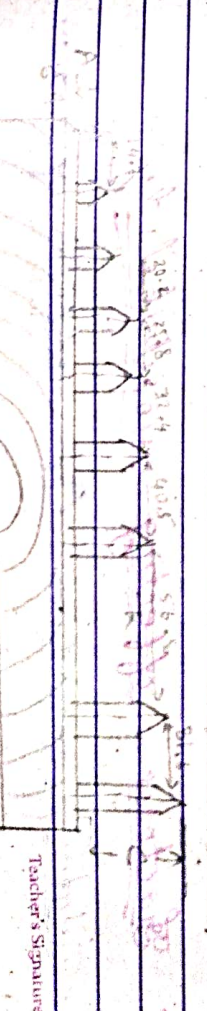
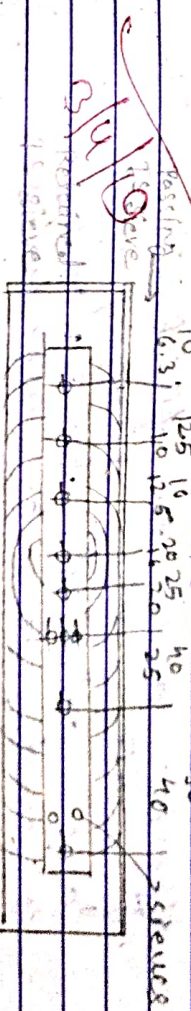
concretes with strength of 5-20 MPa.
In road construction as a filter
for roads and ramps.

v) Slag aggregates - $\rightarrow$ slag aggregates
are obtained by

after crushing of smelter slag.
 $\rightarrow$ The cost of products from
slag concrete is 20-30% lower
than traditional one.

vi) Sand - $\rightarrow$ Sand is used to provide
materials like asphalt and concrete
as well as being used for decorative
purposes.

$\rightarrow$ Sand combines with water and
other aggregates to form solid,
durable concrete.



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Workability :- $\rightarrow$ Workability is the property of concrete by virtue of which it can be easily mixed, transported, placed, compacted and finished.

$\rightarrow$ It can also be defined as the ease of working ability to work easily with the concrete.

$\rightarrow$ It may be described as amount of useful internal work done by worker to achieve full compaction of concrete without loss of handling concrete without segregation for placing the concrete without the loss of homogeneity, i.e. compacting the concrete with minimum efforts and to finish it easily if all of these purposes are achieved the concrete is said to be workable.

$\rightarrow$ Factors affecting workability :-

1) Water Content :- On addition of water

in concrete does not affect its workability, it only increases its fluidity and consistency. But in turn it reduces its strength.

$\rightarrow$ Increase in workability of the concrete can be done by increasing the water content. and consequently changing the cement content also, such that the water/cement ratio remains constant and more paste is available for lubrication.

2) Mix proportions :- $\rightarrow$ Aggregate cement ratio is an important factor influencing the workability. The higher the aggregate cement ratio, less quantity of paste is available for lubrication and, hence the workability of concrete is restrained. But in

$\rightarrow$ But in case of lower aggregate cement ratio more paste is available and thus gives better workability.

3) Surface texture:- $\rightarrow$ If there are rough

aggregates then the surface area increases by same volume reducing the permeability while smooth textured aggregate will give less frictional resistance and thus better workability.

4) Shape of aggregate:- $\rightarrow$ Angular elongated, or

flaky aggregates makes the concrete of high value rounded aggregate provide greater workability and to less surface area.

5) Use of admixture:- $\rightarrow$ It is already

discussed that plasticizers and super plasticizers improve the workability by reducing the water demand upto a great extent.

* Segregation:-

$\rightarrow$ Segregation can be defined as the separation of constituents materials of concrete.

$\rightarrow$ If the sample of concrete exhibits a tendency of separation then the sample is said to be showing the tendency of segregation.
ex:- separation of coarse aggregate from the rest of the concrete mix.

$\rightarrow$ Such a concrete is weak and lacks homogeneity.

$\rightarrow$ The conditions favorable for segregation are badly proportioned mix, where sufficient paste is not available to bind the aggregate, insufficiently mixed concrete with excess of water content.

• Discharging of concrete from height.
• Improper discharge of concrete from the mixer and its transportation.

* Collecting:-

Bleeding -

- It is form of segregation in which some water from the concrete comes out from the surface of concrete, because it is of lowest specific gravity out of all the ingredients of concrete.
- Bleeding is mostly observed in:
 - highly wettable and wet mix
 - Badly proportioned and insufficiently mixed concrete
 - Heavy weather
- Due to bleeding water comes up and accumulates the surface, sometimes along with this water certain quantity of the cement also comes to the surface. When the surface covered upon with this water or float, the aggregates goes down and the cement and water comes up to the top surface.
- This formation of cement paste at the surface is known as "laitance".

* Measurement of Observability :-

- M. S. Khan
M. S. Khan
- (1) Slump Cone Test :- → Slump cone test is the most commonly used method for measuring workability of concrete in a laboratory or at site of work.
- It is used conveniently as a central test.
- Vertical settlement of a standard cone of freshly prepared concrete is called slump.

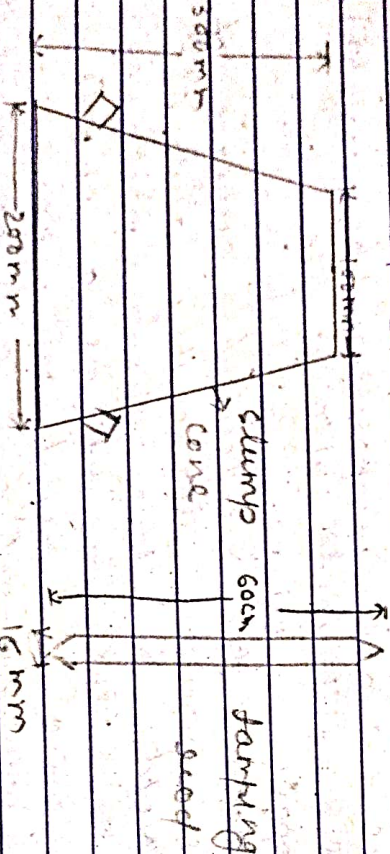
Procedure :-

- 1) Take a mix proportion (by weight), use different w/c ratio to prepare mixes.
- 2) Clean the internal surface of the mould thoroughly and it should be free from moisture.
- 3) Place the mould on a smooth, horizontal, rigid and non absorbent surface, such as carefully levelled metal plate, and fixed it.
- 4) Fill the mould with freshly prepared concrete in three layers and compact each layer by tapping with 25 strokes of tamping rod.

5) After the top layer has been seeded, the excess concrete, make level with a trowel or tapping steel.

6) Carefully lift the mould vertically so as not to disturb the concrete cover.

7) Determine the level difference bet the height of the mould and the highest point of the sub graded concrete.



(iii) Compaction Factor Test:- Compaction factor test

is used for less workable concrete (less w/c ratio).

Procedure:-

- 1) Prepare mix.
- 2) Clean the inner surface of the

upper, lower hopper and the cylindrical mould.

