UNIT-I

Cement

1.1 History of cement:

→ Some kind of cementing materials were used by Egyptians, Romans & Indians in their ancient constructions

→ The invention of portland cement is attributed to Joseph Aspdin

→ Joseph Aspdin took the patent of portland cement on 21st October 1824.

→ The fancy name of portland was given owing to the resemblance of this hardened cement to the natural stone occuring at portland in England

→ In India, Portland cement was first manufactured in 1904 near Madras by the South India Industrial Ltd.

→ 1914 → Indian Cement Co. Ltd.

1.2 Manufacturing of Portland Cement:

→ The raw materials required for manufacture of Portland cement are calcareous materials such as lime stone or chalk & argillaceous material such as shale or clay.

→ The process of manufacture of cement consists of grinding the raw materials, mixing them intimately in certain proportions depending upon their purity

intimately ⇒ known proportions knowledge and composition & burning them in a kiln at a temperature of about 1300 to 1500°c, at which temperature, the material sinter and partially fuses to form nodular shaped clinker. The clinker is cooled and ground to fine powder with addition of about 3 to 5% of gypsum. The product formed by using this procedure is portland cement.

⇒ There are two processes in the manufacturing ~~[illegible]~~ portland cement

1. Wet process
2. Dry process

In addition to this we have the semi-dry process also where the raw materials are ground dry and then mixed with about ~~10-14~~ 10–14% of water & further burnt to clinkering temperature.

⇒ For many years, the wet process remained popular because of the posibility of more accurate control in the mixing of the raw materials.

⇒ Later days dry process gained momentum with the modern development of the technique of dry mixing of powdered materials using compressed air.

⇒ With in next few years most of the cement factories will adopt dry process system.

1.3. Wet Process:

→ The lime stone brought from the quarries is first crushed to small fragments. then it is taken to a ball (or) tube mill where it is mixed with clay (or) shale as the case may be and ground to a fine consistency of slurry with the addition of water about 35 to 50%, where in particles crushed to the finess of Indian standard sieve no.9 [90 microns] are held in suspension

→ The slurry is pumped to slurry tank or basins where it is kept in an agitated condition by means of rotating arms with chains or blowing compressed air from the bottom to prevent settling of lime stone & clay particles.

→ The corrected slurry is sprayed on to the upper end of a rotary kiln against hot heavy hanging chains.

→ The rotary kiln is an important component of a cement factory. It is a thick steel cylinder diameter → 3-8m, lined with refractory materials, mounted on roller bearings & capable of rotating about its own axis at a specified speed.

Length → 30 - 200m

→ The slurry on being sprayed against hot surface of flexible chain losses moisture & becomes flakes.

→ These flakes peel off and fall on the floor.

→ The rotation of kiln causes the flakes to move from the upper end towards lower end of kiln subjecting itself to higher & higher temperature

→ The kiln is fired at lower end. The fuel is either powered coal, oil or natural gass.

→ By the time materials rolls down to the lower end of rotary kiln, the dry materials undergoes a series of chemical reactions untill finally, where the temperature is in the order of 1500°c about 20 to 30 % of the materials get fused.

→ Lime, silica & alumina get recombined. This is where the oxides in raw materials will be combined to form compounds in clinker

→ The clinker (size 3-20mm) drops into a rotary cooler where it is cooled under contoolled conditions. the clinker is stored in silos or bins.

→ The clinker weights about 1100 to 1300 grm per liter. The litre weight of clinker indicates the quality of clinker

→ The cooled clinker is then ground in a ball mill with the addition of 3 to 5% of gypsum in order to prevent flesh setting of the cement.

→ In the ball mill the particles are crushed to the required finess & taken to storage silos from where the cement is bagged or packed.

Wet process

Clay ← Water
↓
Wash mill
↓
Strage basins

Lime stone
↓
Crusher
↓
Storage basins

↳ Wet grinding mill to make slurry ↵ [35-50% water]
↓
Blending of slurry to correct composition
↓
Storage of corrected slurry
↓
Powdered coal, oil or gas ⟶ corrected slurry fed to Rotary kiln [1300-1500°C]
↓
Slurry is converted into clinker
↓
Clinker is ground in Ball mill [3-5% gypsum]
↓
Cement silos
↓
Packing plant.

1.4. Dry Process:

In the dry & semi-dry process the raw materials are crushed dry and fed in correct proportions into a grinding mill, where they are dried and reduced to a very fine powder. The dry powder called the raw meal is then further blended & corrected for its right composition and mixed by means of compressed air.

→ The aerated powder tends to behave almost like liquid and in about one hour of aeration a uniform mixture is obtained

→ the blended meal is further sieved and fed into a rotating disc called granulator.

→ A quantity of water about 12% by weight is added to make the blended meal into pellets.

→ This is done to permit air flow for exchange of heat for further chemical reactions & conversion of the same into clinker further in the rotary kiln.

Lime stone → crusher → Raw Meal

clay → conveyor Belt → Raw Meal

Raw Meal
↓
Raw meal silos
↓
granulator → 4 stage Preheater
↓
Rotary kiln
↓
clinker
↓
clinker is grounded in Ball mill
↓
cement silos
↓
packing plant

→ The equipments used in the dry process kiln is comparatively smaller. the process is quite economical.

→ The total consuption of Coal is in this method is only 100 kg when compared to the requirement of about 350 kg for producing a ton of cement in the wet ~~proces~~ process.

	wet process	Dry process
coal →	350 kg	100 kg

↓

1 ton of cement

Cement

Argillaceous — Calcareous

Clay & shale — Lime stone, chalk

Sp. gravity - 3-3.2

Max size of cement - 90 μ

Min size of cement - 1.5 μ

Avg - 10 μ

* Cement: It is a product obtained in a powdered form by grinding or pulvarising the clinker which is produced by heating the proper proportioning of calcareous & argillaceous materials under 1300 - 1500°c. In addition to this some percentage of gypsum [3-5%] is also to be added

⇒ Hydraulic cement: The cement which sets and hardens even in water and gives a stable product E.g: OPC

- Non-hydralic cement: The cement which does not sets and hardens in water and it is unstable. Eg: POP (plaster of paris]

1.5 Chemical Composition:

The raw materials used for the manufacture of cement consist mainly of lime, silica, alumina and iron oxide.

→ These oxides interact with one another in the kiln at high temperature to form more complex compounds.

- The relative proportion of these oxide compositions are responsible for influencing the various properties of cement

* Chemical composition of cement on oxide basis

Oxide	% content	Avg %
CaO [calcium oxide], lime	60-67%	63%
SiO_2 [silicon Di-oxide], silica	18-25%	20%
Al_2O_3 [Alumina oxide], Alumina	3-8%	6%
Fe_2O_3 [Ferric oxide]	0.5-6%	3%
MgO [Magnesium oxide]	0.1-4%	1.5%
SO_3 [sulphur tri-oxide]	1.3-3%	2%
K_2O [Pottassium oxide], Na_2O [sodium oxide]	0.4-1.3%	1% restricted to 0.6% [AAR]

* Functions of ingredients

Lime [CaO]: Controls strength and soundness

→ If it is deficient it reducess the strength & if it is excess leads to unsoundness of cement

⇒ Soundness of cement: It refers to the ability of cement paste to retain its volume after it has get hardened. After drying of cement mortar or concrete, it should not undergo any appreciable change in volume. If it does there are chances of development of cracks.

→ The unsound cement can cause serious troubles to the durability of structures when such cement is used

⇒ Silica [SiO_2]:

→ It gives strength. If it is excess it causes slow setting and if it is less reduces strength

⇒ Alumina [Al_2O_3]:

→ It is responsible for quick setting

If it is excess - lowers the strength

If it is less - causes slow setting

⇒ Iron Oxide [Fe_2O_3]:

It gives color and helps in fusion of different materials

[fusion → blending, bonding, integration]

⇒ Magnesium Oxide [MgO]:

It imparts colour & hardness.

* **BOGUE'S Compounds:** [Le chartelier & Tornebohm]

→ while burning the raw materials such as calcareous and argillaceous materials to form clinker the ingredients react with one another and produces the products which are studied by R.H. BOGUE and these compounds are called Bogue's compounds

They are C_3S, C_2S, C_3A, C_4AF

Abbreviated formula	Actual formula	Name	% of compound
C_3S	$3CaO\ SiO_2$	Tricalcium silicate	54.1 [Alite]
C_2S	$2CaO\ SiO_2$	Dicalcium silicate	16.6 [Belite]
C_3A	$3CaO\ Al_2O_3$	Tricalcium aluminate	10.83 [Celite]
C_4AF	$4CaO\ Al_2O_3\ Fe_2O_3$	Tetracalcium aluminoferrite	9.1% [Felite]

→ In addition to the four major compounds, there are many minor compounds formed in the kiln. The influence of these minor compounds on the properties of cement or hydrated compounds is not significant.

→ Two of the minor oxides namely K_2O & Na_2O referred to as alkalis in cement are of some importance.

→ This aspect will be dealt with later when discussing alkali-aggregate reaction (AAR).

→ The two silicates namely C_3S & C_2S are the most important compounds resposible for strength. Together they constitute 70 to 80 per cent of cement

→ upon hydration both C_3S & C_2S give the same product called calcium silicate hydrate [$C_3S_2H_3$] & calcium hydroxide [$Ca(OH)_2$].

→ C_3S having faster rate of reaction accompanied by greater heat evolution develops early strength

→ C_2S hydrates and hardens slowly and provides much of the ultimate strength

→ C_3S & C_2S need approximately 24 & 21 percent water by weight, for chemical reaction but C_3S liberates nearly 3 times as much calcium hydroxide on hydration as C_2S. However, C_2S provides more resistance to chemical attack.

→ The compound C_3A is characteristically fast-reacting with water and may lead to an immediate stiffening of paste. & this process is termed as flash set.

→ The role of gypsum added in the manufacture of cement is to prevent such a fast reaction

→ C_3A reacts with 40 per cent water by mass & this is more then that required for silicates.

→ However, since the amount of C_3A in cement is comparatively small, the net water required for the hydration of cement is not substantially affected. It (C3A) provides weak resistance against ~~sulphate~~ sulfate attak & development of strength of cement is perhaps less significant than that of silicates.

→ C_3A phase is responsible for the highest heat of evolution, both during initial period as well as in the long run.

→ Like C_3A, C_4AF hydrates rapidly but its individual contribution to the overall strength of cement is insignificant

→ However, C_4AF is more stable than C_3A.

* <u>Basic Properties of Bogue's Compounds</u>

*1. <u>Tricalcium Silicate</u> (C_3S):

→ It is responsible for early strength.

→ First 7 days strength is due to C_3S

→ It Produces more heat of hydration

→ C_3S need approximately 24 % water by weight

→ A cement with more C_3S content is better for cold weather concreting.

2. Dicalcium silicate (C_2S):

→ It is responsible for the later strength of concrete

→ The hydration of C_2S starts after 7 days. Hence it gives strength after 7 days.

→ C_2S hydrates & hardens slowly and provides much of the ultimate strength

→ It produces less heat of hydration

→ C_2S provides more resistance to chemical attack.

→ It is used for mass concreting like Bridge, piers, Abutments, water retaing structures etc.

3. Tricalcium Aluminate (C_3A):

→ The reaction of C_3A with water is very fast & may lead to an immediate stiffening of paste

→ To prevent this flash set 2 to 3% of gypsum is added at the time of grinding the cement clinkers.

→ C_3A contribution to the overall strength of cement is insignificant but heat of hydration is very high.

4. Tetracalcium Alumino ferrite (C_4AF):

→ C_4AF hydrates rapidly

→ It does not contribute to the strength of concrete

→ The hydrates of C_4AF show a comparatively higher resistance to sulphate attack than the hydrates of C_3A

* Cement & hydration of Portland cement can be schematically represented as below:

Raw material for cement - Calcarious & Argillaceous
[lime, chalk] [clay & shale]

↓

Component elements in raw materials - O_2, Si, Ca, Al, Fe

↓

Oxide composition in raw materials - CaO, SiO_2, Al_2O_3, Fe_2O_3

on burning ↓ clinker formed

Compound composition - C_3S, C_2S, C_3A, C_4AF

on ↓ grinding

Port-land cements - various types of cements

on ↓ hydration

Products of hydration - C-S-H gel + $Ca(OH)_2$

***

[C-S-H → $C_3S_2H_3$]
↳ calcium silicate hydrates

* Hydration of cement:

→ The Anhydrous cement does not bind fine and coarse aggregate. It acquires adhesive property only when mixed with water

→ The chemical reaction between cement and water is known as hydration of cement.

→ The reaction takes place between the active components of cement and water

→ During the hydration the heat will be generated and the reaction takes place

Note: The reaction b/w cement & water is Exothermic.

→ The hydration of cement can be visualised in two ways.

The mechanism of hydration:

① **Solution mechanism**

In this cement compounds dissolve to produce a super saturated solution from which different hydrated products get precipitated

② **Solid mechanism**

The water attacks cement compounds in the solid state converting the compounds into hydrated products starting from the surface and proceeding to the interior of the compounds with time.

Note: The solution mechanism may predominate in the early stage of hydration in view of large quantity of water being available.

→ The solid mechanism may operate during the later stage of hydration.

* **Heat of hydration:-**

→ The reaction of cement with water is exothermic. The reaction liberates a considerable quantity of heat. This liberation of heat is called heat of hydration.

→ On mixing cement with water a rapid heat evolution occurs and lasting for a few minutes. This heat evolution is probably due to the reaction of the solution of aluminates & sulphates [ascending Peak A]

→ This initial heat evolution ceases quickly by gypsum [decending]. [See the fig]

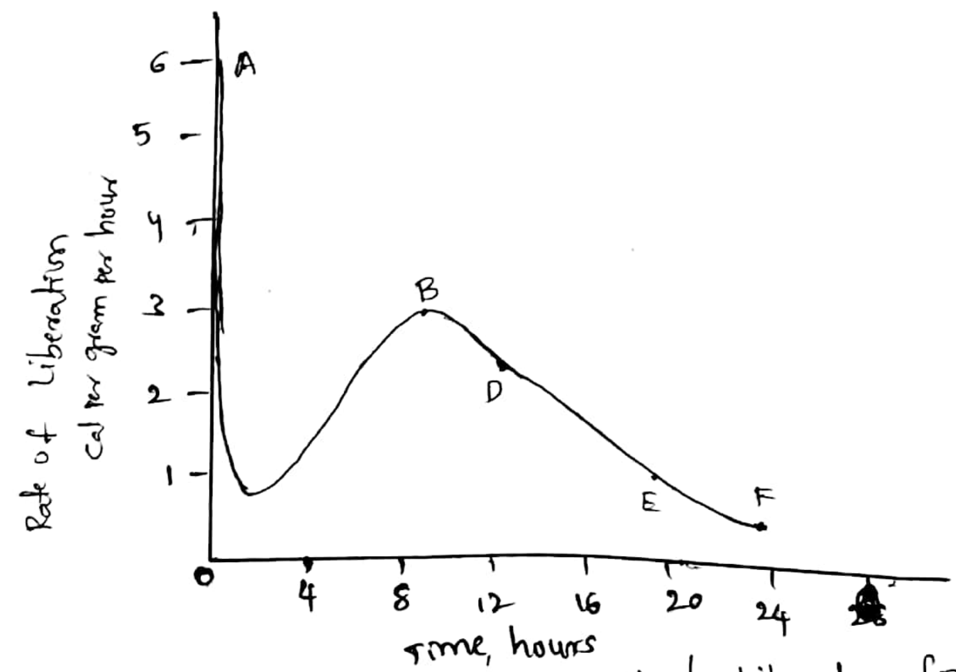

Fig :- Heat Liberation from a setting cement

→ The next heat evolution is due to the reaction of C_3S [ascending peak B]

→ ~~The reaction of compounds~~

→ Different compounds hydrate at different rates & liberates different quantities of heat

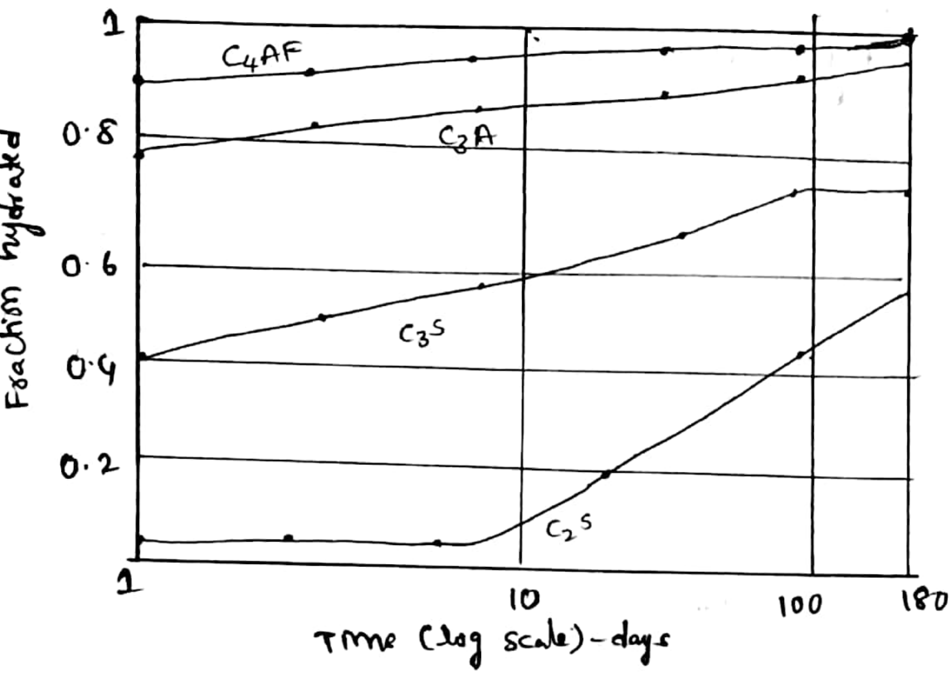

Fig. Rate of hydration of pure compounds

→ Since retardars are added to control the flash setting properties of C_3A.

→ The reaction of compound C_3A with water is very fast and it is responsible for flash setting of cement [stiffening without strength development] and thus it will prevent the hydration of C_3S & C_2S.

→ Fineness of cement also influences the rate of development of heat but not the total heat.

→ The total quantity of heat generated in the complete hydration will depend upon the relative quantities of the major compounds [Bogue's compounds] present in a cement.

→ Heat of hydration.

Compound	Heat of hydration at the given age (Cal/g)		
	3 days	90 days	13 Years
C_3S	58	104	122
C_2S	12	42	59
C_3A	212	311	324
C_4AF	69	98	102

→ Normal cement produces 90-100 cal/g in 28 days

→ After the hydration compounds formed are C-S-H gel & $Ca(OH)_2$

→ The hydration of C_3S produces a comparatively lesser quantity of C-S-H than that produced by C_2S. On the other hand, C_3S liberates nearly 3 times as much $Ca(OH)_2$ on hydration as C_2S.

→ However, $Ca(OH)_2$ is not a desirable product in the concrete mass as it is soluble in water & gets leached out making the concrete porous.

→ The only advantage of $Ca(OH)_2$ is its being alkaline in nature and maintaining a PH value of around 13 in the concrete.

→ A pH value at this level passivates reinforcing steel against corrosion.

→ In general, the quality and density of C-S-H produced due to hydration of C_3S is slightly inferior to that formed by hydration of C_2S.

→ The hydration product of C_2S is rather dense and its specific surface is higher.

* Calcium silicate hydrate (strength)

$CaSO_4$ → calcium sulphate

$$\left.\begin{matrix} C_3S \\ C_2S \end{matrix}\right\} \rightarrow C\text{-}S\text{-}H + \text{Gel pores} + Ca(OH)_2$$

Note: $Ca(OH)_2$ further reacts with sulphur and form $CaSO_4$ which deteriorates concrete

Note: Puzzolonas are introduced to eliminate the undesirable effect of $Ca(OH)_2$

Puzzolonas – flyash, silica fume

$Ca(OH)_2$ → alkaline in nature & avoids corrosion

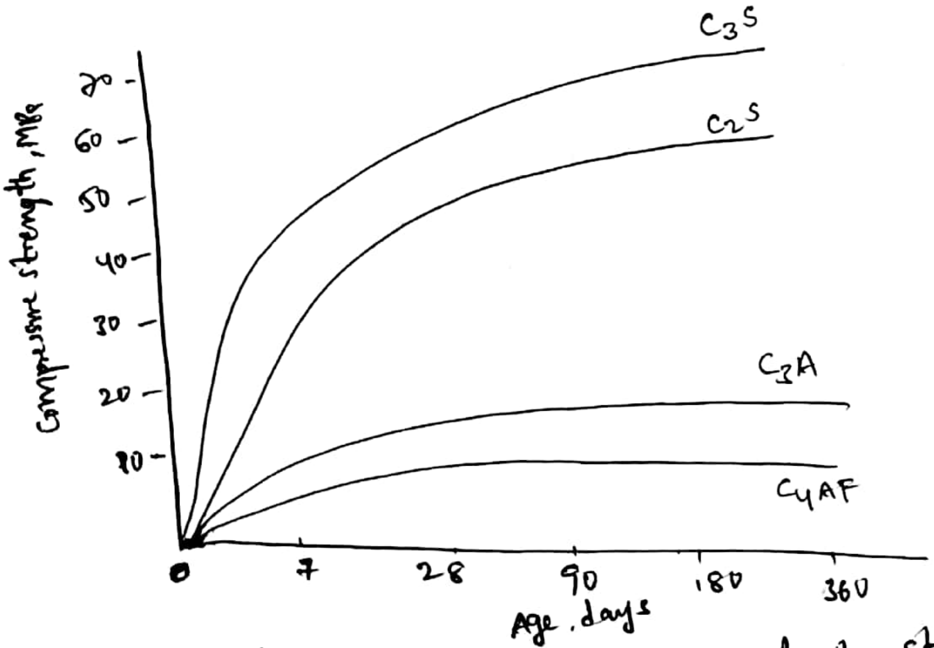

Fig. Contribution of cement compounds to strength of cement

* Calcium Aluminate hydrate [C-A-H]

→ Due to the hydration of C_3A a calcium aluminate system $CaO-Al_2O_3-H_2O$ [C-A-H] is formed.

→ C_3A is responsible for setting of cement

$$\left.\begin{matrix} C_3A \\ C_4AF \end{matrix}\right\} \rightarrow C-A-H \text{ [Setting]}$$

* Summary of behaviour of BOGUE's compounds in cement hydration :

Compound Name	Reaction Time	Strength development	Setting time	Heat Evolution
C_3S	medium	High	Low	Low
C_2S	slow	Low	Low	Low
C_3A	Fast	Low	High	High
C_4AF	Medium	Low	Medium	Medium

* Water Requirement for hydration:

Bound Water: About an average 23% of water by weight of cement is required for complete hydration of portland cement. This water combines chemically with cement compounds & is known as bound water

* **Gel Water:** About 15% of water by weight of cement is required to fill the gel pores & is known as gel water. Therefore a total of 38% of water by weight of cement to complete the chemical reaction. Hence the water cement ratio should not be less than 0.38 in any case, otherwise the process of hydration is incomplete.

* **Structure of hydrated cement:**

→ To understand the behaviour of concrete, it is necessary to acquaint ourselves with the structure of hydrated hardened cement paste.

① **Paste phase:**

It is important because it influence the behaviour of concrete to a much greater extent. The strength, Permeability, durability, shrinkage, creep, elastic properties and volume change properties are greatly influenced by the paste phase.

② **Aggregate phase:**

→ It is though important has lesser influence on the properties of concrete than paste phase.

... strength.

3. Transition Zone:

Concrete is generally considered as 2 phase material if we see at micro level the aggregate particles are dispersed in a ~~material~~ matrix of cement paste.

The transition zone which represents interfacial region between the particles of coarse aggregate and hardened cement paste. This zone is of poorer quality because due to internal bleeding water accumilates below elongated, flaky and large pieces of aggregates. This reducing bond between paste and aggregate. Hence it is called weak zone.

* Physical Properties of Portland Cement:

→ Any measurable characteristics is known as properties.

1. Fineness: The fineness of a cement is a measure of the size of ~~cement~~ particles of cement and is expressed in terms of specific surface of cement.

→ It is a important factor for rate of gain of strength and uniformity of quality

→ The finer the cement, the higher is the rate of hydration, as more surface area available for chemical reaction, This results in the early development of strength

→ more fineness of cement more rate of evolution of heat

2. Setting time: Cement when mixed with water forms paste which gradually becomes less plastic and finally a hard mass is obtained. In this process of setting, a stage is reached when the Cement paste is sufficiently rigid to withstand a definite amount of pressure. The time to reach this stage is termed as setting time. The time is reckoned from the instant when water is added to the Cement.

The setting time divided into two parts

→ The time at which the cement paste loses its plasticity is termed the initial setting time. [not less than 30 min]

→ The time taken to reach the stage when the paste becomes a hard mass is known as the final setting time [not more than 600 min (or) 10 hr]

3. Soundness: The unsoundness of cement is caused by the undesirable expansion of some of its constituents, some times after setting. The large change in volume accompanying expansion results in disintegration & severe cracking. the unsoundness is due to the presence of free lime and magnesia in the cement.

4. Compressive strength: It is one of the important properties of cement. Cement mortar cubes (1:3) having an area of 5000 mm² are prepared & tested in compression testing machine.

5. Heat of hydration: the heat of hydration is defined as the quantity of heat, in calories per gram of hydrated cement, liberated on complete hydration at a given temperature.

6. Specific gravity: The specific gravity of Portland cement is generally about 3.15. Specific gravity is not an indication of quality of cement. It is used in calculation of mix proportions.

* Types of Cements:

1). OPC - Oridinary portland cement
2) RHC - Rapid hardening cement
3) ERHC - Extra rapid hardening cement
4). PPC - Portland Pozzolona cement
5) SRC - Sulphate resisting cement
6). BFC - Blast furnance cement / PSC → portland slag cement
7). QSC - Quick setting cement
8). SSC - Super sulphate cement
9) LHC - Low heat cement
10). AEC - Air entraining cement
11) CC - Coloured cement

12). HPC - Hydrophobic cement

13) MC - Masonry cement

14). OWC - Oil well cement

15). RSC - Rediset cement

16) HAC - High Alumina cement

17) HSC - High strength cement

18) ARC - Acid resisting cement

① Ordinary Portland cement (OPC)

→ This the most important type of cement

Sp. surface Area

① 33 Grade cement
② 43 grade cement
③ 53 grade cement

② Rapid hardening cement (RHC):

→ This cement is similar to OPC but with higher C_3S content and finer grinding. A higher fineness of cement particles provides greater surface area [not less than 325000 mm²/g] for action with water. It gains strength more quickly than OPC.

→ The name indicates it develops strength rapidly. So it is called high early strength cement also.

→ It develops strength at the age of 3 days the same strength as that is expected of OPC in 7 days

Uses:

1. Where formwork is required to be removed early for reuse
2. Road repair works
3. Cold weather concrete

3. Extra rapid hardening Cement [ERHC]:

→ It accelerates the setting and hardening process. A large quantity of heat is evolved in a very short time after placing.

→ This can be mixed, transported, placed, compacted and finished in 20 minutes.

→ The strength of extra rapid hardening cement is about 25% higher than that of RHC at one or two days & 10-20% higher at 7 days.

Note: on the 90th day OPC, RHC, ERHC are same in strength.

4. Portland Pozzolona Cement [PPC]

→ PPC is manufactured by the intergrinding of OPC clinker with 10 to 25% of pozzolanic material.

→ It may be recalled that calcium silicates produce considerable quantities of $Ca(OH)_2$, which is by and large a useless material from the point of view of strength (or) durability. If such useless mass could be converted into a useful cementitious product, it considerably improves quality of concrete

The use of fly-ash performs such a role. The pozzolanic action is shown below

Calcium hydroxide + Pozzolana + Water → C-S-H gel

Advantages:

1. In PPC costly clinker is replaced by cheaper puzzolana Hence economical.
2. Reduction in permeability and offers many other advantages like rusting of steel is avoided and durability of the structure is increased
3. It generate reduced heat of hydration and that too at a low rate hence the cracks will not be developed
4. PPC being finer than OPC and also due to puzzolanic action, it improves pore size distribution and also reduces the micro cracks at the transition zone.
5. Volume will be more as this cement has less density

Specific Surface Area { OPC - 2200 cm^2/gm ; PPC - 3320 cm^2/gm }

5. **Sulphate Resisting Cement [SRC]**

→ OPC is susceptible to the attack of sulphates, in particular to the action of $MgSO_4$.

→ To remedy the sulphate attack, the use of cement with low C_3A content is found to be effective.

→ such cement with low C_3A and comparatively low C_4AF content is known as SRC. In other words, this cement has a high silica content.

Uses:

1. Concrete to be used in marine condition
2. Construction of sewage water treatment works
3. Where the soil is infested with sulphates

6. Portland slag cement [PSC] or BFC

This is obtained by mixing OPC clinker, Gypsum & GGBS [Ground granulated Blast furnace slag]

70% GGBS & 30% clinker & gypsum

Uses: Same as that of SRC

7. Quick setting cement [QSC]

As the name indicates, sets faster. This is obtained by reducing the gypsum content at the time of grinding the clinkers

→ Used in under water construction where pumping is involved QSC such conditions reduces pumping time and makes it economical

8. Super sulphate cement (SSC):

It is manufactured by grinding together 80-85% (GGBS), 10-15% (Gypsum), 5% (OPC clinker)

→ The product more finer than that of OPC

→ specific surface area must not be less than 4000 cm²/gram

→ such cement with low C_3A and comparatively low C_4AF content is known as SRC. In other words, this cement has a high silica content.

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→ The product more finer than that of OPC.

→ specific surface area must not be less than 4000 cm²/gram

→ used in areas where severe effect of sulphate exists. & uses as Sulphate Resisting cement (SRC)

9. Low Heat Cement [LHC]

→ The formation of cracks in large body of concrete due to heat of hydration generated in the short time. This is the kind cement which produces less heat or the same amount of heat at low rate during the hydration process by reducing C_3A & C_3S and increasing C_2S content in the cement

Ex:- Dams, Water Retaining structures

(10) Air Entraining Cement (AEC):

→ The cement is manufactured by mixing small quantity of air-entraining agents like alkali salts of wood resins, sythetic detergents of alkyl-aryl sulfate type & calcium lignosulfate with OPC.

→ The agents in powder or liquid forms are added to the extent of 0.025 to 0.1% by weight of OPC clinker at the time of grinding

→ these cements produce tiny, discrete non-coalesceing air bubbles in the concrete mass which enhances workability and reduces tendency to segregation and bleeding. & Best in frost conditions.

→ 5% voids reduces the strength by 30%

11. Coloured cement (CC)

→ colouring agents are added to the white cement to give colour

→ ~~colour~~ Iron oxide is added to give red and yellow, cobalt to give blue and manganese dioxide to give black colour

White cement
CaO → purity 96% $CaCO_3$
FeO < 0.07%

12. Hydrophobic cement:

→ This type of cement is obtained by adding water repellant film forming substances like stearic acid, boric acid, oleic acid & pentachlorophenol to OPC during grinding of cement clinker

→ The storage of OPC in humid places causes deterioration in the quality of cement. For such places hydrophobic cement is useful.

13. Masonry Cement (MC):

→ Manufactured by intergrinding OPC and hydrated lime, granulated slag or crushed stone

→ Good workability, reduced shrinkage & water retentivity

→ When OPC is used, due to its less water retentivity, the Masonry absorbs water from the mortar resulting a poor bond. this problem can be eliminated by using masonry cement

⑭ High Alumina cement (HAC):

→ HAC is very reactive and produces very high early strength.

→ About 80% of ultimate strength is developed at the age of 24 hours & even at 6-8 hours.

→ HAC is extremly resistant to chemical attack and suitable for under sea water applications.

⑮ Oil-well cement:

The annular space between steel casting and sedimentary rock formation through which oil-well has been drilled, is sealed off by cement slurry to prevent escape of oil or gas

→ depth very high & temperature as high as 350°c under pressure upto 150 MPa. The slurry used for this purpose must remain mobile to be able to flow under these conditions

→ It also have to resist corrosive conditions from sulfur gases & water containing dissolved gas.

→ The cement suitable for above conditions is called oil-well cement

⊛ Testing of cement

1. Fineness test:

→ It is a index of grinding

→ Determined by sieving through 90 micron [IS sieve No. 9]

→ The residue left after sieving should not exceed 10% by weight for OPC.

→ Also determined by Blains Air permeability test.

2 standard consistency:

→ The percentage of water required to make a workable cement paste

→ Determined by vicat's apparatus using vicats plunger [1cm dia]

→ As per Vicat's test "The percentage of water added to the cement at which the needle can not penetrate 5 to 7 mm from bottom of the mould is called standard consistency.

→ For OPC consistency is around 30%

3. Initial setting time

→ The time at which cement starts setting process

→ Determined by vicat's apparatus using vicat's needle [1 mm square needle]

→ For the cement is mixed with 0.85 times the water required for standard consistency

→ As per Vicat's test the time lapsed since the addition of water to the cement upto the time at which needle can not penetrate 5 to 7 mm from the bottom of the Vicat's mould

→ For OPC initial setting time should not be less than 30 minutes

4. <u>Final Setting</u> time:

→ The time at which the cement ends its setting process and becomes hard

→ Determined by Vicat's apparatus using vicat's needle with annular collar of 5 mm diameter

→ As per the test the time lapsed since the addition of water to the cement upto the time at which needle with annular collar can only make a mark on the hard cement surface

→ For OPC final setting time should not be more than 10 hours [600 min]

5. <u>Soundness:</u>

→ The expansion of cement due to the presence of free lime and magnesia is called un-soundness

→ Determined by Le-chatlier apparatus.

→ For the test cement is mixed with 0.78 times the water required for standard consistency

→ As per the test apparatus the expansion at the ends of legs of Le-chahlier apparatus should not be more than 10mm for the cement to be sound.

→ If the expansion exceeds 10mm after standard test procedure, the cement should not be used

→ Auto clave test is also used for the soundness. It is a quick test

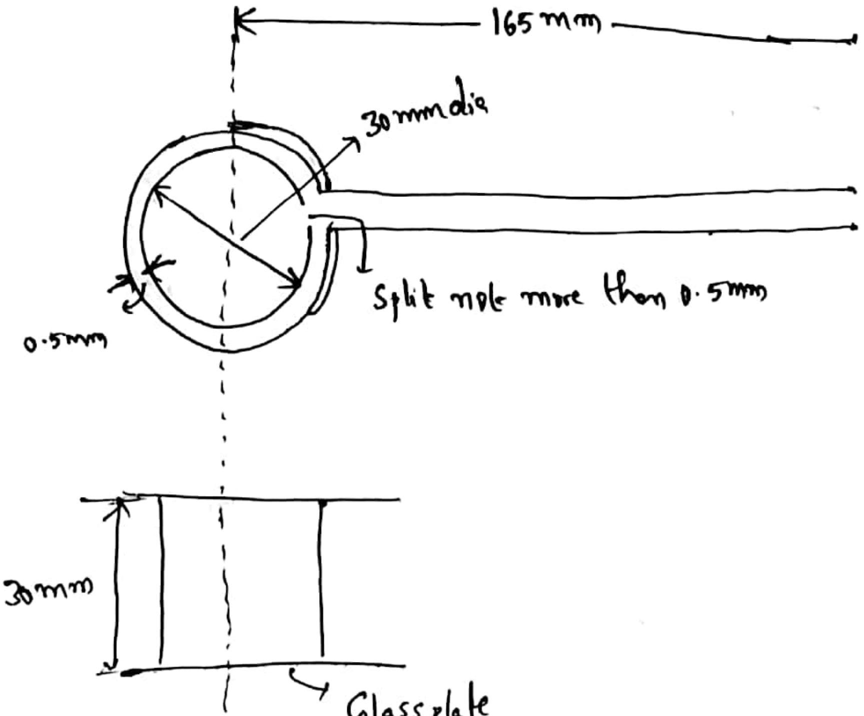


Fig: Le-chatelier apparatus for finding soundness of cement.

→ The cement is gauged with 0.78 times the water required for standard consistency [0.78P], in a standard manner & filled into the mould kept on a glass plate

→ The mould covered on the top with another glass plate.

→ The whole assembly is immersed in water at a temperature of 27°c - 32°c and kept there for 24hr.

→ Measure the distance b/w the indicator points Submerge the mould again in water.

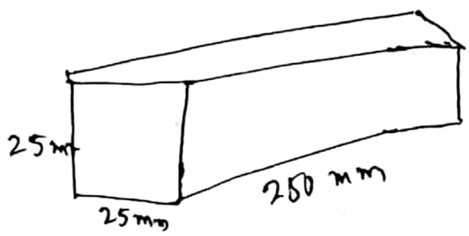
→ Heat the water and bring to boiling point in about 25-30 min and keep it boiling for 3 hours.

→ Remove mould & cool it & measure the distance between the indicator points it should not be more than 10 mm for OPC.

Auto clave Test:

→ The Indian standard specifications stipulates that a cement having a magnesia content of more than 3% shall be tested for soundness by Auto clave test which is sensitive to both free magnesia & free lime.

→ In this test cement specimen 25-25-250 mm is kept in moist atmosphere for 24 hours



→ Then measure the lengths of specimen

→ Then place the cement specimen in a standard auto-clave and the steam pressure inside the autoclave is raised in such a rate as to bring the gauge pressure of the steam to 21 kg/cm² [2.1 N/mm²] in 1-1¼ hour from the time the heat is turned on.

→ This pressure is maintained for 3 hours. The auto-clave is cooled and the length measured again.

→ Diffrence between the two measurements should not exceed 0.8% of length by any direction.

* **Compressive strength of cement.**

→ strength tests are not made on neat cement paste because of difficulties of excessive shrinkage and subsequent cracking of neat cement

→ The strength of cement is indirectly found on cement-Sand mortar in specific proportions

→ Take 555 gms of standard Sand [Ennore sand], 185 grams of cement [ie ratio cement to sand is 1:3]

→ Mix with trowel & add water of quantity $\frac{P}{4}+3$ percent of combined weight of cement & sand.

→ Mould size is 7.07 cm & vibrator will be used ~~for~~ compacting

the mix.

... most ...

⇒ Keep the moulds in under water

⇒ Test the compressive strength for 3, 7, & 28 days respectively.

* **Specific gravity of Cement:**

→ **Apparatus:** Specific gravity Bottle [100ml], Kerosene, Cement, weighing machine.,

Theory: The sp. gravity is normally defined as the ratio between the weight of a given volume of material and weight of an equal volume of Water

⇒ Kerosene which does not react with cement.