3) Take the weight of the cylinder (W₁).

4) Place the concrete mix in the upper hopper up to the top.

5) Open the trap door of upper hopper to allow concrete to fall in the lower hopper.

6) Then open the trap door of the lower hopper to allow concrete to fall in the cylindrical mould.

7) The concrete is made levelled at the top of the cylinder.

8) Take the weight of the cylinder with partially filled compacted concrete (W₂)

9) The cylinder is emptied and then refilled with the same sample of concrete in layers approximately 60mm deep.

10) Each layer is heavily rammed and so as to obtain full compaction.

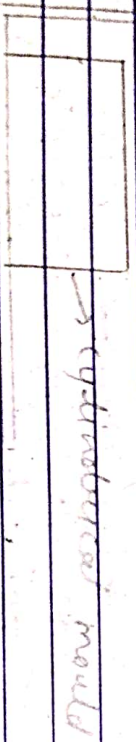
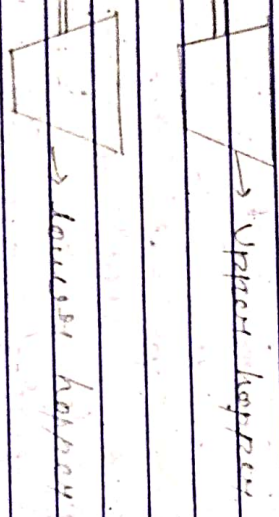
11) Top surface is then carefully made levelled.

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2) Take the weight of fully compacted concrete with cylinder (W₃)

weight of partially compacted concrete
 weight of fully compacted concrete

$$C.F. = \frac{W_2 - W_1}{W_3 - W_1}$$



(III) Flow test:- This test is giving us the ability of concrete to flow under the gravitational force when poured and

B

compacted within the cone and suddenly lifted up.

Procedure:-

- 1) The flow table is used.
- 2) The cone is placed on the flow table and filled with fresh concrete in three 3 layers, each layer 25 times tamp with tamping rod.
- 3) The cone is filled, lifted, allowing the concrete to flow.
- 4) The flow table is then lifted up (12.5mm/sec) at 15 times/min.

5) After this the diameter of the concrete is measured in a different direction and take the average.

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

Percent of flow	Consistency
0-20%	Very Dry
20-60%	Stiff
60-100%	Plastic
100-120%	wet
120-150%	sloppily

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(iv) Vebe consistency test:-

→ It is based on the principle of measuring the time needed to transfer the shape of a concrete mix from a prismatic cone into a cylinder by vibrating and compacting the mix.

→ The mass ve be needed the less workable the mix is.

Procedure:-

- 1) Slump test as described earlier is performed, placing the slump cone inside the sheet metal cylindrical pot of the consistometer.
- 2) The glass disc attached to the swirl arm is turned and placed on the top of the concrete in the pot.
- 3) The electrical vibrator is then switched on and simultaneously a stop watch started.
- 4) The vibration is continued till such time as the conical shape of the concrete disappears

and the concrete assume a cylindrical shape of transparency. A

5) This can be judge by observing the glass disc from the top disappearance of transparency.

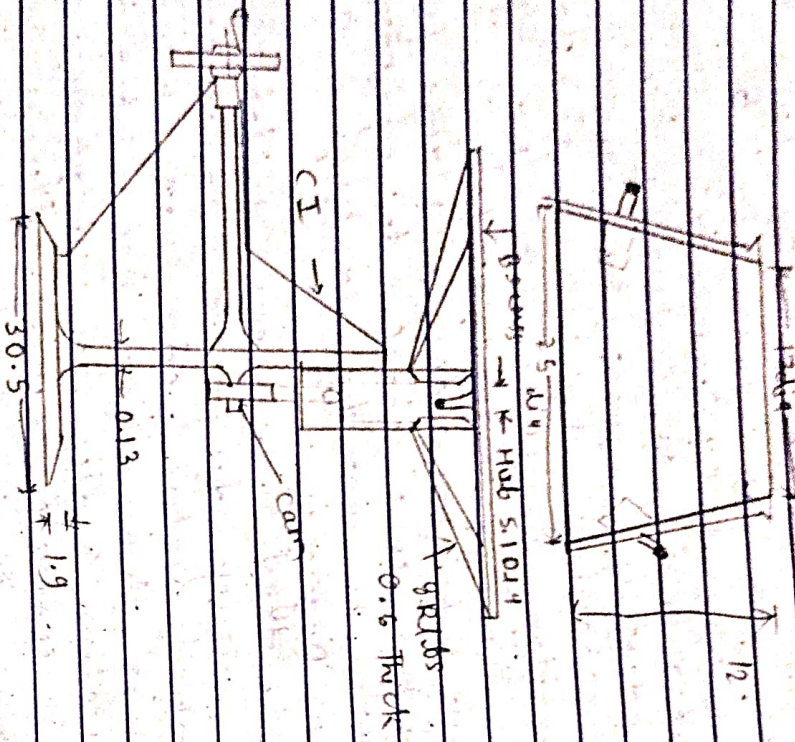
6) Immediately when the concrete fully assume a cylindrical shape, the stop watch is switched off.

7) The time required for a shape of concrete to change from slump cone shape to cylindrical shape in second is known as Vebe Degree.

8) This method is very suitable for very dry concrete where slump value can not be measure by slump test, but the vibration is too vigorous for concrete with slumps greater than about 50 cm.

The test fails if Vebe Time is less than 5 seconds and the test must be repeated when no collapse or shear slump in concrete.

Mould for blow test



All dimensions in cm

Fig - Blow Test Apparatus

Blow Test

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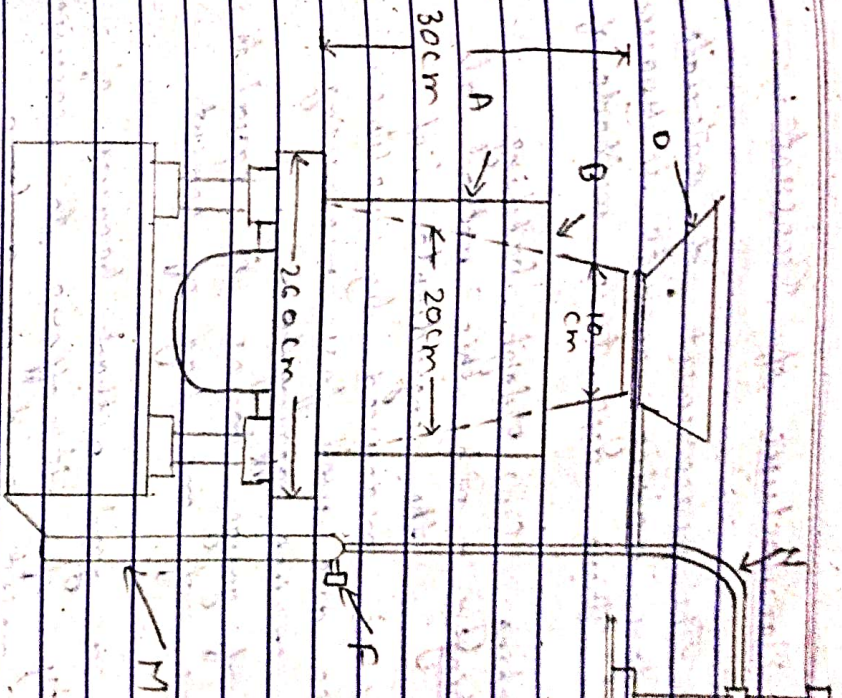


Fig - Vee Bee consistency meter type VBR

Vee Bee Test

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* Sources of Manufacture of Concrete :-

(1) Batching :- The measurement of materials for making concrete is known as batching. There are two methods of batching :-

(i) Volume batching (ii) Weight batching

(1) Volume batching :- In this method all the ingredients of concrete are measured by volume.