Procedure

→ The weight of empty flask is taken as W1

→ $\frac{1}{3}$ weight of Cement + flask = W_2

→ Add Kerosene & weight will be taken

Cement + flask + Kerosen weight = W_3

→ Flask with full Kerosene = W_4

Formula

$$\text{Specific gravity} = \frac{W_2 - W_1}{(W_2 - W_1) - (W_3 - W_4) \times 0.79}$$

Limit: Specific gravity of cement = 3.15

* Grades of Cement:

→ OPC is the most important type of cement

→ We have three grades of OPC

1. 33 grade
2. 43 grade
3. 53 grade

1. 33 grade of OPC:

→ which is governed by IS 269-1989

→ If the 28 days strength is not less than 33 N/mm^2, it is called 33 grade cement.

→ Initial strengths

3 days	-	16 MPa
7 days	-	22 MPa
28 days	-	33 MPa

Speific surface area min = 2250 gr/cm^2

→ This cement is used for general civil construction work under normal environmental condition

→ It can be used for plastering of single storey house

→ Due to low compressive strength, this cement is normally not used where high grade of concrete r'q M 20 & above.

2. 43 grade of OPC:

→ which is governed by IS 8112-1989

→ If the 28 days strength is not less than 43 N/mm^2 it is called 43 grade cement

Initial strengths

3 days - 23 MPa

7 days - 33 MPa

28 days - 43 MPa

→ specific surface area = 2930 cm^2/gr

→ used for RCC works grade upto M30

→ pre cast items such as blocks, tiles, pipes

→ Non-structural works such as plastering, flooring etc

3. 53 grade of OPC

→ which is governed by IS 12269-1987

→ If the 28 days strength is not less than 53 N/mm^2 it is called 53 grade cement

Initial strengths

3 days - 27 MPa

7 days - 37 MPa

28 days - 53 MPa

→ Specific surface area = 3400 cm^2/gr & above

→ RCC works [above M-25]

→ prestressed concrete structures

→ Run ways, concrete Roads, Bridges

→ Problem with 53 grade cement it will undergo more shrinkage.

* Admixtures:

Admixtures: It is defined as a material other than the cement, water and aggregates, that is used as an ingredient of concrete and is added to the batch immediately before or during mixing. Additive is a material which is added at the time of grinding cement clinker at the cement factory.

Admixture is used to modify the properties of ordinary cement concrete so as to make it more suitable for any situation as per our requirements used for different purposes.

⇒ Basically admixtures are of two types.

1. Chemical admixture → additives
2. mineral admixture → replacers.

① Chemical admixtures:

1. workability agents
2. Accelerators
3. Retarders
4. Air entraining agents
5. Air detraining agents
6. Gas forming agents
7. Grouting agents
8. Alkali aggregate expansion inhibitors

(9) Damp proofing & permeability reducing agents
(10) Corrosion inhibiting agents
(11) Bonding agents
(12) Fungicidal, Germicidal & insecticidal agents
(13) Colouring admixtures

(2) Mineral Admixtures (Replacers)/ supplementary additives

(1) Puzzolonas

(1) Workability Agents:

a) plasticizers } water reducers
b) Super plasticizer }

* Workability agents (water reducers):

→ The requirement of right workability is the essence of good concrete. Concrete in different situations require different degree of workability.

→ A high degree of workability is required in situations like deep beams, a thin wall of water retaining structres with high percentage of steel reinforcement, column & beam junctions, pumping of concrete, hot weather concreting, for concrete to be conveyed for considerable distance and in ready mixed concrete industries.

⇒ In conventional methods, the workability can be improved by

(a) Improving the grading of aggregates

(b) Using relatively higher % of fine aggregates.

(c) By increasing cement content

But it is difficult to obtain good workability for a given set of conditions. The easy method generally followed at the site in most of the conditions is by using extra water. But it undoubtedly effect the strength and durability.

Alternatively we have plasticizers and super-plasticizers to help an engineer to face the difficult conditions for obtaining higher workability without using excess of water.

* Action of plasticizers:

The action of plasticizers is mainly to fluidify the mix & improve the workability of concrete.

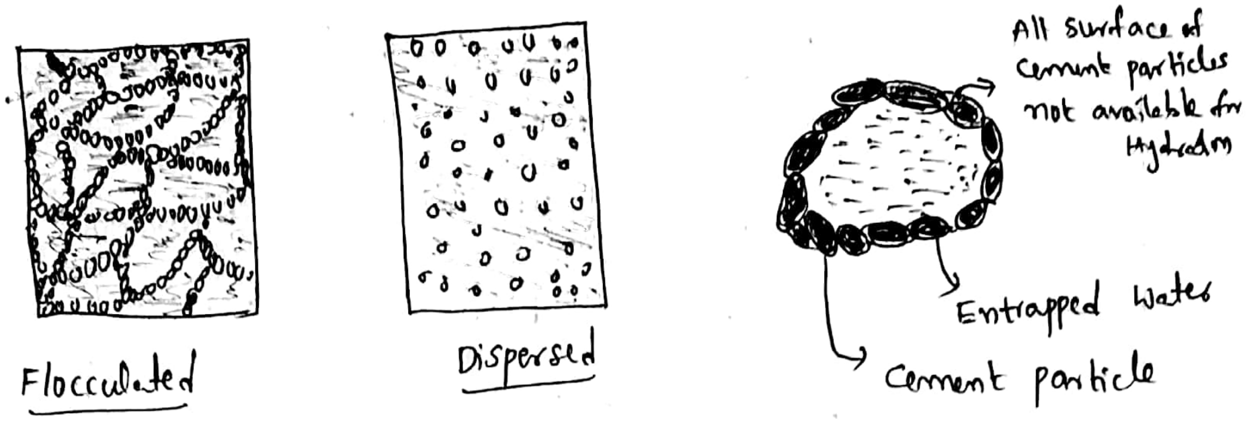
The mechanisms are involved

(1) Dispersion

(2) Retarding Effect

(1) Dispersion:

OPC, being in fine state of division, will have a tendency to flocculate in wet concrete. These flocculation entraps certain amount of water used in the mix and thereby all the water is not freely available to fluidify the mix.



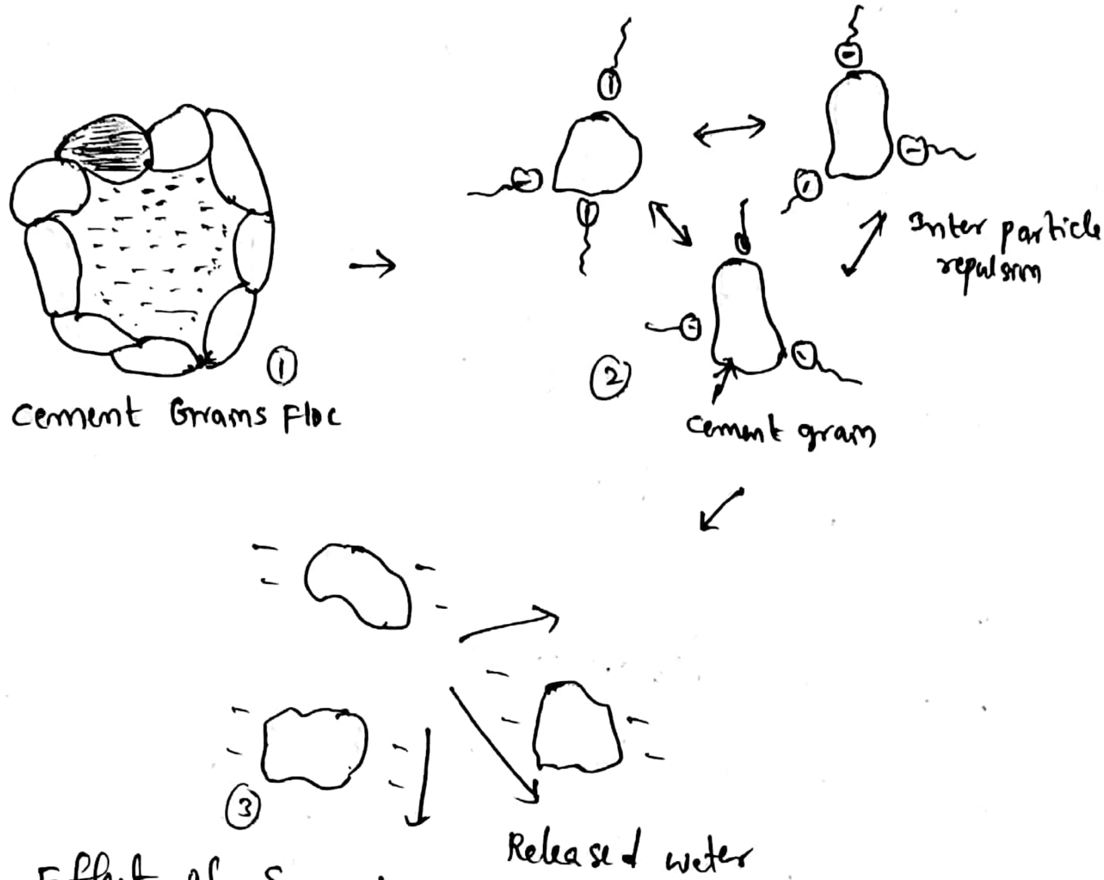


Fig: Effect of Superplasticizer on cement particle floc

→ When plasticizers are used, they get adsorbed on the cement particles. The adsorption of charged polymer on the particles of cement creates particles-to-particle repulsive force which over come attractive forces. The repulsive force is called "Zeta Potential" which depend on the base, solid content, quality of plasticizer used.

→ The result is that the cement particles are deflocculated and dispersed, when cement particles are deflocculated, the water trapped inside the flocs gets released and now available to fluidify the mix.

→ When cement particles get flocculated there will be interparticles friction b/w particle to particle & floc to floc but dispersed condition it will be reduced.

② Retarding Effect.

→ The plasticizers gets adsorbed on the surface of cement particles and form a thin sheath. This thin sheath inhibits the surface hydration reaction b/w water & cement as long as sufficient plasticizer molecules are available at the particle/solution interface. The quantity of available plasticizers will progressively decreases as polymers become entrapped in hydration products.

⇒ plasticizers & super plasticizer can produce at the same water-cement ratio, much more workable concrete.

	water	slump
without plasticizer	1000 ml	100 mm
with plasticizer	1000 ml	130 mm

→ For the same workability, it permits the use of lower w/c ratio. Indirectly hence will help to increase the strength & durability

⇒ plasticizers can be used in 0.1 – 0.4% which can reduce water by 5 – 15% of water respectively.

⇒ Super plasticizer can reduce the water by 30%

Examples for plasticizers:

→ calcium, sodium, Aluminum Lithium sulphates are used as plasticizes
→ Derivatives of lignosulfonic acids & their salts [Ca, Na, ~~...~~ salts]
→ Hydroxylated carboxylic acids & their salts
→ processed carbohydrates

Examples for super-plasticizers:

→ sulphonated malamie-formaldehyde condensates (SMF)
→ sulphonated naphthalene - formaldehyde condensates (SNF)
→ Acrylic polymer based (AP)
→ copolymer of carboxylic acrylic ester (CAE)
→ cross linked acrylic polymer [CLAP]
→ Polycarboxylate ester (PC)
→ Multi carboxylate ethers (MCE)
→ combination of above

② **Accelerators**: These are added to concrete to increase the rate of early strength

→ Earlier removal of formwork

→ Reduce the required period of curing

→ Advance the time that a structure can be placed in service

→ In the emergency repair works

Eg: Calcium chloride [$CaCl_2$]

③ **Retarders**: It is an admixture that slows down the chemical process of hydration so that concrete remains plastic and workable for a long time.

The commonly used retarders are

1) Gypsum
2) Calcium sulphate
3) Sugar

④ **Air entraining agents**:

This is used to modify the properties of plastic concrete regarding workability, segregation, bleeding and finishing quality of concrete and it also modifies the properties of hardened concrete regarding the permeability and frost action.

The air voids present are of 2 types

a) **Entrained air**: It is intentionally incorporated minute spherical bubbles of size 5 - 80 μ distributed evenly in the entire mass of the concrete

b). **Entrapped air**:

These are the voids present in the concrete due to insufficient compaction. These are of any shape and size and are non-uniformly distributed throughout the concrete mass.

Example of Air entraing agents

(a) Natural wood resins

(b) Animal and vegetable fats & oils

(c) Various wetting agents such as alkali-salts

(d) Hydrogen peroxide, & aluminum powder.

(e) Vinsol Resins

(d) Darex.

⑤. **Air detaining agents**:

These materials are used to

1. dissipate excess air or other gases and
2. Remove a part of the entrained air from a concrete matrix.

Ex:- Tributyl-phosphate

Dibutyl phathalate

⑥ Gas- forming Admixtures:

→ These are mainly used to counteract shrinkage & bleeding in the plastic concrete. The most commonly used gas forming agent is aluminium powder [0·005 – 0·02% by wt cement]

Aluminium powder: It reacts with hydroxide present in the hydrating cement to produce minute bubbles of hydrogen. Those bubbles causes a slight expansion in the plastic concrete, thus reducing shrinkage

⑦ Bonding admixtures:

These are water emulsion of several organic materials that are mixed with cement for application to an old concrete surface their function is to increase the bond ~~shrinkage~~ strength between the old and new concrete. The commonly used admixtures are made from natural rubber, synthetic rubber (or) organic polymers.

The polymers include polyvinyl chloride, polyvinyl acetate, acrylics and butadiene styrene copolymers.

⇒ These are added 5–20% by wt of cement depending upon actual bonding requirements

② Mineral Admixtures

→ Mineral additives also called supplementary cementing materials

→ These are generally pozzolanic materials

→ Pozzolana materials are fly ash, GGBS, Rice husk ash, surki etc.

→ These pozzolanas are siliceous and aluminous which in themselves possess no cementing property but it chemically react with $Ca(OH)_2$ liberated on hydration at ordinary temperature to form compounds possessing cementitious property

Advantages of using pozzolana

1. Lowers the heat of hydration and thermal shrinkage
2. Reduces the permeability of concrete
3. Improves workability
4. Lowers the cost [Economical]
5. Reduces the alkali-Aggregate reaction
6. Improves resistance to attack by sulphates

① **Fly ash**: IS code: 3812:2003

→ Fly ash is by product of Thermal plants

→ ASTM broadly classify fly ash into two classes

① class F → < 5% CaO → posses only pozolonic property

② class C → > 5% CaO → posses both pozolonic & cementitious properties

→ specific surface area about 350 to 500 m^2/kg

→ finer than OPC

→ particle size varys 1 to 100 microns.

→ Density of fly ash → 2200 - 2400 kg/m^3

→ Density of cement → 3100 - 3200 kg/m^3

specific gravity → 2.1-2.6

② **GGBS [Ground Granulated Blast Furnance slag]**

→ It is a waste industrial by-product obtained during the production of iron

→ GGBS is non-metalic product having oxide composition similar to that of OPC clinker.

→ Advantage → Lowe heat of evolution, refined pore structure, reduced permeability

→ IS code: 12089-1987

→ Specific surface area → 400-600 m^2/kg [Blaine]

→ specific gravity → 2.9

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Unit-II

Aggregates

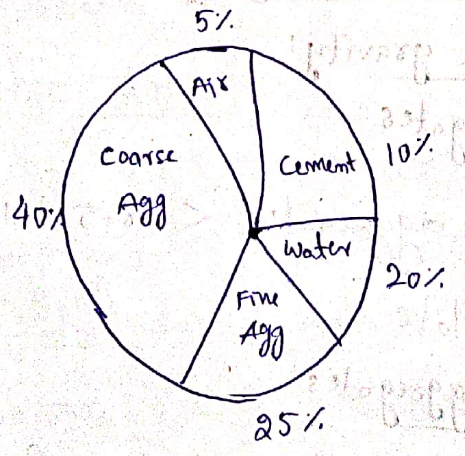
Introduction:

→ Aggregates are the major ingredients of concrete. They constitute 65-80% of total volume, provide a rigid skeleton structure for concrete and acts as economical space fillers.

→ IS code: 383-1970 defines the requirements of Aggregates.

1 cement bag 50kg — 1.24 cubic ft
1 cubic ft — Rs. 240/-

Aggregates bag 1 cubic ft — Rs. 20/-



→ The aggregates are inert and filler materials floating in the cement paste matrix of concrete.

Advantages of aggregates:

1. These are versatile [Plenty]
2. ~~Pliable~~ These rigid
3. strong & durable
4. Does not rust
5. Does not need any coating
6. Fire resistant
7. Economical [cheaply available]
8. Almost suitable for any environmental exposure conditions
9. Reduces thermal cracking
10. Reduces shrinkage.

* classification of Aggregates:

* Based on specific gravity:

1) Light weight aggregates:

→ The density of the aggregates $< 18.5\ kN/m^3$

Ex: shale or slate

2) Normal weight aggregates:

→ The density of the aggregates ranging from 22 to 24 kN/m^3

Ex:- Granite, Basalt

3) Heavy weight aggregates:

→ The density of the aggregates > 1.5 (Normal weight Aggregates)

$> 35\ kN/m^3$

Ex:- Baryles, Magnetite, Limonite

* Based on source :

→ Based on source aggregates are three types

1. Igneous Rocks :

→ Igneous rocks are formed by the cooling of molten magma or Lava at the surface of the crest [trap & basalt] or deep beneath the creast (granite)

→ Most igneous rocks make highly satisfactory concrete aggregates because they are normally hard, tough and dense.

Ex:- Granite, Basalt

2. Sedimentory Rocks :

→ Sedimentory rocks are formed originally below sea bed and subsequently lifted up.

Ex:- Sand stone

3. Metamorphic Rocks :

→ Metamorphic rocks are originally either igneous or sedimentary rocks which are subsequently metamorphosed due to extreme heat and pressure.

→ Metamorphism which changes the structure and texture of rocks.

Ex:- Marble

* **Based on size:**

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

⇒ Using maximum passible size will result in
   (i) reduction of the cement content
   (ii) reduction in water rejuirement
   (iii) reduction of drying shrinkage

⇒ However, maximum size of aggregate that can be used in any given condition may be limited by
   (i) Thickness of section
   (ii) spacing of reinforcement
   (iii) clear cover
   (iv) Mixing, handling & placing techniques.

⇒ Aggregates are divided into two catagories from the consideration of size

   (i) Coarse Aggregate: ≥ 4.75 mm sieve

→ The aggregates which are retained on IS 4.75 mm sieve are called coarse aggregates.

   (ii) Fine Aggregates: < 4.75 mm sieve

⇒ The Aggregates which are passing through IS 4.75 mm sieve are called fine aggregates.

* **Based on shape:**

→ The particle shapes of aggregates influence the properties of fresh concrete more than those of hardened concrete.

(i) **Rounded Aggregates:**

→ Minimum voids ranging from 32 to 33 percent.

→ It gives minimum ratio of surface area to the volume; thus requiring minimum cement paste to make good concrete.

→ The only disadvantage is that the interlocking b/w its particles is less and hence the development of the bond is poor, making it unsuitable for higher strength concrete & pavements

(ii) **Angular Aggregates:**

→ Maximum percentage of voids ranging from 38 to 40%.

→ Interlocking b/w the particles is good, there by providing a high strength than that required by rounded particles.

→ The angular aggregate is suitable for high strength concrete and pavements subjected to tension.

(iii) **Flaky and Elongated Aggregates:**

⇒ Flaky aggregate is its least dimension (thickness) is less than 3/5 of its mean dimension

⇒ Elongated Aggregate is its greatest dimension (length) is greater than 9/5 of its mean dimension

⇒ These are not suitable for making good concrete.

Based on surface texture

⇒ Surface texture is the property, the measure of which depends upon the relative degree to which particle surfaces are polished or dull, smooth or rough.

(i) Glassy
(ii) Smooth
(iii) Rough
(iv) Granulated
(v) Honey-combed (pores)

⇒ As surface ~~area~~ smoothness increases, contact area decreases, hence a highly polished particle will have less bonding area than rough particle.

~~Based~~ Properties of Aggregates:

1. particle shape
2. surface texture
3. strength & stiffness
4. Specific gravity & Bulk density
5. Water absorption & surface moisture content
6. Bulking of sand
7. Soundness of Aggregates
8. Grading of aggregates by sieve analysis

9. Durability of aggregates

10. Chemical and thermal properties

11. Toughness

12. Hardness

① Particle shape:

Type of Agg	Paste requirement	strength	workability
Round	Low	Low	High
Angular	High	High	Low
Flaky/ Elongated	Low	Low	Low

② Surface Texture:

Type of Aggregate	Paste requirement	strength	workability
Rough	High	High	Low
Smooth	Low	Low	High
Glassy	Low	Low	High

3. Strength & stiffness:

Strength: 1. strength of aggregate alone is not going to give good strength of concrete

2. It depends on bond between cement paste and aggregate

3. Quality of cement paste

Note: strength → Resistance to force

Note: The strength of concrete can not exceeding the strength of aggregates

Test: Aggregate crushing value test

Stiffness:

→ It refers to resisting the deformation

→ It is important for maintaining the dimensional stability of concrete under load.

4. Specific gravity and Bulk Density:

Specific gravity: The specific gravity of an aggregate is defined as the ratio of the mass of solid in a given volume of sample to the mass of an equal volume of water at the same temperature.

$$\text{Specific gravity} = \frac{\text{Density of material}}{\text{Density of water}} = \frac{\rho g}{\rho g} = \frac{\frac{m}{V}\cdot g}{\frac{m}{V}\cdot g}$$

→ In concrete technology, specific gravity of aggregates is made use of in design calculations of concrete mixes.

→ specific gravity of fine aggregate → 2.5 to 2.6

→ Specific gravity coarse aggregate → 2.6 to 2.8

Bulk Density: The bulk density of an aggregate is defined as the mass of the material in a given volume and expressed in Kg/liter (or) kg/m³.

→ The bulk density of an aggregate depends on how densely the aggregates is packed in the measure.

→ For a given specific gravity the angular aggregates show a lower bulk density than rounded Aggregates.

→ Bulk density gives valuable informations regarding the shape and grading of the aggregates.

→ The higher the bulk density, the lower is the void content to be filled by sand and cement.

→ The sample which gives the minimum voids (or) the one which gives maximum bulk density is taken as the right sample of aggregate for making economical mix.

→ The method of determing bulk density also gives the method for finding out void content in the sample of aggregate.

$$\text{Bulk density} = \frac{\text{mass of Agg}}{\text{unit volume}} = \text{kg/m}^3$$

6. Water absorption and Surface moisture content:

→ Some of the aggregates are porous and absorptive. Porosity and absorption of aggregates will effect the water/cement ratio and hence the workability of concrete.

→ The porosity of aggregate will also effect the durability of concrete when concrete is subjected to freezing and thawing and also when concrete is subjected to chemically aggressive liquids.

→ Absorption of water by the aggregates is due to the presence of small pores.

→ Saturated surface dry aggregates are used for concrete.

→ In the design of concrete mix the aggregates are assumed to be saturated surface dry aggregates [when all pores of aggregates are full of water]. It will effecting the water/cement ratio. Hence the aggregates are neither air-dry [it is allowed ~~for~~ to dry in air, some of the water from pores will evaporates] nor bone dry [the aggregates are oven dried].

⇒ The water absorption of aggregates is determined by measuring the increase in weight of an oven dry sample when immersed in water for 24 hours. The ratio of the increase in weight to the weight of the dry sample expressed as percentage is known as absorption of aggregate.

⇒ The surface moisture expressed as a percentage of the weight of the saturated surface dry aggregate is termed as moisture content.

<u>Note</u>: The strong rocks does not absorb more than 10%.

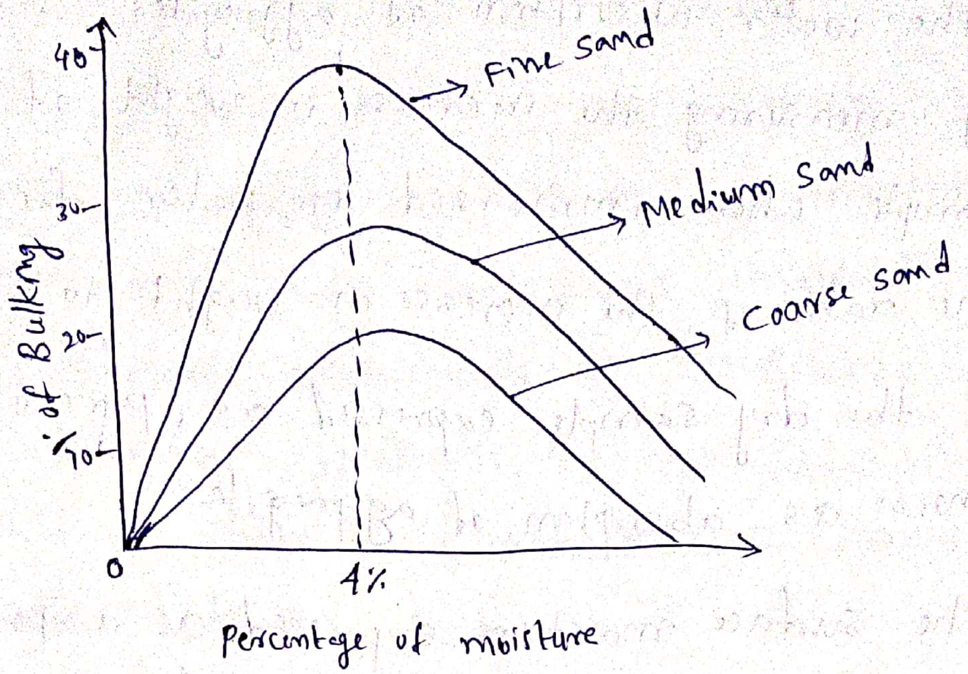
Granite ≯ 1%

6. Bulking of Sand:

⇒ The presence of moisture in the fine aggregate increases its volume and is known as bulking of sand.

→ The free moisture form a thin film around the each aggregate and exerts surface tension. This keeps the particles away from one another and thus aggregates bulks in volume.

→ The Bulking increases with the fineness of the sand. It may be as large as 30 - 40%.



River sand → Maximum bulking → 30% bulking

Robo sand [M-sand] → Maximum bulking → 40% bulking

⇒ At 4% of water content the bulking is maximum

⊛ **Effect of bulking of sand:**

→ when sand is added in mixing the concrete by volume batching, the actual amount of sand mixed will be less than the required due to bulking effect.

→ this results in a strong [rich] mix and the concrete will be honey combed.

→ Thus it is necessary to modify the amount of sand depending on its bulking effect.

Note: Volume of dry sand = volume of wet sand

⊛ Deleterious Substances in aggregates:

The materials whose presence may adversely affect the strength, workability and long term performance of concrete are termed deleterious materials. These are considered undesirable as constituent because their intrinsic weakness, softness, fineness or other physical or chemical characteristics harmful to concrete behavior.

⇒ Depending upon their action, the deleterious substances found in aggregates can be divided into three broad categories

1. Impurities interfering with the process of hydration of cement

   Ex:- decayed vegetable matter, organic loam

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

3. Un-sound particles which are weak or bring about chemical reaction between the aggregates and cement paste

   Ex:- shale, clay lumps, wood, coal

Note: The total amount of deleterious materials should not exceed 5% as per IS : 383-1970.

7. Soundness of aggregates:

⇒ The soundness indicates the ability of the aggregate to resist excessive changes in volume due to changes in environmental conditions, e.g., freezing and thawing, thermal changes, and alternating wetting & drying

⇒ Aggregates which are porous, weak and containing any undesirable extraneous matters undergo excessive volume change when subjected to the above conditions.

⇒ Aggregates which undergo more than the specified amount of volume change is said to be un-sound aggregates.

⇒ If concrete is liable to be exposed to action of frost, the coarse and fine aggregate which are going to be used should be subjected to un-soundness test.

⇒ The soundness test determine the resistance to disintegration of aggregates by saturated solution of sodium sulfate [Na_2SO_4] or magnesium sulphate [$MgSO_4$].

⇒ According to IS: 383-1970, the average loss of weight after ten cycles should not exceed 12 and 18% when tested with Na_2SO_4 and $MgSO_4$, respectively

8. Alkali Aggregate Reaction (AAR)

⇒ For long time the aggregates have been considered as inert materials but later on it was clearly brought out that the aggregates are not fully inert.

⇒ Some of the aggregates contain reactive silica which react with alkalis present in cement [Na_2O & K_2O].

Ex:- traps, andesites, rhyolites, siliceous lime stones

⇒ As a result the alkali silicate gel of unlimited swelling type is formed which results in the disruption of concrete ~~which~~ with the spreading of cracks and finally leads to failure of the concrete structures.

@ Factors promoting alkali aggregate reaction:

(i) ~~Read~~ Reactive type of aggregates

(ii) High alkali content in cement

(iii) Availability of moisture

(iv) Optimum temperature

(i) Reactive type of aggregate:

→ The potential reactivity of an aggregate can be determined by petrographic examination of thin rock sections.

⇒ There are two methods

(a) Mortar bar expansion test

(b) Chemical test on aggregates

* Mortar bar expansion test by stanton:

⇒ Testing of aggregates [whether they are reactive or non-reactive]

1. Cast a specimen 25mm×25mm ×250 mm
2. Then it should be cured and stored in a standard manner.
3. Measure the length of the specimen periodically at 1, 2, 3, 6, 9 & 12 months
4. Find out the difference in length of the specimen to the nearest 0.001%.
5. The aggregates under test are considered harmful if it expands more than 0.05% at 3 months and 0.1% at 6 months.

(ii) High Alkali content in cement:

→ The high alkali content in cement is one of the most important factors contributing to the AAR.

⇒ In the field experience has never detected serious deterioration of concrete through the process of alkali aggregate reaction when the cement contain alkalis content less than 0.6 %

(iii) Availability of Moisture:

⇒ ~~Program~~ Progress of chemical reaction involving AAR in concrete requires the presence of water. It has been seen in the field and laboratory that lack of water greatly reduces this deterioration.

⇒ therefore it is essential to note that the deterioration due to alkali aggregate reaction will not occur in the interior of mass concrete. It is more on the surface of concrete.

⇒ It is suggested that reduction in deterioration due to alkali-aggregate reaction can be achieved by application of water proofing agents to the surface of concrete.

(iv) Optimum temperature:

→ The ideal temperature for the promotion of alkali aggregate reaction is in the range of 10° to 40°C.

* Mechanism of deterioration of concrete by Alkali Aggregate Reaction (AAR):

→ This reaction has not been perfectly understood, however from the known information the mixing water turns to be a strongly caustic solution.

→ This caustic liquid attacks reactive silica to form alkali silicate gel of unlimited swelling type.

⇒ If continuous supply of water and correct temperature is available the formation of silica gel is continuous.

⇒ This growth of silica gel exerts osmotic pressure to cause cracking particularly in thinner section of concrete like pavements and roof slabs and there is no much effect on main concrete section.

⇒ The formation of pattern cracks due to the stress induced by the growth of silica gel results in subsequent loss in strength and elasticity.

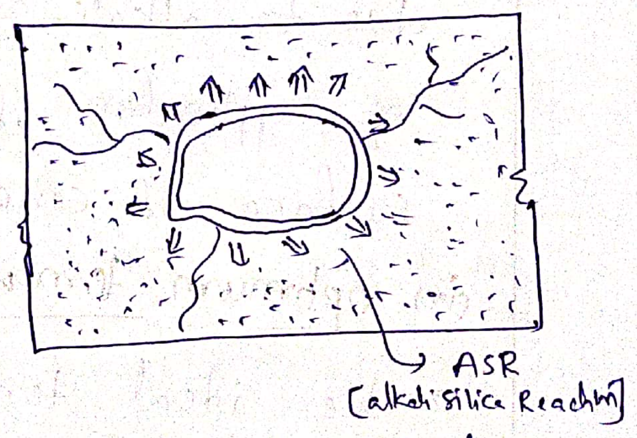


Fig: Alkali-Aggregate Reaction

* Control of Alkali-Aggregate Reaction:

(i) Selection of non-reactive aggregates
(ii) By the use of low alkali cement
(iii) By the use of corrective admixtures such as pozzolonas
(iv) By controlling the void space in concrete
(v) By controlling moisture condition and temperature.

8. Grading of aggregates by sieve analysis:

* Sieve Analysis:

It is an operation of dividing a sample of aggregates into fraction. The particle size distribution of an aggregate as determined by sieve analysis is termed grading of the aggregate

⇒ It is conducted to determine the fineness modulus [FM]. FM is an index of Coarseness (or) fineness of the material.

⇒ The sieving operation can be performed by manually or by mechanical means.

→ The sieves of 80mm to 150 μ are arranged one above the ~~other~~ other with the largest opening at the top.

→ After sieving for 15 mins the material retained on each sieve is to be weighted.

→ Then we should calculate the value of F.M

Sieve sizes

Coarse Aggregate:
- 80 mm
- 40 mm
- 20 mm
- 10 mm
- 4.75 mm

Fine Aggregate:
- 4.75 mm
- 2.36 mm
- 1.18 mm
- 600 μ
- 300 μ
- 150 μ

⇒ Fineness modulus is the ratio of sum of cummulative percentage to 100.

$$F.M = \frac{\Sigma \text{ cummulative \% retained}}{100}$$

⇒ The following limits may be taken as guidence

⇒ Fine Aggregate → FM value 2.2 to 3.2

Fine sand: 2.2 to 2.6

Medium sand: 2.6 to 2.9

Coarse sand: 2.9 to 3.2

⇒ Coarse aggregate → F.M value: 5.5 to 8

Note: A sand having a FM more than 3.2 will be unsuitable for making satisfactory concrete

Problem 1: Find out the Fineness modulus of fine aggregate of given sample [1000 grams]

Sieve size	Mass retained in grams	% of mass retained	Cummulative % of mass retained
4.75 mm	0	0	0
2.36 mm	100	10	10
1.18 mm	220	22	32
600 μ	250	25	57
300 μ	230	23	80
150 μ	200	20	100
		Total ⇒	Σ = 279

$$F.M = \frac{\Sigma \text{ cummulative \% retained}}{100}$$

$$= \frac{279}{100} = 2.79$$

Medium sand → 2.6 - 2.9

F.M = 2.79

↳ Medium sand

Problem 2: Find out the Fineness modulus of ~~the~~ coarse aggregate of the given sample [15 kg]

Sieve size	Mass retained in kg	% of mass retained	Cummulative % of mass retained
80 mm	0	–	–
40 mm	0	–	–
20 mm	6	40	40
10 mm	5	33.33	73.33
4.75	4	26.66	100
2.36	0	–	100
1.18	0	–	100
600 μ	0	–	100
300 μ	0	–	100
150 μ	0	–	100
			Σ = 713.33

$$F.M = \frac{713.33}{100} = 7.133$$

$$\boxed{F.M = 7.133}$$

Note: The F.M represents the weighted average size of the sieve on which the material is retained, the sieve being counted from to finest [i.e from bottom]

Ex:- F.M of '3' indicates the third sieve from the finest sieve i.e 600 μ.

* Grading of aggregates:

→ The particle size distribution of an aggregate is determined by sieve analysis is termed grading of the aggregate.

→ The gradation of coarse aggregates plays an important role in workability and paste requirements.

→ The gradation of fine aggregates affects the workability and finishability of concrete.

→ Grading is a very important property of the aggregate used for making concrete.

→ It is well known that the strength of concrete is depending W/C ratio provided the concrete is workable. It means one of the most important factors for producing workable concrete is good grading of aggregate.

→ Good grading implies that a sample of aggregate contains all standard fractions of aggregate in required proportion such that the sample contains minimum voids.

→ A sample with minimum voids requires minimum paste to fill up the voids in aggregates. Minimum paste means less quantity of cement & water which will increase the economy, strength & durability.

* The various types of gradation are

(i) Uniform grading: In uniform grading, all particles are of the same size. Note that this produces a large volume of voids irrespective of particle size. Hence the paste requirement for this concrete is high.

(ii) Continuous grading: It incorporates a combination of particles of many sizes. Hence it minimizes the volume of voids but increases the particle surface area. This is the preferred gradation

(iii) Gap grading: This involves grading in which one are more sizes are omitted. This type of concrete is generally used for architectural (or) aesthetic purposes.

* Grading pattern of the available coarse & fine aggregate & specified combined grading: % of passing IS 383-1970

I.S sieve	C.A	F.A	Combined Agg
40 mm	100	100	100
20 mm	96	100	98
10 mm	35	100	61
4.75 mm	6	92	42
2.36 mm	0	85	35
1.18 mm	0	75	28
600 mm	0	60	22
300 mm	0	10	5
150 mm	0	0	0

* Grading limits for fine aggregates

IS 383-1970

% of passing by weight

IS sieve	Zone I	Zone II	Zone III	Zone IV
10 mm	100	100	100	100
4.75 mm	90-100	90-100	90-100	95-100
2.36 mm	60-95	75-100	85-100	95-100
1.18 mm	30-70	55-90	75-100	90-100
600 μm	15-34	35-59	60-79	80-100
300 μm	5-20	8-30	12-40	15-50
150 μm	0-10	0-10	0-10	0-15

FM = 3.37 - 2.10

Note: It must be remembered that the grading of fine aggregates has much greater effect on workability of concrete than grading of coarse aggregate

⇒ The very coarse or very fine sand usually is not satisfactory for producing good concrete

⇒ If sand is coarse that results in bleeding and segregation. If it is fine requires greater amount of water, so that reduces workability.

Note:- As per IS code in normal construction we are using Zone II sand.

⇒ Zone ④ is very fine material and should not be used in R.C.C.

(A) Grading curves:

Gradation: The sieve analysis is conducted to determine the particle size distribution for the sample of aggregates which we call gradation.

Grading curve: the result of sieve analysis is expressed in graphical form is known as grading curve.

⇒ Expressing grading limits by means of a chart gives a good pictorial view. The comparision of grading pattern of a number of samples can be made at one glance. For this reason grading of aggregates is shown by means of grading curves.

⇒ The curve showing the cummulative percentages of material passing the sives represented on the ordinate wise sieve openings on obscissa.