→ Gauge boxes are used for measuring fine and coarse aggregate.

→ The volume of gauge boxes is equal to the volume of one bag of cement (35 litres).

→ It is not a good method because of the difficulty of it offers to measure the volume of moist sand in a loose condition of weights much less than the same volume of dry compacted sand.

(ii) Weight batching :- → This batching is more preferable than volume batching as it is more accurate and leads to more uniform

preparation of bulking of sand does not

get any effect to this batching.
→ This method, adopted for large projects, → Weight batching is used for this purpose.

(2) Mixing :- In this process all the materials are thoroughly until the mixed in required proportion until the paste shows uniform colour and consistency. There are two methods adopted for mixing concrete :-

(i) Hand mixing (ii) Machine mixing

(i) Hand mixing :- → Hand mixing is practised for small scale unimportant concrete works.

→ 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. Pour the cement on the top of it, and mix them dry be shovelled, turning the mixture over and over again until uniformity of colour is achieved.

→ This operation is continued till such time a good uniform, homogeneous concrete is

obtained.

→ This uniform mixture is spread out in thickness of about 20 cm. plaster is taken in a water can fitted with a seat - head and specialised over the mixture and simultaneously turned over.

(ii) Machine mixing :- → Machine mixing is efficient, and also economical, when the quantity of concrete to be produced is large.

→ Many types of mixers are available for mixing concrete are :-

(i) gutting type (85T, 100T, 140T, 200T)
As per IS 1791 - 1985 :- → It consist

of a conical drum which rotates on an inclined axis.

→ It has only one opening.

→ The drum charged directly and discharge by tilting the drum.

(ii) Non tilting type (200NT, 280NT, 375NT, 500NT)
1000NT :- → The mixing drum is cylindrical in shape.

→ It has opening on both sides.

→ The ingredients are changed in from

one opening and discharge from other opening.

(iii) Reversing (200R, 280R, 375R, 500R, 1000R) :-

→ It produces concrete in single batches.

→ The entire drum rotates around its axis as materials are loaded through a charge chute at one end of the drum and exit through a discharge chute at the opposite end of the drum.

→ To get better efficiency, the sequence of changing the loading skip is as under:-

→ Firstly, about half the quantity of coarse aggregate is placed in the skip over which about half the

quantity of fine aggregate is poured. → In that, the full quantity of cement

i.e., one bag is poured over which the remaining portion of coarse aggregate and fine aggregate is deposited in sequence.

→ Before the loaded skip is discharged to the drum, about 25% of the total quantity of water required for mixing, is introduced into the blades at the bottom of the drum.

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→ Immediately on discharging the dry material into the drum, the remaining 75% of water is added to the drum.

→ Concrete mixers are generally designed to run at a speed of 15 to 20 revolutions per minute.

→ When proper mixing, it is seen that about 25 to 30 revolutions are required.

(3) Transpasting:- Concrete can be transported by a variety of methods and equipments are:-

- Mastay pan
- thick barrow
- Crane, bucket and slope tray
- Truck mixer and drum
- Belt conveyors
- Chute
- Skip and hoist
- Pump and pipe line

(a) Mastay pan:- It is the most common method adopted in this country for transporting the concrete.

→ It is labour intensive. In this case, concrete is carried out in small quantities.

(b) thick barrow:- It is used for

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transporting concrete to be placed at ground level.

→ This method is employed for longer distance as in the case of concrete road construction.

(c) Crane bucket and slope way:-

→ Crane and bucket is one of the weight equipment for transporting concrete above ground level.

→ Crane can handle concrete in high rise construction projects.

→ Rope way and bucket are used, where simple method of transporting concrete is found not feasible such as in valley or the construction work of piers in the river or for dam construction.

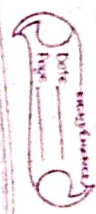
(d) Truck mixer and drum:-

→ For large concrete quantities particularly for concrete to be placed at ground level, trucks and dumpers can be used.

(e) Belt conveyor:- Belt conveyors can place

large volume of concrete

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above access is limited...
 - Belt conveyors have very limited adjustable reach, travelling slower and variable speed of the forward and reverse.

(f) Chute :- It is used for transporting concrete from ground level to a lower level.

(g) Skip and hoist :- This method is adopted for transporting concrete vertically up for multi-storey building construction.

(h) Pump and pipe line :- Pumping of concrete is universally accepted methods of concrete transportation and pumping. It is adopted because pumping become more reliable and also enable the concrete to be pumped over a long better understand.

(4) Compaction :- Placing :- It is process at job site, it is important factor to



yield optimum results.
 The precautions to be taken and methods adopted while placing the concrete in the under mentioned condition, will be discussed :-

- 1) All the loose earth must be removed from the bed.
- 2) Any sort of trees passing through the foundation must be cut.
- 3) If the foundation bed is too wet and rain soaked, the water and slush must be removed completely.
- 4) The earth must be properly compacted and made sufficiently damp to prevent absorption of water from concrete.
- 5) The concrete must be dumped and not poured.
- 6) Concrete must be placed in just required thickness.

(5) Compaction :- Compaction of concrete is process to remove the entrapped air from the concrete.

On the process of mixing, transporting to get entrapped in the concrete. It has been proven experimentally that

1% air in the concrete approximately reduces the strength 6%.

The following methods are adopted for compacting the concrete:-

- (a) Hand Compaction
- (i) Radding (ii) Ramming (iii) Tamping
- (b) Compaction by vibration
- (i) Internal vibrator (Needle vibrator)
- (ii) External vibrator (External vibrator)
- (iii) Table vibrator
- (iv) Platform vibrator
- (v) Surface vibrator
- (vi) Vibratory roller
- (c) Compaction by pressure and jolting
- (d) Compaction by spinning

(a) Hand Compaction:- Hand compaction of concrete is adopted in case of unreinforced concrete works of small magnitude.

Hand compaction consists of ramming, rodding or tamping.

(i) Rodding:- The thickness of the layer of concrete is limited to about 15 to 20 cm.

Rodding is nothing but packing the concrete with about 2 m. long 16mm

dia rod to pack the concrete thru the reinforcement and sharp corners and edges.

(ii) Ramming:- Ramming should be done with light ramming can be permitted in unreinforced foundation concrete on ground floor construction.