→ Grading curve gives

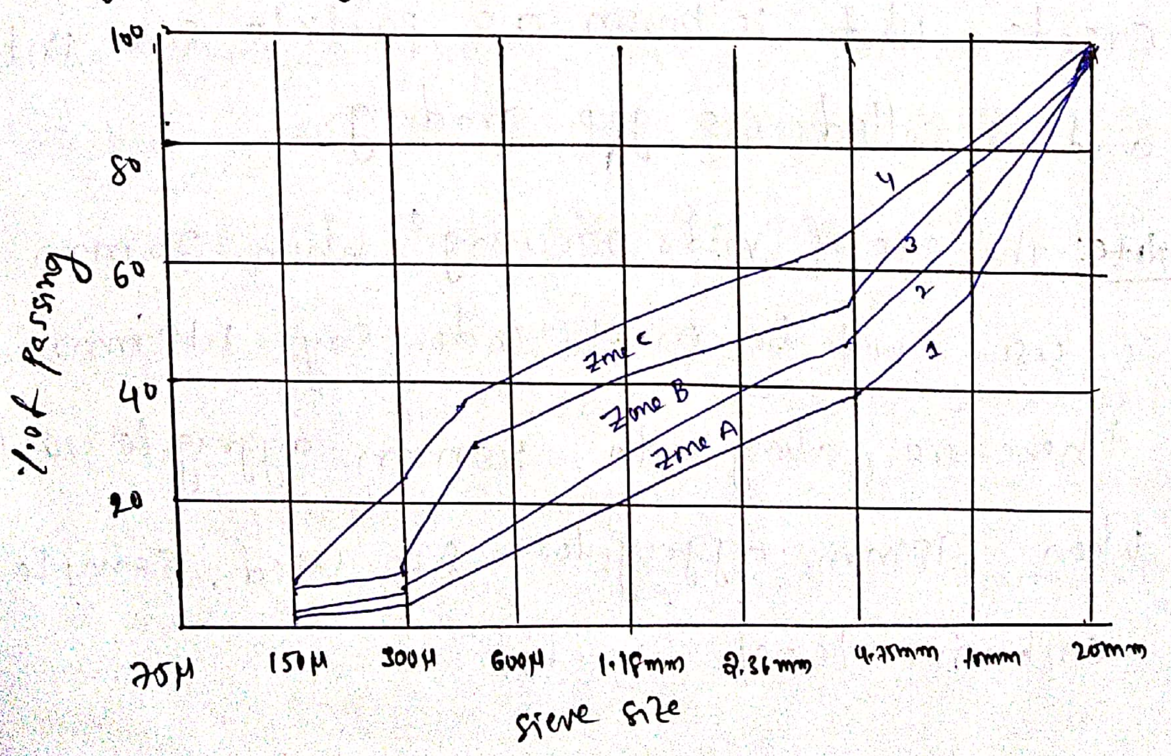
1. In case the actual grading curve is lower than the specified grading curve, the aggregate is coarser and segregation of mix might take place.

2. In case actual curve lies above the specified curve, the aggregate is finer and more water required, thus increasing quantity of cement.

3. If actual curve steeper than specified curve, it indicates of middle size particles and leads to harsh mix.

4. If actual curve is flatter than the specified curve, the aggregate will be deficient in middle size particles.

Ex:- Type grading curve for 20mm aggregate



Note:- Curve No. 1 is coarsest grading.
Curve No. 4 is finest grading.

⊛ Gap-grading:

- Originally, in the theory of continuous grading it was assumed that the voids ~~for~~ present in the higher size of aggregates are filled up by next lower grade and similarly voids created by the lower size are filled up by one size lower than those particles and so on.

It was realised later that the voids created by a particular fraction are too small to accommodate the very next lower size. The next lower size is to occupy the voids being itself bigger than the size of the voids. It will create what is known as particle size interference and is called as gap grading.

Note: The size of voids occuring when 20mm aggregate is used will be in the order say 1.18mm, so therefore, along with 20mm aggregate, only when 1.18mm aggregates size used, sample contains least voids.

* Advantages of gap grading:

1. Sand required will be about 26% as against 40% in the case of continuous grading.

2. Specific surface area is low, because of high percentage of Coarse aggregate & low percentage of F.A.

3. Requires less cement and lower water/cement ratio

4. Because of point contact b/w C.A to C.A & also on account of lower cement and matrix content, the drying shrinkage is reduced.

* Specific surface:

The surface area per unit weight of the material is termed as specific surface. This is an indirect measure of the aggregate grading. This is increases with the reduction in the size of the aggregate particles so that fine aggregates contribute lot more to the surface area than coarse aggregates.

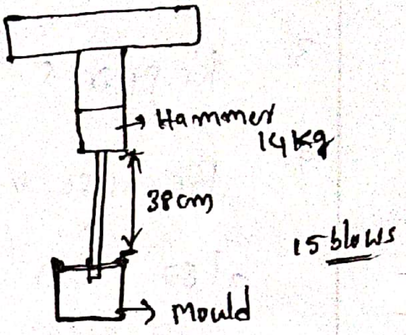
⇒ upto 300 μm of particles require more water and reduces workability but < 300 μm being so fine contributes more towards workability due to their over riding influence by acting like ball-bearing

* **Toughness :**

With respect to concrete aggregates, toughness is usually considered the resistance of material to failure by impact load.

Test : Aggregate Impact Value

Procedure :



1. Take the sample of aggregates approximately 2 kgs [Passing → 12.5mm size, Retain → 10mm size]
2. place the sample of aggregates in a mould to the top level (ie. levelled)
3. Apply the load of 14kg of a metal hammer for 15 blows falling from a height of 38 cm.
4. Weight the material of finer material passing through 2.36mm sieve.
5. The ratio of the weight of the fine particles formed to the weight of total sample is expressed as percentage. This is known as aggregate impact value.

$$\text{Aggregate Impact Value} = \frac{\text{weight of passing material}}{\text{total wt. material}} \times 100$$

→ The aggregate impact value should not be greater than 30% for wearing Coarse [surface coarse] such as runways, roads & pavements

→ The value should not be more than 45% for works other than wearing Coarse

* **Aggregate Crushing value:**

→ The compressive strength of parent rock does not exactly indicate the strength of aggregate in concrete. For this reason assessment of strength of the aggregate is made by using a sample of bulk aggregate in a standard manner. This test is known as aggregate crushing value test.

→ Aggregate crushing value gives a relative measure of the resistance of an aggregate sample to crushing under gradually applied compressive load

* **Test for aggregate crushing value**

Procedure:

→ Take about 6.5 kg material consisting of aggregates passing 12.5 mm and retained on 10 mm sieve.

→ The aggregates in a surface dry condition is filled into the standard cylindrical measure in 3 layers and tamped 25 times with tamping rod.

→ weight of sample contained in the cylindrical measure is taken (A)

→ The whole assembly placed in a compression testing machine and subjected to a load of 40 tonnes at a rate of 4 tons/min.

→ After the load load is released the crushed aggregate is sieved through a 2.36 mm sieve The fraction passing the sieve is weighed (B).

→ The ratio of material passing through the sieve to the total weight of the sample is called crushing value.

The aggregate crushing value $= \frac{B}{A} \times 100$

where B = weight of fraction passing 2.36 mm sieve
A = weight of sample taken in mould

→ The value $\ngtr$ 30% for wearing coarse (surface coarse) such as runways, roads & air field pavements

→ The value $\ngtr$ 45%. for aggregate used for concrete other than for wearing surfaces.

* Hardness of Aggregate

→ The hardness of the aggregate defined as its resistance to wear obtained in terms of aggregate abrasion value.

→ Apart from testing aggregate with respect to its crushing value, impact resistance, testing the aggregate with respect to resistance to wear is an important test for aggregate to be used for road constructions, ware houses floors and pavements construction.

⇒ Three tests are in common use to test aggregate for its abrasion resistance.

(i) Deval attrition test
(ii) Dorry abrasion test
(iii) Los Angels test

(i) **Deval attrition test:** [IS 2386 part IV]

→ In this test particles of known weight are subjected to wear and tear in an iron cylinder rotated 10,000 times at certain speed.

→ The proportion of material crushed finer than 1.7 mm size is expressed as a percentage of the original material taken.

→ This percentage is taken as the attrition value of aggregates

$$\text{Attrition value} = \frac{\text{material weight passing through 1.7mm sieve}}{\text{Total weight of material}} \times 100$$

Note: This test is inferior to the Los angeles test.

ii) Dorry abrasion test:

→ This test involves in subjecting a cylindrical specimen of 25 cm height and 25 cm diameter to the abrasion against rotating metal disk sprinkled with quartz sand.

→ The loss in weight of the cylinder after 1000 revolutions is determined.

→ The hardness of the rock sample is expressed as

$$\text{Hardness} = 20 - \frac{\text{loss of weight in grams}}{3}$$

Note: Good rock shows an abrasion value not less than 17. A rock sample with a value of less than 14 is considered as poor.

(iii) Los Angels Test:

→ It was developed to overcome some of the defects found in Deval attrition test.

→ This test is characterised by the quickness with which a sample of aggregates may be tested.

→ This test is applicable to all types of commonly used aggregates which makes it popular.

→ The test involves taking specified quantity of standard sized material [oven dried] in a standard cylinder along with specified number of abrasive charge. [Iron balls]

→ Revolving at a speed of 20-33 rpm for 500-1000 revolutions.

→ The particles smaller than 1.7mm is seperated out.

→ the loss in wt is expressed as % of original weight considered which gives the abrasion value of aggregates.

$$\text{Abrasion Value} = \frac{\text{Weight of material passing 1.7mm size}}{\text{Total weight of material}} \times 100$$

→ **Note:** The abrasion value should not be more than 30% for wearing surfaces & not more than 50% for concrete other than wearing surface

* Angularity Number (shape of aggregates).

→ One of the method of expressing the angularity qualitatively is by a number called angularity number. It is suggested by SHERGOLD. This is based on the percentage of voids in the aggregates after compaction in a specified manner

*** Procedure:**

A quantity of single sized aggregates is filled into metal cylinder of 15 Liter capacity.

→ The aggregates are compacted in a standard manner and the % of voids are found out.

→ If the void ratio is 33% and the angularity of such aggregate is considered as zero.

→ If the void ratio is 44%, the angularity of such aggregate is considered as 11

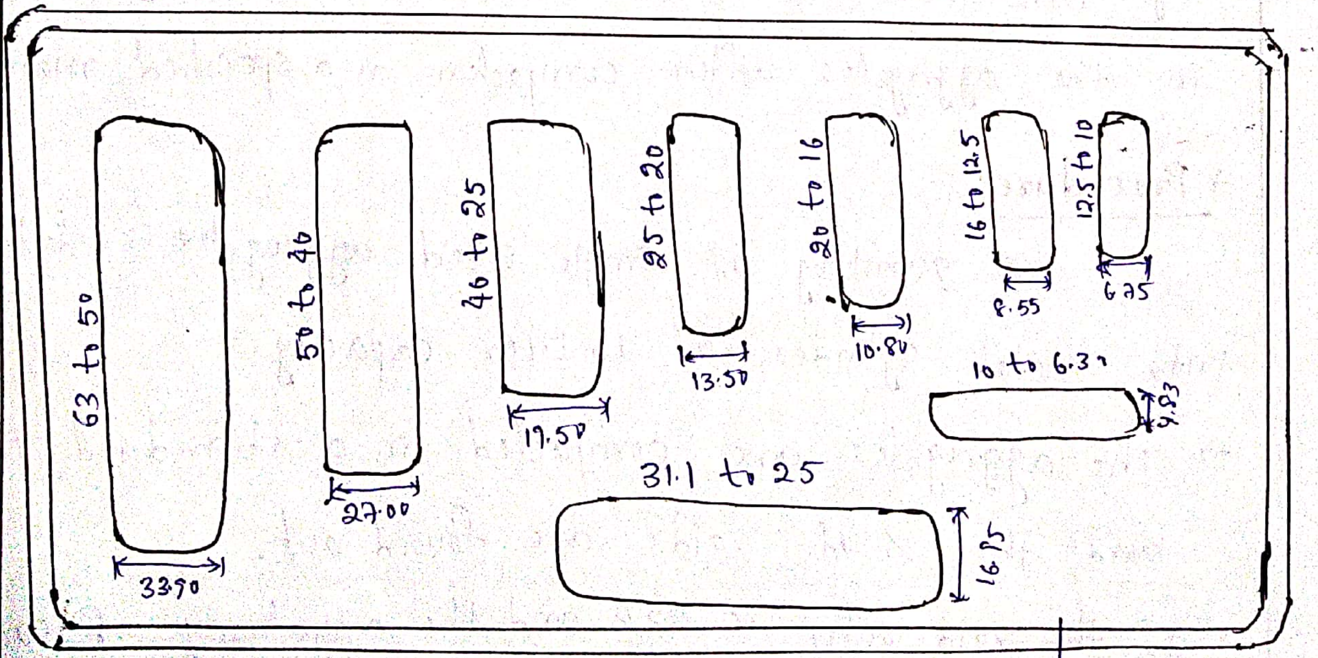
Note 1. The angularity number '0' (zero) indicates that most of the particles are round shaped and angularity number 11 indicates most of the aggregates are angular in shape

Note 2: The normal aggregates which are suitable for making concrete may have angularity number between 0 of 11 and closely to 11.

* Test for Flakiness Index :

→ The FI of aggregate is the ~~the~~ % by weight, of particles in it whose least dimension (thickness) is less than 3/5th (0.6) ~~mean~~ of their mean dimension.

→ Note: This test not applicable to sizes smaller than 6.3mm



1.6mm thick metal sheet

All dimensions are in mm

Procedure

- → A sufficient quantity of aggregates are taken such that a minimum of 200 pieces of any fraction can be tested
- → Each fraction is gauged in term for thickness on the metal gauge (0.6 times the mean sieve size)
- → The total amount passing in the gauge is weighed to an accuracy of 0.1% of the weight of the sample taken
- → The Flakiness Index is taken as the total weight of the materials passing from various thicknesses & expressed as % of the total weight of sample taken.

Ex:-

Size of aggregate (thickness) @ passing through (mm)	ⓑ Retaining on (mm)	Dimension = 0.6(mean size) ⇒ $(\frac{a+b}{2}) \times 0.6$ (mm)	Wt of aggregate passing in (grams)
63	50	33.9	800
50	40	27	575
40	31.5	21.45	480
31.5	25	16.95	400
25	20	13.5	342
20	16	10.8	180
16	12.5	8.55	75
12.5	10	6.75	50
10	6.3	4.89	16
			2918

FORMULA

$$\text{Flakiness Index} = \frac{\text{weight of aggregate passing}}{\text{total weight of Aggregate}} \times 100$$

total wt = 9 kg

$$F.I = \frac{2918}{9000} \times 100 = 32.42\%$$

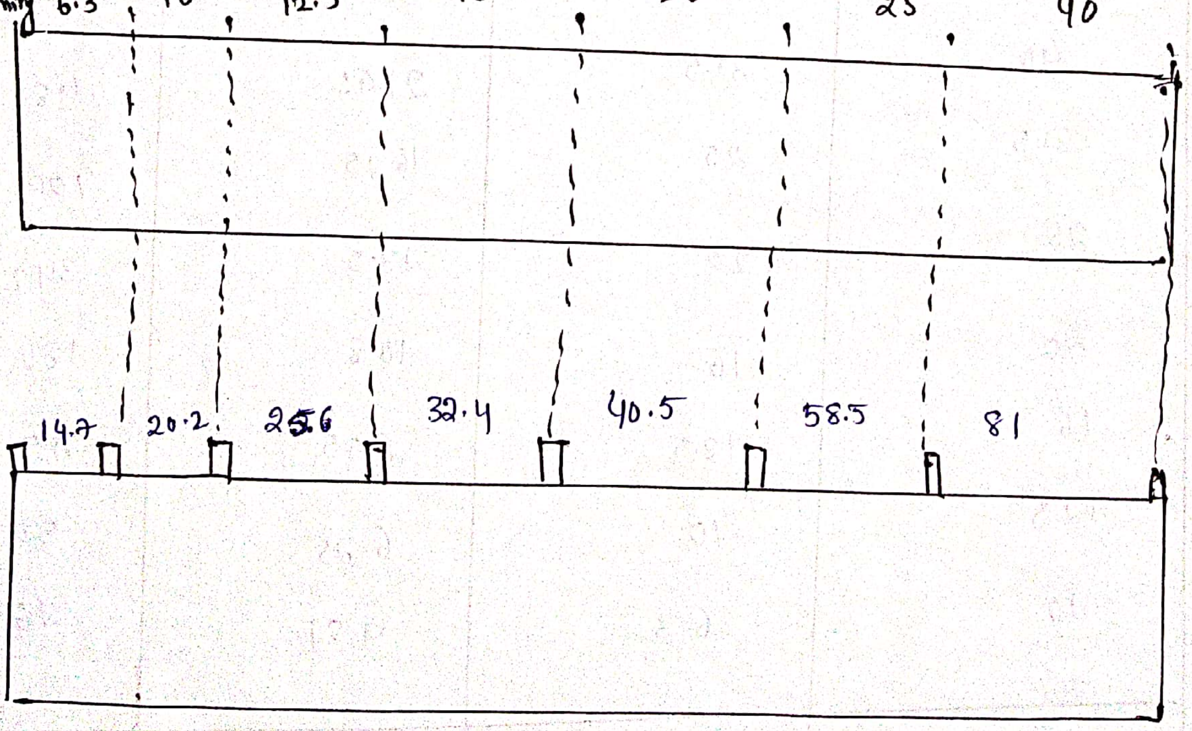
⇒ Flakiness Index should not be more than 35%

$$F.I \ngtr 35\%$$

* Elongation Index:

⇒ It is the percentage by weight of particles whose greatest dimension (length) is greater than 9/5th (1.8) of its mean dimension.

passing	10	12.5	16	20	25	40	50
Retaining	6.3	10	12.5	16	20	25	40



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→ The elongation index is not applicable to sizes smaller than 6.3mm

* Procedure:

→ A sufficient quantity of aggregate is taken to provide minimum number of 200 pieces of any fraction to be tested

→ Each fraction shall be gauged individually for length on the metal gauge [1.8 mm times mean size)

→ Total amount retained by the gauge length shall be weighed to an accuracy of at least 0.1% of wt of the sample

→ The elongation index is the total weight of the material retained on the various length gauges expressed as percentage of total weight of the sample gauged

Size of aggregates		Gauge = 1.8x mean sieve size (mm)	Weight of aggregates retained (grams)
Passing (mm)	Retained (mm)		
50	40	81	50
40	25	58.5	125
25	20	40.5	155
20	16	32.4	185
16	12.5	25.65	275
12.5	10	20.25	316
10	6.3	14.7	417
			1523

$$\text{Elongation Index} = \frac{\text{weight of aggregate retained}}{\text{total weight of aggregates}} \times 100$$

$$E.I = \frac{1523}{7000} \times 100$$

$$= 21.75\%$$

Note: Elongation index should not be more then 15%

→ More than 15% undesirable.

$$E.I \ngtr 15\%$$

* **Test for Bulk Density and Voids:**

Bulk density: It is the weight of material in a given volume. It is normally expressed in kg/m^3 (or) kg/Litre

Table: Size of container for Bulk Density Test

Size of largest aggregate (mm)	Normal Capacity (Litres)	Inner diameter (cm)	Inside Height (cm)	Thickness of metal (mm)
≤ 4.75	3L	15	17	3.15
> 4.75 & < 40	15L	25	30	4
> 40	30L	35	31	5

* Specific gravity of Aggregates

⇒ IS : 2386 (Part III) - 1963 gives procedure to find out specific gravity of Aggregates

$$\text{Specific gravity} = \frac{\text{wt of solid}}{\text{wt of standard liquid}}$$

→ Take sample of aggregates & weigh them

⇒ place the aggregate in pycnometer & fill the water upto full immersion of sample & keep it 24 hours for total saturation of material.

→ Fill the pycnometer with water ~~not~~ take weight.