(iii) Tamping:- It is used for compacting roof or floor slab over broad pavement where the thickness of concrete is comparatively less and the surface to be finished smooth and level.

→ Tamping is done with the help of wooden cross beam of section about 10x10cm.

(b) Compaction by vibration:- Where high required, it is necessary that stiff concrete with low water/cement ratio be used, to compact such concrete vibratory equipment must be used.

Where are some different types of vibrators as follows:-

(i) Internal vibrator:- The internal vibrator is most commonly used. This is also called

"Needle vibrator" or "Poker vibrator".

- This is essentially consists of a power unit, a flexible shaft and a needle. It is operated by electricity or petrol engine or air compressor.
- The frequency of vibration varies upto 1200 cycles of vibration per minute. The needle varies from 20mm to 75mm and its length varies from 25cm to 90cm.

(ii) External Vibratory [Gauguin's Vibratory]

- Gauguin's 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.
- This method of vibrating concrete is particularly useful and adopted where reinforcement, lateral ties and spacers interfere too much with the internal vibration.
- The efficiency of external is lower than the efficiency of internal vibrator.

(iii) Table Vibrator :- → This is the special case of journal's 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.
- This is mostly adopted in the laboratory use and in making small but precise precast R.C.C. members.

(iv) Platform Vibrator :- → Platform vibrator

- it is larger in size. This is used in the manufacture of large precast concrete elements such as electric poles, railway sleepers, prefabricated roofing elements etc.
- The platform vibrator is also coupled with jacking or shock giving arrangements.

(v) Surface Vibrator :- → Surface vibrators

- are also known as "Screed Board vibrators".
- A small vibrator placed on the screed

board gives an effective method of compacting and levelling of thin concrete members, such as floor slabs, roof slabs and road surface.

→ In general, surface vibrators are not effective beyond about 15 cm.

→ In modern construction practices like vacuum deaerating technique, or slip form paving technique, the use of screed board vibrators are common feature. In above situations double beam screed board vibrators are often used.

(vi) Optional 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.

→ Such roller compacted concrete of grade M10 has been successfully used as base course, 15 cm thick, for the Delhi - Mathura highway (V) and Mumbai - Pune express highways.

(vii) Compaction by Vibration and Spinning :-

→ This is the effective method 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 gives jolts, which the combined action of the jolts vibrations and pressure, the stiff concrete gets compacted to a dense mass to give good strength and volume stability and yield very high strength.

(viii) Compaction by Spinning :- → This method

adopted for the fabrication of concrete pipes.

→ The plastic concrete when spun at a very high speed, it gets well compacted by centrifugal force.

→ Stented products such as "flume pipes", "spin pipes" are compacted by spinning process.

→ Spinning instructions on use of vibrators :-

→ Height of concrete layer shall be placed in a thickness not more than 60 cm

and an initial placing in thickness not more than 15cm.

→ Depth of immersion of vibrator 10 to 20 cm.

→ Spacing and Number of Insertion Positions

→ With concrete of 0.78 to 0.85 compacting factor, the vibrator shall be operated at points 35 to 45 cm apart.

→ Speed of Insertion and Withdrawal of the vibrating Head → The rate of withdrawal is determined by the rate at which the compaction in the active zone is completed.

A speed 3 cm/s gives sufficient consolidation. The vibrating head shall be irregularly and uniformly inserted in the concrete.

→ Duration of vibration → New filling shall be vibrated while the concrete is plastic & preferably within one hour. The duration of vibration dependent upon the height of layer, size and characteristics of the vibrator and workability of concrete mix.

→ Vibrating the Reinforced concrete → The reinforcement should be designed to leave off used space for the vibrating head.

offshore, possible, the reinforcement may be grouped so that the width of groups of bars does not exceed 25 cm and a space of 7.5 cm exists between the groups of the bars.

→ Vibrating near the measurement of the distance of the vibrator from the formwork is 10 to 20 cm.

→ Characteristics of Immersion Vibrator:

S.N.	Length of the vibrating Needle (mm)	dia of the vibrating Needle (mm)	Recommended frequency of vibration under no load state Min. Vibration (vpm)	Recommended vibration Acceleration (m/s ²)
(i)	up to 350	up to 35	9000	30 to 50
(ii)	250 to 500	over 35	9000	over 30
(iii)	up to 600	up to 60	7000	up to 60
(iv)	750 to 1000	up to 75	7000	up to 75
(v)	1000 to 1475	up to 90	6000	up to 90

(c) Curing :- Curing of concrete is the last and one of the most important activities required to be taken in the process of concrete construction.

→ Curing of concrete is the process of maintaining moisture and temperature condition of concrete for fast hydration reaction.

→ The cement requires a water/cement ratio about 0.23 for hydration and a water/cement ratio of 0.15 for filling voids. In other words, if water/cement ratio of about 0.38 would be required to hydrate the cement.

Curing methods may be divided into four categories :-

- (a) Plaster curing
- (b) Membrane curing
- (c) Application of acid
- (d) Miscellaneous

(a) Plaster Curing :- → This is by far the best method of

curing as it satisfies all the requirements of curing, namely, permeation of hydration, elimination of shrinkage

and absorption of the heat of hydration. Plaster curing can be done in the following ways :-

- (a) Immersion
- (b) Ponding
- (c) Spraying or fogging
- (d) Sheet covering

→ The precast concrete items are usually 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 are concrete columns etc. are cured by spraying water.

→ In some cases, wet coverings such as wet gunny bags, hessian cloth, jute matting, straw etc. are wrapped to vertical surface for keeping wet concrete. For horizontal surfaces saw dust, earth or sand are used as wet covering to keep the concrete in wet condition for long time.

(b) Membrane Curing :- → This method is

used where there is acute shortage of water, or in case of

Application of water for water curing is not possible for reasons of economy.

→ It means also creation of conditions for progressive hydration.

→ It is also pointed out that the quantity of water mixed for making concrete is more than sufficient.

to hydrate the cement provided the water is not allowed to go out from the body of concrete.

→ If this means concrete could be covered with membrane which will effectively seal off the evaporation of water from concrete.

It is found that the application of membrane as a sealing compound after a short spell of water curing for one or two days is sometimes beneficial.

→ Some of the materials that can be used for this purpose are bituminous compounds, polyethylene

oil, polyester film, water proof paper, asphalt etc.

(c) Application of Heat → When concrete is subjected to higher temperature it accelerates the hydration process resulting in faster development of strength.

→ A faster attainment of strength will contribute to many other advantages mentioned below:-

(a) Concrete is vulnerable to damage only for short time.

(b) Concrete member can be handled very quickly.

(c) Less space will be sufficient in the casting yard.

(d) A smaller curing tank will be sufficient.

(e) The works can be put on to service at a much early time.

The exposure of concrete to higher temperatures is done in the following manner:-

(a) Steam curing at ordinary pressure
(b) Steam curing at high pressure
(c) Curing by infra red radiation
(d) Electrical curing
(e) Steam curing at ordinary pressure

→ This method of curing is often adopted for precast concrete elements.

placed in a chamber the door is closed and the steam is applied.