A = wt of pycnometer + water + sample

⇒ B = wt of pycnometer + full water

→ C = wt of saturated surface dry aggregates

D = wt of oven dried sample

$$\text{Specific gravity of Fine Aggregate} = \frac{D}{C-(A-B)}$$

⇒ specific gravity of fine aggregate lies between = 2.5 - 2.6

→ Specific gravity of coarse aggregate is lies between 2.6 - 2.8

* Procedure:

→ Take cylinder of appropriate size depending on the size of the aggregates of accurate size internally

→ The cylindrical measure is filled 1/3rd each time with single sized aggregates

→ The compaction can be done with a tamping rod of 16mm dia & 600 mm length for 25 times on each layer

→ The cylindrical measure is carefully struck of to a level using tamping rod as a stright edge

→ the net weight of aggregate in the measure is determined

$$\text{Bulk density} = \frac{\text{net weight of aggregates in kg}}{\text{Capacity of container in Litre}}$$

units: kg/L (or) kg/m^3

$1L = 10^{-3} m^3$

* voids:

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

where G_s = specific gravity of aggregate

γ = Bulk density in kg/litre

* Water absorption test:

This is determined by measuring the increase in weight of an oven dried sample when immersed in water for 24 hr.

→ The ratio of the increase in wt to the weight of dry sample expressed as percentage is known as water absorption of Aggregates

$$\text{Water absorption} = \frac{\text{increase in weight of Aggregate}}{\text{weight of dry sample}} \times 100$$

*Note: water absorption is important in coarse aggregate
Moisture content is important in fine aggregate

* Moisture Content Test:

→ Determination of moisture content in a aggregate is of vital importance in the control of the quality of concrete particularly with respect to workability & strength.

→ It can be measured by

(i) Drying method
(ii) Displacement method
(iii) Calcium Carbide method
(iv) Electrical meter method
(v) Automatic measurement

(i) Drying method: This is carried out in a oven and the loss in weight before and after drying will give the moisture content of the aggregate (surface water)

(ii) Displacement Method:

→ In the laboratory the moisture content of aggregate can be determined by means of pycnometer or by using Siphon - Can Method

→ The principle used is that the specific gravity of normal aggregate is higher than that of water and that a given weight of aggregate having some moisture content will occupy a greater volume than the same weight of aggregates when dry.

→ From the difference b/w specific gravity of dry and wet aggregates, ~~meth~~ the moisture content of aggregates can be calculated

(iii) Calcium carbide method:

→ This is a quick and reasonably accurate method of determining the moisture content of fine aggregate

Procedure:

1. Weight 6 g of representative sample of wet sand and pour it into the container

2) Take 1 scoop full of calcium carbide powder & put it into the container

3) close the lid of the container and agitate it vigorously.

4). Calcium carbide reacts with surface moisture and produces acetylene gas, the pressure of which drives the indicator needle on the pressure gauge.

5). The pressure gauge is so calibrated that it gives the directly % of moisture

Note: The process can be completed with in 5 min

(iv) Electrical Meter method:

→ The principle that the resistance gets changed with the change in moisture content of the aggregate has been made use of.

→ These are used to find out moisture content and also regulate the quantity of water to be added to the continuous mixer.

(v) Automatic measurement:

→ In modern batching plants, the surface moisture in aggregates is atomatically recorded by means of some kind of sensor arrangement.

→ The arrangement is made in such a way that the quantity of free water going with aggregates is automatically recorded and simultaneously that much quantity of water is to be reduced.

* **Thermal Properties of Aggregates:**

→ Rock and aggregate possesses three thermal properties which are significant in establishing the quality of aggregate for concrete construction.
They are
(i) Coefficient of expansion (α)
(ii) Specific heat
(iii) Thermal conductivity

→ The coefficient of thermal expansion of the concrete increases with the coefficient of thermal expansion of aggregate.

→ If the coefficient of expansion of coarse aggregate and of cement paste differs too much, a large ~~chang~~ change in temperature may introduce differential movement which may break the bond between the aggregate and the paste.

→ If the coefficients of the two materials differ by more than $5.4 \times 10^{-6}/°C$ the durability of concrete subjected to freezing and thawing may be affected

→ For aggregates, the coefficient of thermal expansion(α) lies b/w approximately 5.4×10^{-6} & $12.6 \times 10^{-6}/°C$.

→ For hydrated Portland cement 'α' value varies between 10.8×10^{-6} to $16.2 \times 10^{-6}/°C$

→ For concrete, α value → $5.8 \times 10^{-6} - 14 \times 10^{-6}/°C$ depending upon the type of aggregate, mix proportions, degree of saturation etc.

→ It can be determined by Verbeck's dilatometer.

→ The coefficient of thermal expansion also affects the fire resistance of the concrete

⇒ The specific heat of the aggregate is a measure of its heat capacity, where as the thermal conductivity is the ability of the aggregate to conduct the heat.

⇒ The specific heat and thermal conductivity of properties of aggregate influence the specific heat and thermal conductivity of the concrete, and are important in case of mass concrete and where insulation is required.

* **Maximum size of Aggregate:**

→ In general, larger the maximum size of aggregate, smaller ŧ is the cement requirement for a particular water-cement ratio. This is due to the fact that the workability of concrete increases with increase in the maximum size of the aggregate.

⇒ Maximum size of aggregates depends on

(i) Thickness of the section
(ii) spacing of reinforcement
(iii) clear cover
(iv) mixing, handling and placing techniques

⇒ Generally the maximum size of aggregate should be as long as possible within specified limits.

But in any case not greater than 1/4th of the minimum thickness of the member

Note: (i) For heavily reinforced concrete member the nominal maximum size of aggregates should be usually restricted to 5mm less than the min clear distance between the main bars (or) 5 mm less than the minimum cover to the reinforcement whichever is smaller

⇒ Using maximum size of aggregates results in reduction of cement content, reduction in water content and increased in strength.

Unit - III

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Fresh Concrete

*** Fresh concrete:**

The fresh concrete (or) Plastic concrete is a freshly mixed material which can be moulded into any shape. The relative quantities of cement, aggregates and water mixed together, control the properties of concrete in the wet state as well as in the hardened state.

*** Advantages of concrete:**

1. It is economical
2. It possesses a high compressive strength and the corrosion and weathering effects are minimum
3. It can be easily handled and moulded into any shape or size according to specification
4. Since, it is strong in compression and has unlimited structural applications in combination with steel.
5. It can be pumped and hence it can be laid in difficult positions also
6. It is durable, fire resistant and requires less (or) little maintenance.

Disadvantages of concrete:

1. It has low tensile strength and hence cracks will be developed easily. Therefore, it is to be reinforced with steel bars.

2. Fresh concrete contracts on drying and hardened concrete expands on wetting. Provision for construction joints to be made to avoid the development of cracks.

3. It is liable to disintegrale by alkali aggregate reaction.

4. The lack of ductility inherent in concrete as a material is a disadvantage with respect to earth-quake resistant design

* Workability:

→ As per ACI [American concrete Institute] definition
It is defined as the property of freshly mixed concrete or mortar which determines the ease and homogenity with which it can be mixed, transported, placed, compacted and finished

→ It may difined as ease of placement and resistance to segregation

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As per Road Research Laboratory U.K, It may be defined as the amount of useful internal work necessary to produce full compaction without lossing its homogenity

⇒ A workability suitable for mass concrete is not necesseerily sufficient for thin (or) heavy reinforced sections.

⇒ For these reasons it is defined as a physical property of concrete alone without reference to the circumstances of a particular type of construction

⇒ Workability is necessary to compact concrete to the maximum possible density

Note: Every job requires a particular workability

→ The workability of fresh concrete is a complex system of two critical parameters, consistency and homogeneity.

→ A mixture could have a very fluid consistency and be very placeable, but if it segregates it would not be considered to have good workability due to lack of homogeneity.

* **Consistency:**

It is a general term to indicate the degree of fluiding (or) degree of mobility. A concrete which has high consistency and which is more mobile need not be of right workability for a particular job.

* **Homogeneity:** Which means uniform and stable distribution of cement, aggregate and water and resistance to segregation is a critical physical property of plastic concrete.

* **Factors Affecting Workability:**

⇒ Several factors are affecting workability of concrete, which are

(i) Water content

(ii) Mix proportions [Grade of concrete]

(iii) Size of Aggregates

(iv) Shape of Aggregates

(v) Surface Texture of Aggregates

(vi) Grading of Aggregates

(vii) Use of Admixtures.

(i) Water content:

→ This is the one of the most important factors affecting workability. Water content in a given volume of concrete, will have significant influence on the workability.

→ The higher the water content per cubic meter of concrete, the higher will be the fluidity of concrete.

⇒ It should be noted that from the desirability point of view increase in water content is the last resource to be taken for impoving workabilty

⇒ More water can be added, provided a correspondingly higher ~~quality~~ quantity of cement is also added to keep the water/cement ratio constant, so that the strength remains same.

(ii) Mix Proportions [Grade of concrete]:

→ Aggregate/cement ratio is an important factor influencing workability.

→ The higher the aggregate/cement ratio, the leaner is the concrete.

→ In lean concrete, less quantity of paste is available for providing lubrication, per unit surface area of aggregate and hence the mobility of aggregate is restrained. On the other hand, in case of rich concrete with lower aggregate/-cement ratio, more paste is available to make the mix cohesive and fatty to give better workability

(iii) <u>Size of Aggregate</u>:

For a given quantity of water and paste, a bigger size of aggregate will give higher workability because of bigger the size of aggregate, less is the surface area and hence less amount of water is required for wetting of surface and the less paste is required for ~~required for~~ lubricating to reduce internal friction.

(iv) Shape of Aggregate:

→ The shape of aggregates influences workability in good measure.

→ Angular, elongated (or) flaky aggregate makes the concrete very harsh when compared to rounded aggregates (or) cubical shaped aggregates.

→ Contribution to better workability of rounded aggregate will come from the fact that for the given volume (or) weight it will have less surface area and less voids than angular or flaky aggregate.

→ Not only that, being rounded in shape, the frictional resistance is also greatly reduced. This explains the reason why river sand gravel provide greater workability to concrete than crushed sand and aggregate.

(v) Surface Texture of Aggregate:

→ The influence of surface texture on workability is again due to the fact that the total surface area of rough textured aggregate is more than the surface area of smooth rounded aggregate of same volume.

⇒ From the earlier discussions, the rough textured aggregate will show poor workability where as smooth or glassy aggregate will give better workability

→ A reduction of inter particle frictional resistance offered by smooth aggregates also contributes to higher workability

(vi) Grading of Aggregates:

→ This is one of the factors which will have maximum influence on workability

→ The better the grading of aggregates less is the void content and higher the workability.

→ A well graded aggregate is the one which has least amount of voids in a given volume

⇒ When the total voids are less, excess paste is available to give better workability.

⇒ With excess amount of paste, the mixture become cohesive and fatty wet which prevents segregation of particles.

(vii) Use of Admixtures: Of all the factors mentioned above, the most important factor which affect the workability is the use of admixtures.

⇒ It is simply described that use of plasticizers and super plasticizers greatly improve the workability of concrete.

→ The use of air entraing agents and puzzolonic materials greatly increase the workability of concrete.

* Measurement of Workability:

⇒ The following tests are commonly used to measure workability of concrete.

(i) slump test
(ii) compaction factor test
(iii) Flow Test
(iv) Vee Bee Consistometer Test
(v) Kelly Ball Test

(i) Slump Test:

→ It is the most commonly used method of measuring consistency of concrete which can be employed either in laboratory or at site of work.

→ It is not a suitable method for very wet (or) very dry concrete.

→ The slump test indicates the behaviour of a compacted concrete under the action of gravitational forces.

→ It is used conveniently as a control test and gives an indication of the uniformity of concrete from batch to batch.

→ Repeated batches of the same mix, brought to the same slump, will have the same water content and water cement ratio, provided the weights of aggregate, cement and admixtures are uniform and aggregate grading is within acceptable limits.

→ The test is carried out with a mold called the slump cone [frustum of a cone]

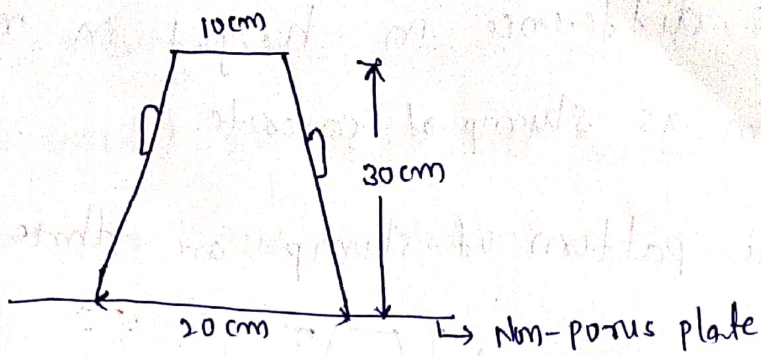


Fig: Typical mould for slump test.

→ Apparatus for conducting the slump test essentially consists of metallic mould in the form of a frustum of a cone.

→ The slump cone is placed on a horizontal and non-absorbent surface and filled in three equal layers of fresh concrete.

→ Each layer being tamped 25 times with a standard tamping rod of 16 mm dia & 600 mm length.

→ The top layer is struck off level and the mould is lifted vertically without disturbing the concrete cone.

→ This allows the concrete to subside. This subsidence is referred as 'slump' of concrete.

→ The difference in level between the height of the mould and that of the highest point of the subsided concrete is measured

→ This difference in height in mm is taken as slump of concrete.

⇒ The pattern of slump are three

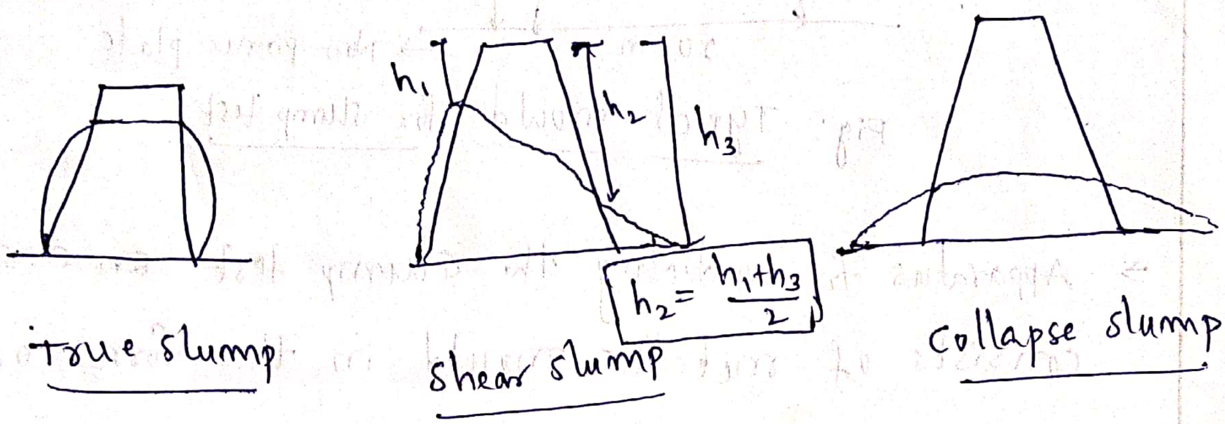


Fig: Types of slump

⇒ The concrete after the test when slumps ~~evenly~~ evenly all around is called true slump.

⇒ In case of very lean concrete, one-half of the cone may slide down the other which is called a shear slump.

⇒ concrete may collapse in case of very wet concrete.

⇒ The slump test is essentially measure of consistency or the wetness of the mix.

⇒ It is suitable for concretes of medium to high workabilities [i.e 25 mm to 125 mm]

⇒ Despite many limitations, the slump test is very useful on site to check day-to-day (or) hour to hour variation in the quality of mix.

⇒ The slump test has more practical utility than the other tests for workability.

⇒ The slump test is limited to concretes with maximum size of aggregate less than 38mm.

(ii) **Compacting Factor Test:**

→ The compacting factor test is designed primarily for use in the laboratory but it can also be used in the field.

→ It is more precise and sensitive than slump test and is particularly useful for concrete mixes of very low workability.

→ The compacting factor test gives the behaviour of fresh concrete under action of external forces.

→ This test works on the principle that it determines the degree of compaction achieved by a standard amount of work done by allowing the concrete to fall from a standard height. The degree of compaction is called the compaction factor.

* Essential Dimension of Compacting factor Apparatus

Upper Hopper, A

	Dimension, (cm)
Top internal dia	25.4
Bottom internal dia	12.7
Internal height	27.9

Lower hopper, B

	Dimension (cm)
Top Internal dia	22.9
Bottom Internal dia	12.7
Internal height	22.9

Cylinder, C

	Dimension (cm)
Internal dia	15.2
Internal height	30.5

→ Distance b/w bottom of upper hopper and top of lower hopper — 20.3

→ Distance b/w bottom of lower hopper and top of cylinder. — 20.3

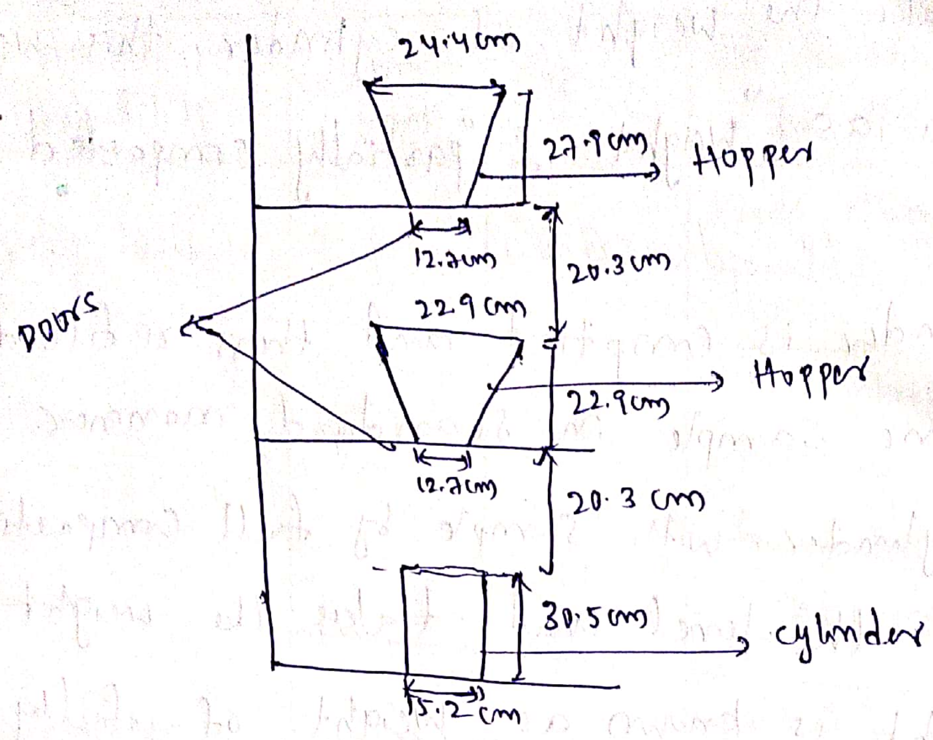


Fig: Compacting Factor Apparatus

⇒ It measures the compactability of concrete which is an important aspect of workability.

⇒ The sample of concrete to be tested is placed in the upper hopper up to the brim.

→ The top door is opened so that the concrete falls into lower hopper.

→ Then the trap-door of the lower hopper is opened and the concrete is allowed to fall into the cylinder.

→ Excess of concrete remaining above the top level of cylinder is then cut off.

⇒ Then take the weight of cylinder, this weight is known as "weight of "partially compacted concrete"

⇒ The cylinder is emptied and then refilled with same sample in standard manner.