→ The steam may be applied either continuously or intermittently.

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

(b) Steam curing at high pressure:- → In the steam curing

at atmospheric pressure, the temperature of the steam is naturally below 100°C .

The steam will get converted into water thus it can be called in a way,

as hot water curing.

→ This process is also called "Autoclaving".

It is used for pre cast concrete products and particularly for light weight concrete products.

→ The following advantages are derived from high pressure steam curing process:-

1) High pressure steam cured concrete develops in one day, or less, the strength as much as the 28 days

strength of normally cured concrete.

2) High pressure steam cured concrete exhibits higher resistance to sulphate attack, freezing and thawing action and chemical action. It also shows less efflorescence.

3) High pressure steam cured concrete exhibits lower drying shrinkage, and moisture movement.

→ In high pressure steam curing, concrete is subjected to a maximum temperature of about 175°C which corresponds to a steam pressure of about 8.5 kg/sq. cm.

(c) Curing by Infra-red Radiation:- →

→ Curing of concrete by Infra-red Radiation has been practised in very cold climate regions in Russia.

→ It is claimed that much more rapid gain of strength can be obtained than with steam curing and that avoid initial temperature does not cause a decrease in the ultimate strength.

→ The system is often adopted for the curing of hollow pre concrete products. The normal operative temperature is kept at about 90°C.

(d) Electrical Curing:- This method is applicable mostly to very cold climate regions in the use of electricity. Concrete can be cured electrically by passing an alternating current through the concrete itself, either thru electrodes buried in or applied to the surface of the concrete. Care must be taken to prevent the moisture from going out leaving the concrete completely dry.

(e) Miscellaneous:-
→ CaCl₂ is used either as a surface coating or as an admixture.
→ It has been used satisfactorily as a curing medium.
→ Both these method are based on the fact that CaCl₂ 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.

(f) Finishing:-
→ Finishing is the last operation in making concrete. It applies to all concrete operations, whether for concrete road pavement or for the flooring of a domestic building, careful finishing is of great importance.
→ Different types of finishes are:-
(a) Floor finish
(b) Surface treatment
(c) Applied finishes

→ sand facing	→ Rough cast finish
→ combed finish	→ Pebble Dash
	→ Fair Face
	→ Non-slip finish
	→ Water resistant floor finish

c) Grinding and Polishing

- 4) Creasiness
- 5) Higher Concrete Finish

→ Requirement of good finish:-

- 1) Durable
- 2) Non absorptive texture
- 3) Suitable texture
- 4) Free from cracks
- 5) Creasing
- 6) Impervious passage of water, acids and other liquids.
- 7) Easy to clean and be safe against slipping.
- 8) Good appearance.

★ Safety Precautions Observed in following precautions

- 1) The formwork at the surface which is to receive the fresh concrete should be properly cleaned, prepared and well watered.
- 2) It is desirable to deposit concrete as near as practicable to its

Final position.

- 3) The large quantities of concrete should not be deposited at a time. Otherwise the concrete will start to flow along the formwork and consequently the resulting concrete will not have uniform composition.
- 4) The concrete should be dropped vertically from a reasonable height.
- 5) The concrete should be deposited in horizontal layers of about 15cm height. If too much concrete, the layers may be of 400 mm to 500 mm.
- 6) As far as possible, the concrete should be placed in single thickness, in case of deep section, the concrete should be placed in successive horizontal layers and proper care should be taken to develop enough bond when successive layers.
- 7) The concrete should be thoroughly worked around the reinforcement and trapped in a way that no honeycombed surface appears on removal of the formwork.
- 8) The concrete should be placed on

the formwork as soon as possible. But in no case, it should be placed after 30 min. of its preparation.

9) During placing, it should be seen that all edges and corners of concrete surface remain unbroken, sharp, and straight in line.

10) The placing of concrete should be carried out uninterrupted & here determined construction joints.

★ Tools:- The following tools which are used in concreting are as:-

1) Screeds:- Screeds are long, straight, stiff tubing or boards used to smooth concrete shortly after it is poured.

2) Vibrators:- Internal, also called needle or probe includes a vibrating probe that is immersed in the wet concrete.

→ Form:- attaches to the outside of the concrete form.

→ Surface:- surface attaches to a steel

to vibrate the concrete surface during curing.

3) External vibrators:- vibrating metal table for vibrating concrete inside a mold.

4) Mixers:- portable mixers allow you to mix small amounts of concrete at the job site.

5) Vapor Barriers:- vapor barriers are used to stop moisture from evaporating from concrete surfaces, which weakens the concrete.

6) Saws:- Concrete saws are used to cut central joints while the concrete is setting.

7) Shovels:- shovels are essential for moving small amounts of concrete around a pour to fill

voids or depressions and to get a hard to reach areas.

8) Floats - A bull float is a large float used to smooth and level the surface of the concrete immediately after it is screeded.

9) Concrete Cautters - Concrete cutters, or gas cutters, are used to create control joints on sidewalks, walkways, driveways and residential slabs, where a concrete saw typically is not used.

10) Curing Compound - Curing compound is applied directly to wet concrete surface to reduce cracks and help the concrete set at the desired rate.

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Chapter - 6 Strength of Concrete

* Water cement ratio :- $\rightarrow$ Strength of concrete mainly

depends upon the strength of cement paste. The strength of cement paste depends upon the dilution of paste by other woods the strength of paste increases with cement content and decreases with air and water content.

$\rightarrow$ It is not only the water / cement ratio but also degree of compaction which indirectly means the volume of air filled in voids of concrete which is taken into account in estimating the strength of concrete.

$\rightarrow$ Lower water / cement ratio could be used when the concrete is vibrated completely to achieve higher strength and higher density cement ratio is taken in a count when concrete is

hand compacted.

$\rightarrow$ In both the case when water cement ratio is below the practical limit the strength of concrete falls rapidly due to introduction of voids.

* gel space ratio :- $\rightarrow$ The strength of concrete at any water / cement ratio depends on the degree of hydration of cement and its chemical as well as physical properties.

The temperature at which hydration takes place, the air content, the change in effective water / cement ratio and the formation of cracks are also responsible in the strength of concrete.

$\rightarrow$ The strength of concrete can be made correctly related to the solid products of hydration of cement as the space available for the formation of these products.

Get space can be defined as the ratio of the volume of hydrated cement paste to the sum of volume of hydrated cement and the capillary pores.

➤ Powers's experiment shows that strength of concrete has a relation with gel space ratio. The found out this relation to be $240x^3$.

$$\boxed{\text{gel space ratio} = 240x^3}$$

where, x = gel space ratio and $240x^3$ = intrinsic strength of the gel in MPa.

→ The relation ship b/w strength and water/cement ratio will hold though for 28 days strength of fully compacted concrete but the relationship b/w strength and gel space ratio is independent of edges, ages.

★ Gain strength :- → The concrete develops strength with continued hydration.

→ The rate of gain of strength is faster to start with and rate gets reduced with age.

→ It is customary to assume the 28 days strength as the full strength of concrete.

→ Actually concrete develops strength beyond 28 days as long as curing conditions have not been permitting to consider this increase of strength beyond 28 days for design purposes. It is used to get immersed with the factor of safety.

→ The increase in strength beyond 28 days is taken into the consideration in design of structures.

→ The factors that affect the rate of gain strength is fineness of cement, water/cement ratio, aggregate types and its properties.

★ Maturity Concept of Concrete :- → It is the sum of product of temperature (above datum level - 11°C at which hydration starts)

and those over which this temperature occurs.

$$\text{Maturity} = \Sigma (\text{Time} \times \text{Temperature})$$

→ It is used to predict the state of strength development.

→ The percentage strength of identical concrete at any given maturity given by Placeman

$$\text{strength at any maturity as a percentage of strength at maturity of } 19,800^{\circ}\text{Ch} = A + B \log_{10} \frac{\text{maturity}}{10^3}$$

The values of coefficients, A and B depend on the strength level of concrete.

* Effect of Maximum size of Aggregates on strength:- → the larger the aggregate, the lower is the total surface area and, therefore,

the lower is the requirement of water for the same.

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workability.

→ The use of larger size aggregate did not contribute to higher strength as expected from the theoretical consideration due to following reasons.

→ The larger maximum size aggregate gives lower surface area per development of gel bonds which is responsible for the lower strength of concrete.

→ Secondly, larger aggregate size causes a more heterogeneous distribution in the concrete which will prevent the uniform distribution of load when stressed.

→ When large size aggregate is used, due to internal bleeding, the transition zone will become much weaker due to the development of micro cracks which result in lower compressive strength.

* Relation Between Compressive and Tensile strength:- → the strength of concrete in compression and tension

are closely related, but the

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relationship is not of the type of direct proportionality.

→ The ratio of the steel strengths depends on general level of strength of concrete. On other words,

low higher compressive strength concrete shows higher tensile strength but the state of increase of tensile strength is of decreasing order.

→ The type of coarse aggregate influences this relationship. Crushed aggregate gives relatively higher flexural strength than compressive strength. This is attributed to improved bond strength between cement paste and aggregate particles.

→ The tensile strength of concrete, as compared to its compressive strength, is more sensitive to imperfections, this is due to the inferior quality of gel formation and due to the fact that imperfections caused concrete may suffer from more shrinkage cracks.

→ On the basis of study, Central road research laboratory (CRRI) has

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suggested following relation b/w tensile strength and compressive strength

$$f_t = 11x - 3.4$$

where, f_t = compressive strength of concrete in MPa

x = Flexural strength of concrete MPa

The relation is reproduced below :-

(i) $f_t = 15.30x - 9.00$ for 20mm max size aggregate

(ii) $f_t = 14.12x - 10.4$ for 20mm max size natural gravel

(iii) $f_t = 9.9x - 0.55$ for 40mm max size crushed aggregate

(iv) $f_t = 9.8x - 2.52$ for 40mm max size natural gravel

→ The Indian Standard IS-456 of 2000 gives the following relationship b/w the compressive strength and flexural strength

$$\text{Flexural strength} = 0.7 \sqrt{f_{ck}}$$

where,

f_{ck} = Characteristic compressive strength of concrete in N/mm²

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* Bond Strength :-

of/can consider the bond strength from

two different angles :-

- 1) The bond strength b/w paste and steel reinforcement.
- 2) The bond strength b/w paste and aggregate.

1) Bond strength b/w paste and steel reinforcement

→ Bond strength b/w paste and steel reinforcement is of considerable importance.

→ Bond strength arises primarily from the friction and adhesion b/w concrete and steel. The roughness of the steel surface is also one of the factors affecting bond strength.

→ The bond strength is also a function of specific g_s . Cement which consists of higher percentage of g_s will give higher specific surface of gel, thereby giving higher bond strength.

On the other hand, concrete containing g_s or the concrete cured at higher temperature results in smaller specific surface

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a reinforcement is of concrete and steel assumptions of reinforced concrete.

of gel which gives a lower bond strength.

→ g_s has been already pointed out that high pressure steam cured concrete surface is about 1/20 of the specific surface of the gel produced by normal curing. Therefore, bond strength of high pressure steam cured concrete is correspondingly lower.

→ The bond strength of concrete is approximately proportional to the compressive strength up to about 20 MPa.

2) Aggregate - Cement Bond Strengths :-

→ Concrete can be regarded as a chain in which aggregates are the links bonded together by cement paste.

→ The strength of concrete as a whole is depending upon the strength (bond strength) of the hydrated hardened cement paste (hcp).

→ Strength of hcp is depending upon w/c ratio and the products of hydration in particular the $C-S-H$ gel.

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- The factor of transition zone influenced the bond strength between aggregate and paste.
- The explanation that the strength of concrete is limited by strength of the paste, will hold good when we consider concrete as true phase material. If we take a closer look into the structure of the concrete, a third phase comes into consideration i.e., interface layer the paste and aggregate known as transition zone.
- This transition zone is a place of weakness, it is composed of some small concrete particles the quality of paste is poorer.
- Due to internal bleeding, water accumulated below elongated, flaky and large pieces of aggregates. This reduces the bond between the paste and aggregate.

★ High Strength Concrete:-

- High strength concrete has a compressive strength greater than 40 MPa.
- High strength concrete is made by

lowering the water/cement ratio to 0.35 or lower. The often silica fume is added to prevent the formation of free calcium hydroxide crystals in the cement matrix, which might reduce the strength at the cement aggregate bond.

→ High strength concrete is used in high rise structures, shear walls, foundations, bridges, highway bridges, spans greater than lengths and for economical advantages.

Advantages

Disadvantages

* Joints in Concrete Construction :-

- 1) Construction joint
- 2) Expansion joint
- 3) Contraction joint
- 4) Isolation joint

1) Construction Joint :- → Construction

temporary joints left b/w subsequent concrete operation.

→ the position of construction joints should be planned before concreting is started.

→ These joints are made at such places where concrete is not damaged by maximum bending moment.

→ The walls and columns construction joints should be horizontal.

→ The procedure for joining the new concrete to the old concrete are also included in construction joint.

2) Expansion Joint :- → Concrete is

sensitive to change

in temperature and it expands and contracts as the temperature changes.

→ This expansion in concrete develops compressive stress and contraction causes tensile stress.

→ The purpose of expansion joint is to allow expansion of concrete due to the rise of temperature with respect to construction temperature.

• Design Consideration :- → The spacing of joint is about 2.5 cm after every 4.5 m of distance.

→ Mastic pads are used at the expansion joints as a filler material.

→ Dished bars are used in expansion joints.



expansion joint (2.5 cm)

Note:- → Adjacent to the expansion joint the structure should be supported on separate walls or columns.

→ Reinforcement should not extend across the expansion joint.

→ The spacing of the joint should be such that the total expansion should not be greater than 1.25 cm for sumbri constructed structures and not more than 2.5 cm for winter constructed structures.

3) Contraction Joints:- → Concrete contracts on shrinkage due to shrinkage stresses are developed when this shrinkage in concrete is restrained then cracks are developed. To avoid the formation of these cracks contraction joints are provided.