⇒ The cylinder with sample by full compaction strike of the level and take the weight this weight is known as 'weight of fully compacted concrete'

$$\text{The compaction Factor} = \frac{\text{Wt of partially compacted concrete}}{\text{Wt of fully compacted concrete}}$$

⇒ The compacting factor test has been held to be more accurate than slump test.

⇒ For concrete of very low workabilities of the order of 0.7 or below, the test is not suitable, because this concrete cannot be fully compacted for comparison in the manner described in the test.

Table : Workability :

Degree of workability	Slump (mm)	C.F	Use for which concrete is suitable
Very low	0 – 25	0.78	Roads vibrated by power operated vibrators
Low	25 – 50	0.85	Roads vibrated by hand operated machine and mass concrete foundation where there is light reinforcement
Medium	50 – 100	0.92	Normal Reinforced concrete manually compacted & heavily reinforced section with vibrators
High	100 – 150	0.95	For sections with congested reinforcement

(iii) Flow Test :

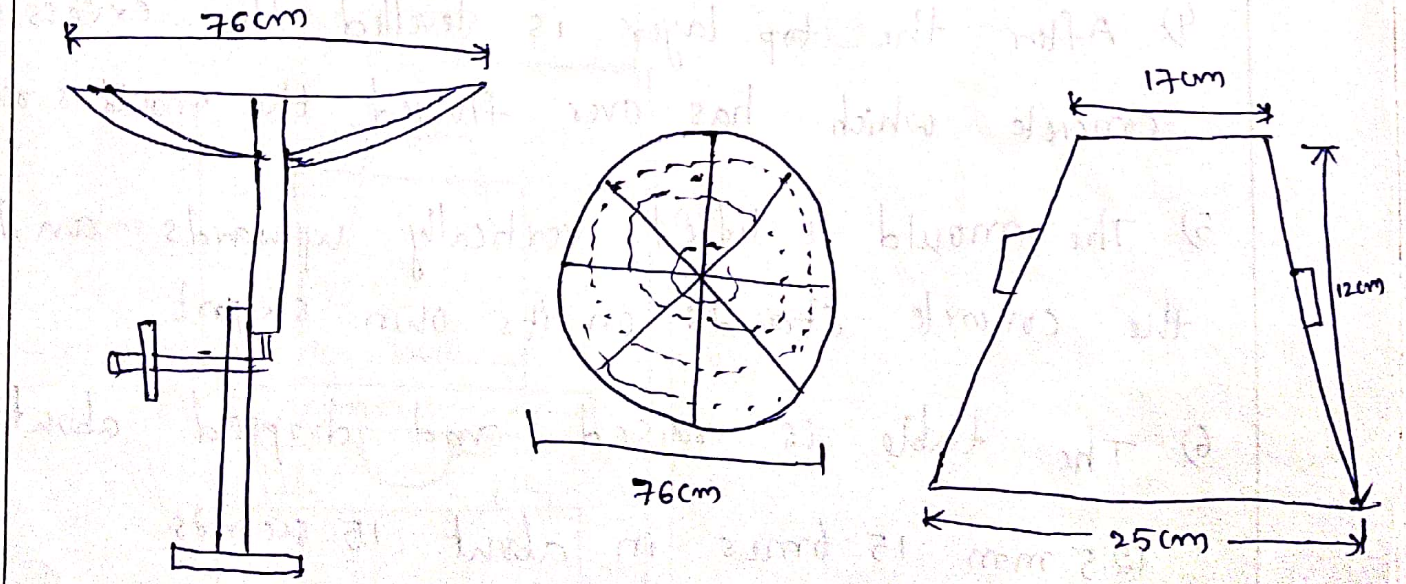


Fig: Flow Table Apparatus

→ This is a laboratory test which gives an indication of the quality of concrete with respect to consistency.

⇒ In this test a standard mass of concrete is subjected to jolting. The spread or flow of concrete is measured and this flow is related to workability

Procedure:

1). The table top is cleaned of all gritty materials and is wetted.

2). The mould is kept on the centre of the table firmly held and is filled in two layers.

3). Each layer is compacted with a tamping rod of 16mm ∅ and 600 mm length for 25 blows.

4). After the top layer is levelled the excess of concrete which has over flowed, the mould is removed

5) The mould is lifted vertically upwards and the concrete stands on its own support

6). The table is raised and dropped about 12.5 mm 15 times in about 15 seconds.

7) The diameter of the spreaded concrete is measured in about six directions to the nearest 5mm and the average spread is noted

8). The flow of the concrete is the % increased in the average diameter of spreaded concrete over the base diameter of the mould.

$$\text{Flow per cent} = \frac{\text{spread diameter in cm} - 25}{25} \times 100$$

→ The value could range anything from 0 to 150%

(iv). Vee-Bee Consistometer Test:

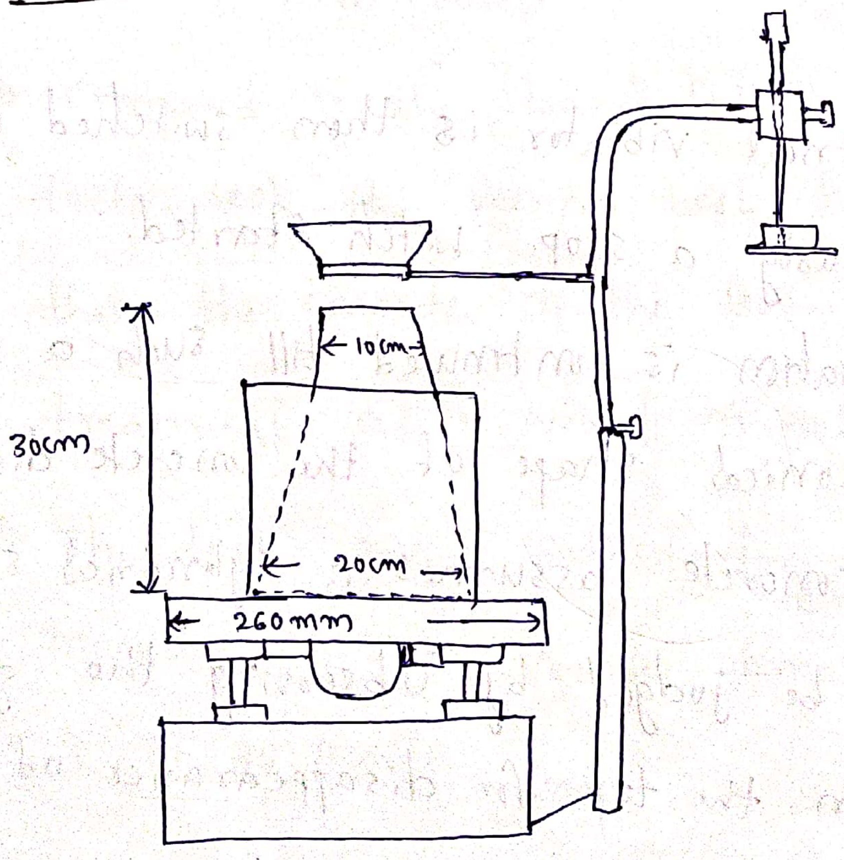


Fig: Vee-Bee Consistometer

→ This is a good laboratory test to measure indirectly the workability of concrete.

⇒ This test consists of a vibrating table, a metal pot, a sheet metal cone, a standard iron rod.

⇒ slump test is described earlier is performed, placing the slump cone inside the sheet metal cylinderical pot of the consistometer.

⇒ The glass disc attached to the swivel arm is turned and placed on the top of the concrete in the pot.

⇒ The electrical vibrator is then switched on and simultaneously a stop watch started.

⇒ The vibration is continued till such a time as the conical shape of the concrete disappears and the concrete assumes a cylindrical shape

⇒ This can be judged by observing the glass disc from the top for disappearance of transparency

→ Immediately when the concrete fully assumes a cylindrical shape, the stop watch is switched off.

→ The time required for the shape of concrete to change from slump cone shape to cylindrical shape in seconds is known as Vee Bee Degree.

⇒ This method is very suitable for very dry concrete whose slump value cannot be measured by slump Test, but the vibration is too vigorous for concrete with a slump greater than about 50 mm.

⇒ Compared to the slump test and compacting factor test, the Vee-Bee test has an advantage that the concrete in the test receives a similar treatment as it would in actual practice.

⇒ The test gives satisfactory results for mixes with the Vee bee time varying between 3 to 30 seconds.

(V) Kelly Ball Test: [ASTM C60]

⇒ This is a simple field test consistency of the measurement of the indentation made by 15cm diameter metal hemisphere weighting 13.6 kg. when freely placed on fresh concrete.

⇒ This test has been devised by Kelly and hence known as Kelly Ball Test.

⇒ This has not been covered by Indian standard specification.

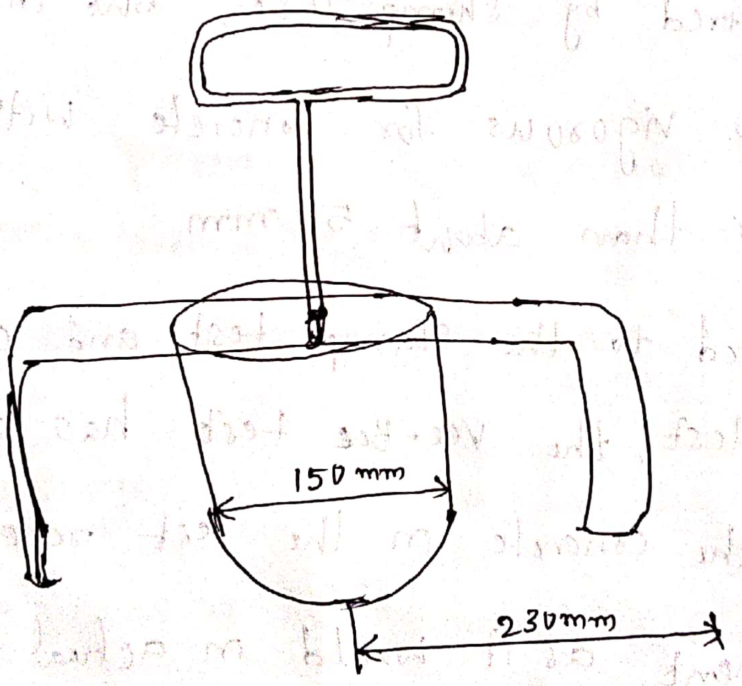


Fig: Kelly Ball

* Procedure

1) The surface of the concrete is levelled
2) The Ball is lowered gradually on the surface of the concrete
3) The depth of penetration is read immediately on stem to the nearest 6 mm

Note: It can be performed in about 15 seconds and it gives much more consistent result than slump test

Advantages:

1) It can be performed on the concrete placed in site
2) It is clamed that this test can be performed faster with a greater accuracy

Disadvantages:

1) It requires a large sample of concrete
2) It cannot be used when the concrete is ~~placed~~ placed in thin section
3) The minimum depth of concrete is 200mm

(iii) (b) Flow Table Test :

→ The BIS has recently introduced another new equipment for measuring flow value of concrete.

→

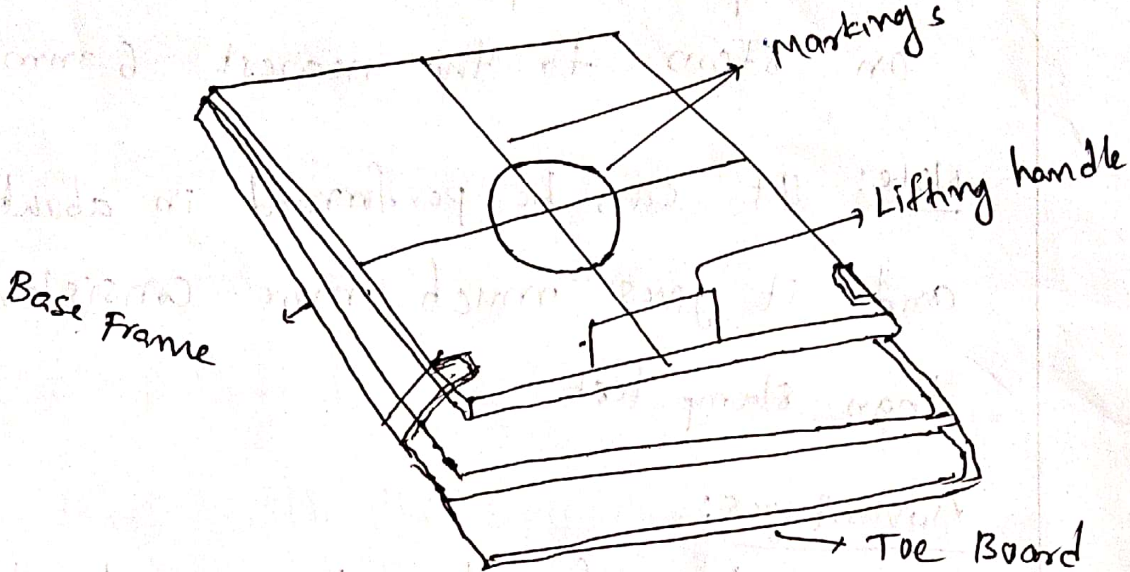
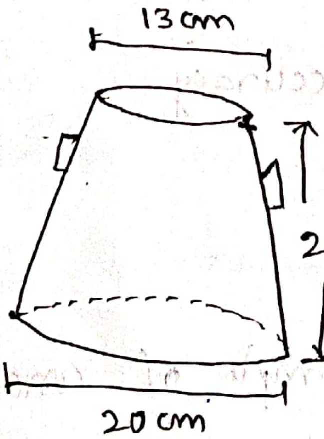
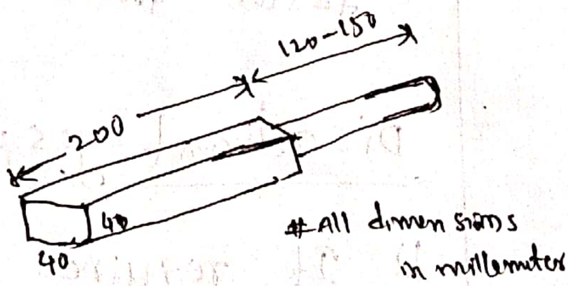


Fig : Flow Table Apparatus



Concrete Mould



Tamping Bar

⇒ Flow table Apparatus consists of

a) Flow table 700 x 700 mm size

(b) Concrete Mould

(c) Tamping Bar

Procedure:

→ The table is made level and properly supported before commencing the test, mould is cleaned

→ The slump cone is placed centrally on the table and filled with concrete in two layers.

→ Each layer is tamped lightly 10 times with wooden tamping bar

→ After filling the mould the concrete is struck off flush with the upper edge of slump cone

→ After that cone is slowly raised vertically by the handles.

→ After this, the table top raised to 40mm by the handle and allowed to fall 15 times in 15 seconds.

→ The concrete spreads itself out & the diameter of concrete spread shall then be measured in two directions, parallel to the table edges.

→ The arithmetic mean of the two diameters shall be the measurement of flow in millimeters.

$$d = \frac{d_1 + d_2}{2}$$

* Segregation:

Segregation can be defined as the seperation of the constituent material of concrete.

A good concrete is one in which all the ingredients are properly distributed to make a homogeneous mixture.

⇒ If a concrete is showing the tendency for segregation such concrete is not only going to be weak; lack of homogeneity is also going to induce all undesirable properties in the hardened concrete

* Types of segregation:

(1). Coarse aggregate separating out (or) settle down from the rest of the concrete

(2) Paste (or) matrix separating away from coarse aggrigate

(3). Water separting out from the rest of the material being a material of a lowest specific gravity.

* Causes for Segregation:

The conditions favourable for segregation are

1). The badly proportioned mix where sufficient matrix is not there to bind and contain the aggregates

2). Insufficiently mixed concrete with excess water content

3). Dropping concrete from heights as in the case of columns

4). When concrete is discharged from a badly designed miller

5). Conveince of concrete by conveyor belts for long distance (or) lifting of concrete to the upper floors.

6). It should be remembered that dry mix concrete should be vibrated comparatively. If excess vibration is done for too wet mix segregation takes place.

7). While finishing the concrete floors (or) pavements with a view to achieve smooth surface, the masins are likely to work with a trowel (or) flowed immediately after placing concrete.

This immediate working on the concrete without any time interval is likely to press the Coarse aggregate down, this leads to segregation.

* **Remedies to overcome segregation:**

1). A well made concrete taking into consideration various parameters such as grading, shape, size and surface texture of aggregate with optimum quantity of water makes a cohesive mix.

2). By correctly proportioning the mix

3) Proper handling at every stage of work [mixing, transportation, compaction, placing]

4) At any stage if segregation is observed remixing for a short time would make a concrete again homogeneous.

* Bleeding :

Bleeding is a particular form of segregation, in which some of the water from the concrete comes out to the surface of the concrete, being the lowest specific gravity among all the ingredients of concrete.

→ It is due to highly wet mix badly proportioned concrete and insufficiently mixed concrete.

It can be controlled by

1). Proper proportioning
2). Uniform and complete mixing
3). Use of finely divided puzzolonic materials
4) By using of rich mix [high quantity of cement]

* Method of test for Bleeding of Concrete:

This method covers determination of relatively quantity of mixing water that will bleed from a sample of freshly mixed concrete

Apparatus:

1) Cylindrical container 250mm diameter & made height of 280 mm
2) Tamping rod
3) Pipette
4) Measuring Jar

* Procedure:

1) A sample of freshly mixed concrete is filled in 50mm layer for a depth of 250 ± 3mm [5 layers] and each layer is tamped by giving strokes and top surface is made levelled

2) A cylindrical container is kept in a levelled surface free from vibration at a room temperature. It is covered with a lid.

3). The water accumulated at the top is drawn by means of pipette at 10mins intervals for first 40 mins and 30 min interval subsequently till bleeding siezes.

$$\text{Bleeding water \%} = \frac{\text{Total quantity of bleeding water}}{\text{Total quantity of water in the Sample of concrete}} \times 100$$

* **LAITANCE:** Due to bleeding water comes up and accumulates at the surface. Some times, along with this water certain quantity of cement also comes to the surface.

* **Remedies:**

1). Accumulation of water can be reduced by proper ~~com~~ compaction

2). Formation of laitance and consequent bad concrete can be reduced by delaying the finishing operation

(3)

* **Setting time of Concrete:**

It differs widely from setting time of cement. This does not coincide with the setting time of cement with which the concrete is made. This is depending on

(1). Water-cement ratio

(2) Temperature conditions

(3) Type of cement we used

(4) Use of mineral admixtures

(5) Use of chemical admixtures

⇒ The setting parameter of concrete is more of practical significance for site engineers than setting time of cement.

⇒ The setting time of concrete is found by the penetrometer test. This method of test is covered by IS 8142 - 1976 & ASTM C-403.

* **Penetrometer Test:**

* Apparatus required:

1). cylindrical container [150 mm ø & 150 mm height]

2). needles [16mm², 32 mm², 65 mm², 161 mm², 323 mm² & 645 mm²]

Each needle stem is ~~so~~ scribbled circumferentialy at a distance of 25 mm from the bearing area

Procedure:

1). Collect the representatively sample of concrete in sufficient quantity

2). Sieve it through 4.75 mm sieve and the resulting mortar is filled in container.

3). Compact the mortar by tamping

4). Level the surface & keep it covered to prevent the loss of moisture

5). Remove the bleeding water if any by means of pipette.

6). Insert ~~the~~ a needle of appropriate size depending on degree of setting of the mortar in the following manner.

ⓐ. Bring the bearing surface of the needle in contact with mortar surface.