→ Contraction joints are also known as control joints or dummy joints.

(mb 2.0)

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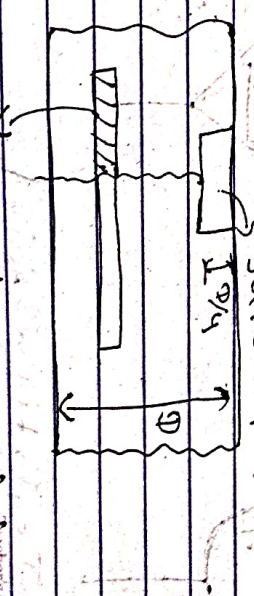
→ Contraction joints can be avoided by providing sufficient reinforcement in the structural element to take up shrinkage stresses.

→ The spacing b/w contraction joints may vary from 5-10m.

→ Contraction joints are made by placing thicker and then removing it when the concrete is hardened.

→ It is also provided by cutting grooves in the concrete and filling them with suitable joint filling compound.

→ The depth of joint should be about $\frac{1}{11}$ of the thickness of slab.



20mm bar coded

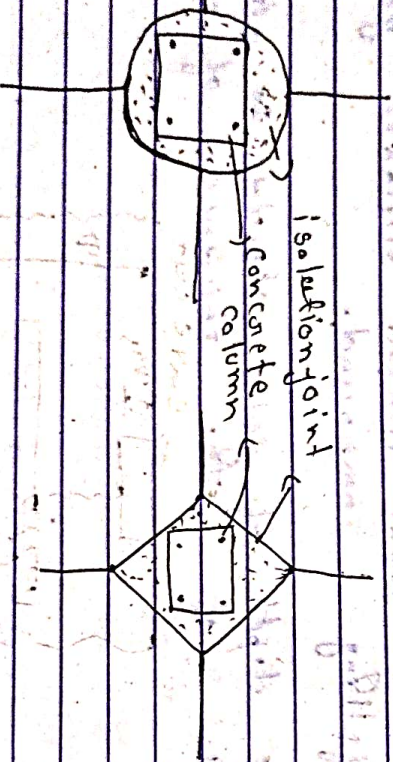
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4) Isolation Joint :- $\rightarrow$ This type of joint is provided

where the concrete floor needs the permanent structural element such as walls, columns etc.

$\rightarrow$ the depths of isolation joint in the should be kept equal to the full depth of concrete floors and its width must be 10-12 mm.

$\rightarrow$ This joints should be filled with resilient material and should be topped with joint filling material to avoid moisture.



Isolation joint

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* Destructive and Non Destructive Testing of Concrete :-

1) Destructive - $\rightarrow$ compressive strength test
Tensile strength test

1) Compressive strength test :-

Destructive test are the test in which we can not use the sample after the test as it is failed.

Procedure :- 1) In this test a sample

is prepared using mould of cube shape of either 150mm side (if nominal size of aggregate used is 20mm) or 100mm side (if nominal size of aggregate used is 10mm)

2) The prepared is then filled with the given ratio of concrete

also in four layers with 25 times tamping after each layer.

The excess is removed from the sample and the surface

is made plane. The sample is immersed

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in water for curing upto desired age after its being of drying.

4) After curing the sample it is removed from the curing tank and resting under its rubbed off from its surface and it is placed in compression testing machine.

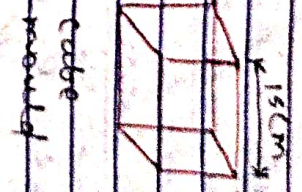
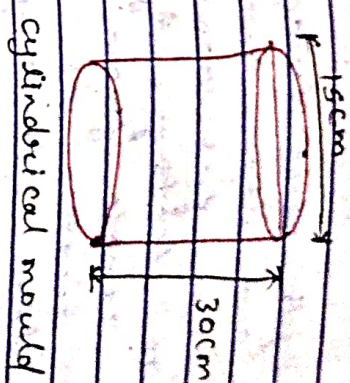
5) Now load is applied on the sample gradually and the load at which the sample fails is noted. These such samples are tested.

$$\text{Compression strength} = \frac{\text{Load}}{\text{Area}}$$

c) This test may also be performed on cylindrical mould. The height of the cylindrical sample is 2 times of its diameter.

* Note:- compressive strength of cylindrical = 0.8 compressive strength of cube

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2) Concrete strength test / Flexural strength test:-

1) The tensile strength of concrete is difficult to measure directly. Therefore, flexural strength property of concrete are found to be dependable source of it.

2) The value of modulus of rupture depends on dimensions of the beam and the manner of loading.

3) The standard size of specimen used in this test is 15 x 15 x 70 cm.

4) This mould is again filled with the concrete with proper compaction done with tamping

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Seed.

- 5) The test sample are dried for 24 hours and then are stored in water for not less than 48 hours before testing. After removing the sample from water, extra water is removed and then the sample is placed in the tensile flexural strength testing machine. The bed of the testing machine is provided with three steel rollers, 38 mm diameter on which the sample is supported.
- 7) The specimen is placed in a way that the load is applied to the upper most surface along the three line spaced 20 or 139 mm apart.
- 8) The excess of the specimen is carefully aligned with the axis of the loading device.
- 9) The load is applied gradually to the specimen at the

rate of 400 kg/min.

10) The load is increased until the specimen fails and it is recorded. The flexural strength of the specimen is expressed as modulus of rupture (f_b) and

$$f_b = \frac{P \times L}{b \times d^2} \text{ in MPa.}$$

→ Indirect Tension Test method:-

- 1) Cylinder splitting tension test (split cylinder test)
- 2) Ring tension test

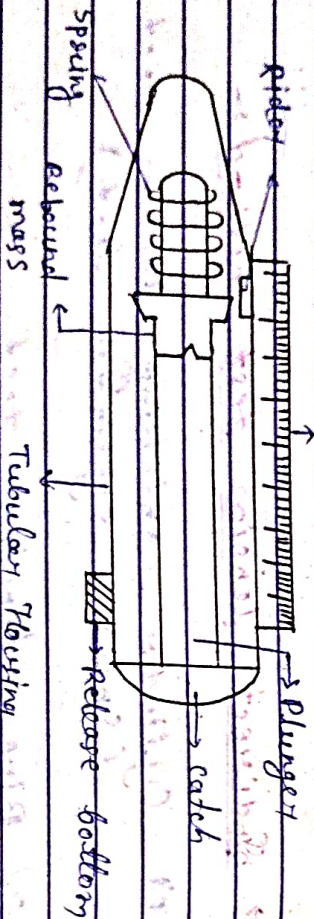
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2) Non Destructive Testing :-

- 1) Schmidt Rebound Hammer test
 - 2) Penetration test
 - 3) Ultrasonic pulse velocity test
 - 4) Pull out test
- Non destructive test are the test in which we can use the sample after test also

1) Schmidt Rebound Hammer test :-



Rebound Hammer

- Schmidt rebound hammer is an equipment used for measuring the hardness of surface of for which empirical relation has been established.
- Blue strength and rebound number, as weight is about 108 kg and is

Suitable for laboratory as well as field testing :-

- It consists of a spring controlled hammer that slides on a plunger within a tubular housing.
- When the release button is released it strikes the spring and rebound back side. It measures this distance by the scale called as rebound number.

- More the rebound number better is the quality of structure.
- This test can be done in horizontal/vertical or at any angle position.

2) Penetration test :-

- In this test the equipment consist of a probe which has a given or desired loaded cartridges is a depth gauge for measuring penetration of probe.
- The diameter of probe is 6.35 mm and its length is 8 cm, it is driven into the concrete by means of a pendulum charge.
- Depth of penetration provides an indication of the compressive strength

of concrete.

→ It has the potential for providing an indication of the compressive strength of concrete. Quick means of assessing the strength developed with curing.

3) All the basic Pulse velocity test :-

- This test is based upon calculating the time of travel of the pulse through a given thickness of the member from which further the velocity of pulse is calculated and related to the quality of structure.
- The pulse can be generated either by mechanical means or by electrical means.
- The presence of reinforcement in concrete affects the pulse velocity.
- Lesser the time of travel of pulse, better is the quality of structure.

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Topic - 11
27th Design

* Concrete Mix Design

→ It process of selecting suitable ingredients for concrete and determining their proportion which will produce most possible economical concrete that satisfies the job requirement i.e. concrete having certain compressive strength, workability and durability.

* Principle of Proportioning :-

The fundamental objective of proportioning concrete ingredients is to produce concrete having strong and durable concrete having appropriate strength, workability, tightness and some other essential properties at minimum cost.

* Objectives of Proportioning :-

→ The mix must be workable so that it can be finished and placed without extra effort.

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→ Low cement consumption with the attainment of desired properties

→ High strength concrete with improved strength, impermeability, density and workability.

→ affects the cement content, ingredients and workability, reducing cost, the strength and impermeability of concrete must increased with the density of mix.

* Factors to be considered in Mix Design :-

- 1) Grade of Concrete
- 2) Type and Grade of Cement
- 3) Type and size of aggregate
- 4) Degree of workability
- 5) W/C ratio
- 6) Durability.

* Methods of Mix Design :-

* Mean Strength :- This is the average strength obtained by dividing the same

sum of strength of all cubes by the number of cubes

$$\bar{x} = \frac{\sum x}{n}$$

Where $\bar{x}$ = mean strength
 $\sum x$ = sum of strength of cubes
 n = number of cubes.

* Variance :- This is the measure of variability. It is difference b/w any single observed data from the mean strength.

$$s^2 = \sum_{i=1}^n \frac{(x_i - \bar{x})^2}{n-1}$$

Where, s^2

* Standard Deviation :- This is the

square deviation of all the results. This is denoted by "s",

$$\sigma = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n-1}}$$

where σ = standard deviation
 n = no. of observations
 $\bar{x}$ = particular value of observation
 $\bar{x}$ = arithmetic mean.

* Methods of Mix Design :-

* Co-efficient of Variation :- It is an

alternative method of expressing the variation of the results.

It is a non dimensional measure of variation obtained by dividing the standard deviation with arithmetic mean and is expressed as

$$\frac{\sigma}{\bar{x}} \times 100$$

* Methods of Mix Design :-

- 1) Arbitrary Proportion
- 2) Engineer's Modulus Method
- 3) Maximum Density Method
- 4) Surface Area Method
- 5) IRC - 44 (India Road Congress) Method.
- 6) DOF Method
- 7) ACI Method
- 8) Indian Standard Method (IS-10262-2009)

Mix Design By Indian Standard Method (IS - 10262 - 2009)

→ The Bureau of Indian Standard recommends guidelines for mix design which are applicable for general type of construction using normal ingredients of concrete.
 → The design is carried out for a specific characteristic strength (upto 28 days) but less than (N/mm^2) and workability of concrete using graded aggregate.

→ this Method can be used for both reinforced concrete design and pre-stressed concrete design.

→ Assumptions:-

- 1) The compressive strength of concrete is based on the w/c ratio of the concrete mix.
- 2) Given a given type of shape, size and grading of aggregate the amount of water determines the compressibility of concrete.

→ Steps of Design for IS Method:-

- 1) The determine target mean strength the target mean strength (f_{td}) is determined from the specified characteristic compressive strength of 28 days and the standard deviation which is based on quality control.

for f_{td} & k_s

where, k_s = risk factor = 1.65
if a target mean strength & characteristic compressive strength is a standard deviation

2) Selection of water cement ratio:-

IS Method recommends to establish relationship between free water cement ratio and characteristic strength of concrete using the standard curve given in IS codes.

3) Estimation of entrapped air:-

The air content is estimated from the max. size of aggregate from the table given in IS codes.

4) Determination of water content and to find the ratio of fine aggregate to total aggregate

In the SS design method the quantity of water per unit volume of concrete and the ratio of fine aggregate to total aggregate depends upon type and size of aggregate.

→ IS code recommends -

- For concrete up to M35 grade
 - max size of aggregate is 40 mm
- For concrete above M35 grade
 - max size of aggregate is 20 mm

The ratio of fine aggregate to total aggregate varies inversely in figure to the max size of aggregate.

5) Calculation of Cement Content :-

The cement content per unit volume is calculated from the ratio of the quantity of water to unit volume of concrete.

$$\frac{w/c}{\text{Quantity of water}} = \frac{\text{Quantity of cement}}{\text{Quantity of cement}}$$

$$\text{Quantity of cement} = \frac{\text{Quantity of water}}{\text{water cement ratio}}$$

Note :- The quantity of cement content so calculated should be checked for min value for the required durability.

c) Calculation of Aggregate Content :-

For fine aggregate -

$$V_a = \left\{ \frac{1}{1 + \frac{C}{S_c} + \frac{1}{P} \frac{f_a}{S_{fa}}} \right\} \times 100$$

Ex: Concrete aggregate - 1

$$V = \left\{ W + \frac{C}{S_c} + \frac{1}{1-P} \times \frac{C_a}{S_{ca}} \right\} \times \frac{1}{100}$$

where, V = volume of total fresh concrete - volume of entrapped air (m^3),

W = mass of water per m^3 of concrete in kg or liter,

C = mass of cement per m^3 of concrete in kg

S_c = specific gravity of cement

S_{ca} = specific gravity of aggregate

or

f_a , C_a = Total quantity of fine aggregate and coarse aggregate per m^3 of concrete, in kg.

Approximate air content:-

Maximum size of aggregate	Entrapped air percent
10	30
20	20
40	10

S_a , S_{ca} = specific gravity of fine and coarse aggregate

7) Actual quantity required for the mix:-

→ The above mix proportion has been on the assumption that aggregates are saturated and surface dry.

→ Hence, for any deviation from this condition has to be applied in the quantities of mixing water and aggregate.

→ Adjustment in aggregate moisture.

In this step all the obtained values of air content, moisture and cement content and volume of coarse aggregate and fine aggregate are collected.

10/10/20

14. California Library Books (E)