④

⑤. Gradually and uniformly apply a vertical force downwards on apparatus until the needle penetrates to a depth of 25 ± 1.5 mm

ⓒ Record the force required to produce 25mm penetration and the time of inserting from the time water is added to cement.

⑦ ~~Repeat the~~ calculate the penetration resistance

$$\text{Penetration resistance} = \frac{\text{Recorded force}}{\text{Bearing area of the needle}}$$

Repeat the next trail by inserting needle atleast 25 mm away from previous one.

⑧ Plot a graph of penetration resistance on Y-axis and elapsed time on X-axis

⇒ Minimum six trails should be made and continue the test untill one penetration resistance of atleast 27.6 MPa is reached.

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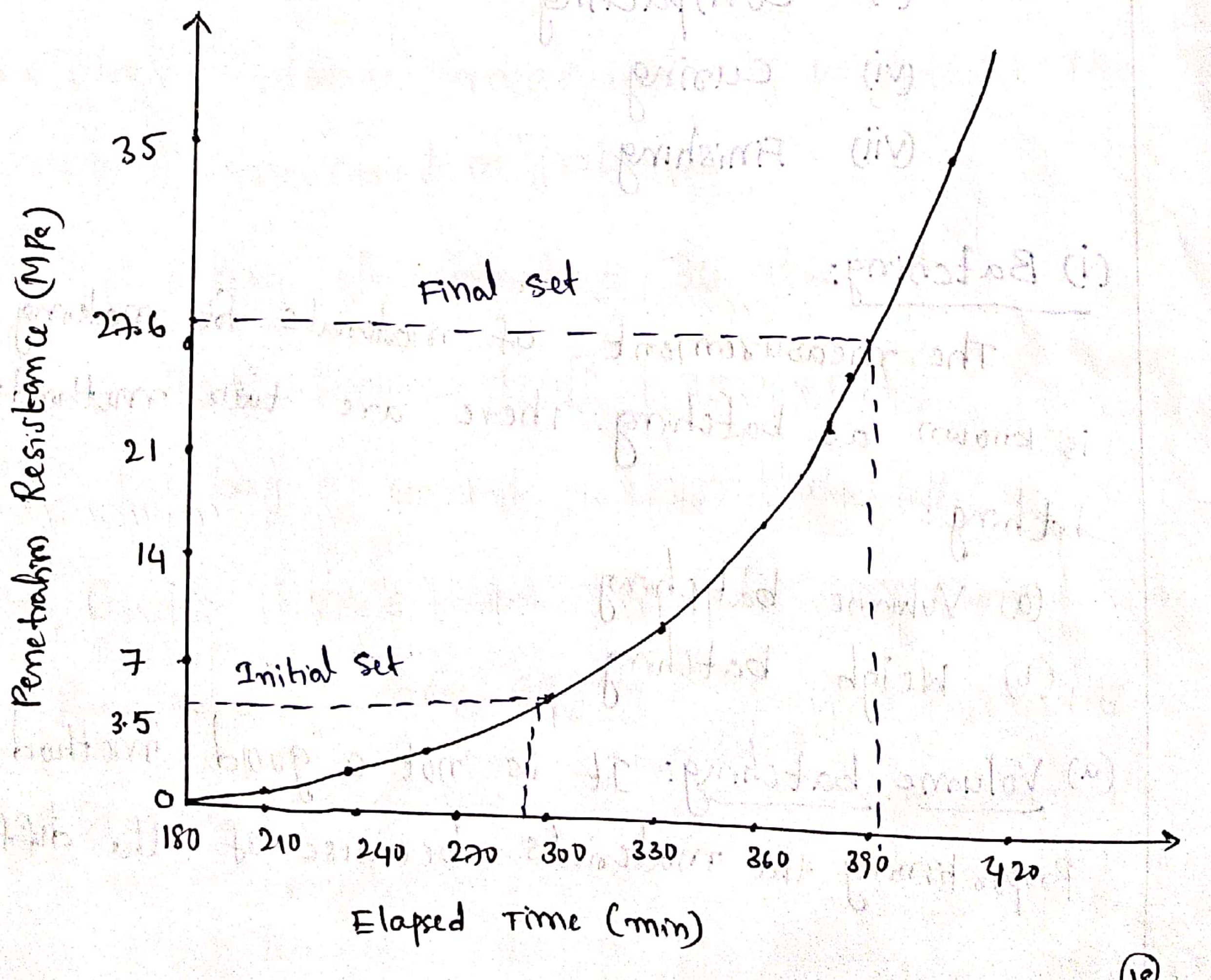
→ Connect the various points by a smooth curve.

→ Draw a horizontal line of penetration equal to 3.5 MPa. The point of intersection of this with the smooth curve is read on x-axis, which gives initial setting time

⇒ Similarly a horizontal line is drawn from the penetration resistance of 27.6 MPa. Point it cuts the smooth curve which read on x-axis gives the final setting time



⊛ Process of Manufacture of Concrete:

It is interesting to see that for producing good (or) bad concrete only the difference is care taking at every stage of manufacturing of concrete. The various stages of manufacture of concrete are

(i) Batching
(ii) Mixing
(iii) Transporting
(iv) placing
(v) Compacting
(vi) curing
(vii) Finishing

(i) Batching:

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

(a) Volume batching
(b) Weigh batching

(a) Volume batching: It is not a good method of proportioning the materials because of the difficulty

It offers to measure granular material in terms of volume. Volume of moist sand in a loose condition weighs much less than the same volume of dry compacted sand.

The amount of solid granular material in a cubic meter is an indefinite quantity. Because of this, for quality concrete material have to be measured by weight only. However, for unimportant concrete (or) for any small job concrete may be batched by volume.

⇒ Cement always measured by weight. It is never measured in volume.

1 bag of cement = 35 liters

1000 liters = $1 m^3$ [35.23 cft]

1 bag of cement = 1.235 cubic feet

⇒ Gauge boxes are used for measuring the fine and coarse aggregates.

Size of gauge box → [Made up of wood, timber (or) steel plates]

Length = 33.33 cm

Breadth = 30 cm

Height = 35 cm

(ii) **Weigh Batching:**

→ strictly speaking weigh batching is the correct method of measuring the materials

→ For important concrete, invariably, weigh batching system should be adopted.

→ It facilitates accuracy, flexibility and simplicity.

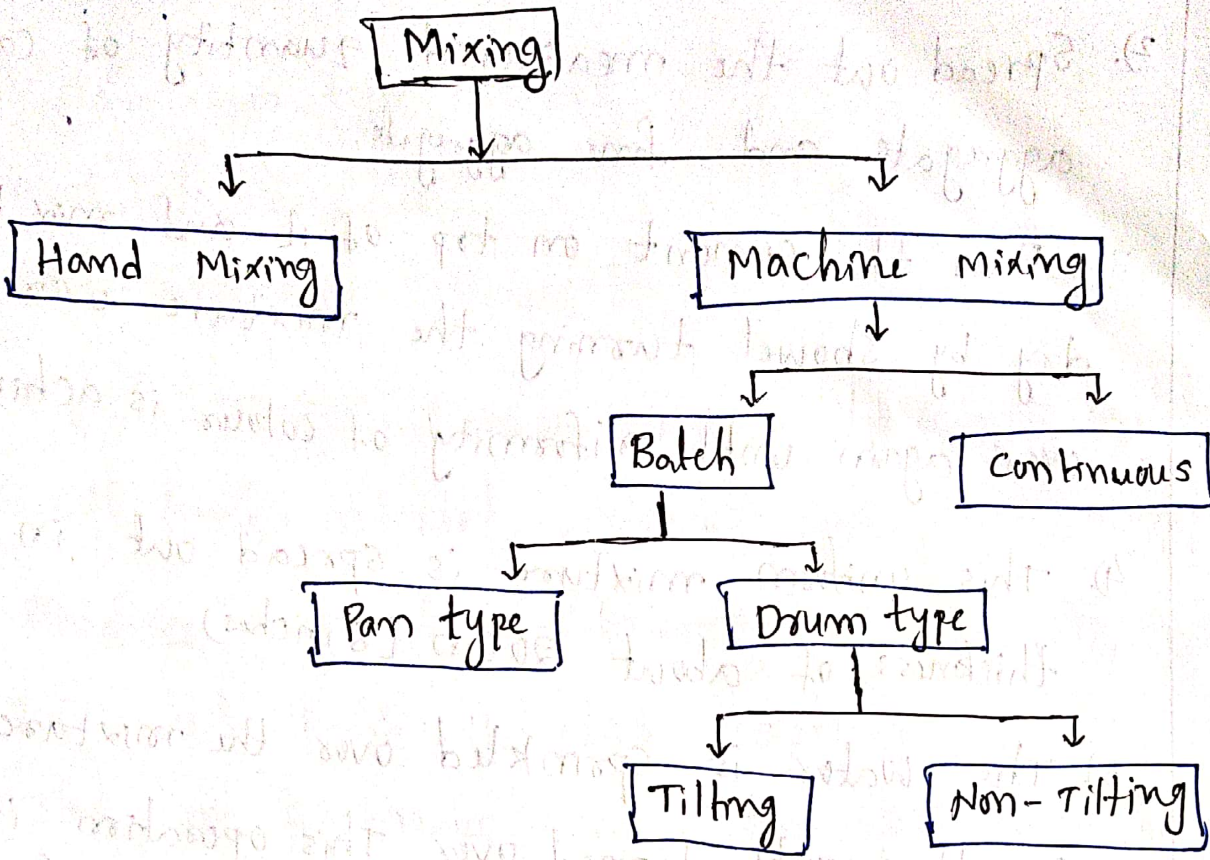
→ Various type of weigh batcher's are available

(iii) **Mixing:**

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

ⓐ Hand mixing

ⓑ Machine Mixing



Hand Mixing:

→ Used for small scale unimportant works

→ Produces low quality concrete

→ Mixing not thorough and efficient

→ It is desirable to add 10% more cement to cater for the inferior concrete produced by this method

Procedure:

1) It should be done over an impervious strata using of sufficiently large size to take one bag of cement

2). Spread out the measured quantity of coarse aggregate and fine aggregate.

3) Pour the cement on top of it and mix them dry by showel turning the mixture over and over again until uniformity of colour is achieved

4). This uniform mixture is spread out in thickness of about 20 cm [8 inches)

5). The water is sprinkled over the mixture and simultaneously turned over. This operation is continued till such a time a good uniform, homogeneous concrete is obtained.

Machine Mixing:

Mixing of concrete is almost invariable carried out by machine for Reinforced concrete works and for medium or large scale mass concrete work.. Machine mixing is not only efficient, but also economical, when the quantity of concrete to be produced is large

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It have two type mixers

a) Batch mixers

b) continuous mixer

⇒ Batch mixers produce concrete, bactch by batch with time interval, whereas continuous mixers Produce concrete continuously without stoppage till such time the plant is working.

⇒ This type continuous mixers are used in large works such as dams. & normal concrete work batch mixers are used.

⇒ Batch mixers again divided into

(i) Pan type mixers

(ii) Drum type mixers

(i) <u>Pan type mixers:</u>

In pan mix this is not mobile, so it is used in the plants and laboratories. This is Particularly efficient for the stiff mixes

Pan mixer consist of a circular pan rotating about vertical axis in some types the pan is static and the paddles travels. In other type paddles are stationary and pan rotates about vertical axis.

⇒ In both the cases the moment of concrete is same and concrete in every part of the pan is thoroughly mixed.

⇒ The drum type mixers are again divided in to two types

(i) Tilting type drum mixer

(ii) Non- Tilting type drum mixer

(i) Tilting type drum mixer:

→ It is generally in the shape of double conical frustum type is lifted for discharging.

→ The efficiency of the mix depends on the shape and design of vanes fixed inside the drum

→ These vanes direct the concrete to trace a circulatory part.

→ The mixed concrete is discharged from the open top of the drum by tilting it downwards.

→ These are available in sizes of 85 Liters, 100 liters, 140 liters, 200 liters, 280 liters.

(ii) Non- tilting drum type:

→ This essentially consists a cylindrical drum with two circular openings at the ends and blades fixed inside the drum.

→ The drum rotates about a horizontal axis can not be tilted.

→ The materials are loaded from one-side and discharged from other sides

→ These are available in sizes of 200 L, 280 L, 375 L, 500 L, 1000 liters.

Note: 1) Tilting type is always better than non-tilting type (i.e tilting has no segregation)

2). For M15 & above grades 200 liters tilting type is adequate.

How to load materials into loading skip :

1). To get better efficiency, half of the quantity of coarse aggregate is placed in the skip

2) over which half of the quantity of FA is poured

3). on the that full bag of cement is poured.

4) over which the remaining portion of CA & FA is poured

5). This prevents the spilling of cement while discharging into drum

6). Before placing the materials into drum about 25% of water is poured into the drum to wet and prevent any sticking of cement on the blades (or) at the bottom of drum

7) After pouring the dry materials pouring 75% remaining 75% water is added to drum.

* Mixing Time :

⇒ For proper mixing it is seen that 25-30 rpm are required in a well designed mixer.

→ The compressive strength of concrete increases with the time of mixing but mixing time beyond 2 mins, the improvement in compressive strength is not very significant.

→ Generally mixing time is related to the capacity of mixer. The mixing time varies between 1½ to 2½ minutes.

→ Bigger the capacity of the drum more is the mixing time

* Re-tempering of concrete:

→ The process of remixing of concrete if necessary with addition of the required quantity of water is known as "re-tempering of concrete"

→ But we should add some cement corresponding to water content.

→ As far as possible retempering is to be avoided.

(iii) Transporting:

→ Concrete can be transported by variety of methods and equipments

→ The precautions to be taken while transporting concrete is that the homogeneity obtained at the time of mixing should be maintained while being transported to the final place of deposition.

⇒ The methods adopted for transportation of concrete are

(a) Mortar Pan

(b) Wheel Barrow, Hand Cart

(c) Crane, Bucket and Rope way

(d) Truck mixer and Dumpers

(e) Belt Conveyors

(f) Chute

(g) Skip and Hoist

(h) Transit mixer

(i) Pump and Pipe Line

(j) Helicoptor

(a) Mortar Pan:

→ This is a common method adopted

→ It is a labour intensive

→ This method nullifies the segregation to some extent

→ It can be adopted for concreting at the ground level (or) above ground level without much difficulties

(b) Wheel Barrow:

→ It is normally used for transporting concrete to be placed at ground level

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

→ It is likely that the concrete gets segregated due to vibration.

(c) Crane, Bucket & Rope Way:

→ It is one of the right equipment for transporting concrete above ground level.

→ For the concrete works in a valley or the construction work of a pier in the river (or) for dam construction, this method adopted

(d) Truck mixer and Dumpers:

→ For large concrete works particularly for concrete to be placed at ground level, trucks and dumpers (or) ordinary open steel body tipping lorries can be used

(e) Belt conveyors:

→ Belt conveyors have ~~a~~ very limited applications in concrete construction

→ The principal objection is the tendency of the concrete to segregation.

→ It is necessary that the concrete should be remixed at the end of delivery before placing on the final position.

(f) chute:

→ chutes are provided for transporting concrete from ground level to a lower level.

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→ It is adopted, when movement of labour cannot be allowed due to lack of space or for fear of disturbance to reinforcement.

(g) <u>Skip and Hoist</u>:

→ This is one of the widely adopted methods for transporting concrete vertically up for multistorey building construction.

⇒ For high rise building it is most effective.

(h) <u>Transit mixer</u>:

→ Transit mixer is one of the most popular equipments for transporting concrete over a long distance particularly in Ready-mixed concrete plant (RMC).

→ The truck mounted having a capacity of 4 to 7 m^3.

→ The concrete is transported to the site by keeping agitated all along at a speed varying b/w 2-6 revolutions/minute.

→ The batching is done at central batching plant and mixing is done in the truck mixer either in transit (or) immediatly prior to discharging the concrete at site.

(i) Pump and Pipe line:

→ Pumping of concrete is universally accepted as one of the main methods of concrete transportation and placing

→ It can be best adopted for under water concreting.

(iv) Placing of concrete:

→ It is not enough that a concrete mix is correctly designed, batched, mixed, and transported. It is almost important that the concrete must be placed in a systematic manner to yield optimum results.

→ To secure good concrete it is necessary to make certain preparation before placing

1). The forms must be examined for correct alignment and adequate rigidity to with stand the weight of concrete & impact loads during the construction.

2). The forms must be checked for tightness to avoid any loss of mortar which may results in honey combing

3). Before placing concrete forms are cleaned and treated with a releasing agent to facilitate their removal when concrete is set.

4). The reinforcement should be checked for conformity with the detailing plans for size, spacing and location.

5). Anchor bolts, pipe conducts and any other fixtures should be firmly fixed.

6) Rubbish such as saw dust, wires etc. and any coatings of the hardened mortar is removed.

7). If it is placed in foundation remove loose earth and any trees etc and wet the ground to avoid absorption of water from concrete before placing.

8). placing concrete under water proper care must be taken.

(v). Compaction of Concrete:

→ It is the process adopted for expelling the entraped air from the concrete.

→ If the air is not removed fully the concrete losses strength considerably.

→ That means 5% of air voids reduces strength by 30%

→ The 10% air void's reduces strength by 50%

Hence it is imparative that 100% compaction of concrete is the most important one.

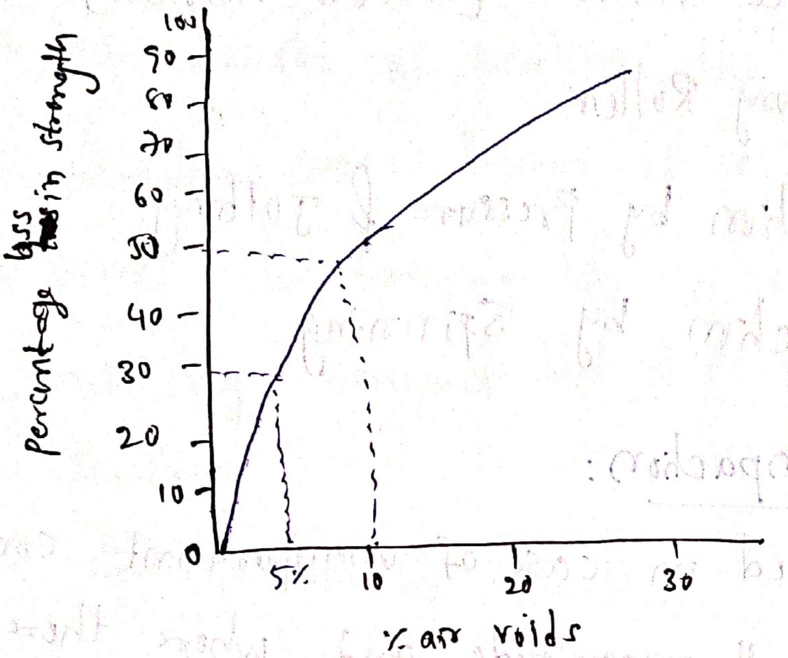

Fig: Relation b/w loss of strength & air-void space

* Methods adopted for compaction :

(a) Hand compaction

(i) Rodding

(ii) Ramming

(iii) Tamping

(b) Compaction by Vibration

(i) Internal vibrator [Needle vibrator]

(ii) Form work vibrator [External vibrator]

(iii) Table vibrator

(iv) plat form vibrator

(v) Surface vibrator [Screed vibrator]

(vi) Vibratory Roller

(c) Compaction by Pressure & Jolting

(d) compaction by Spinning

(a) Hand compaction:

→ It is adopted in case of unimportant concrete work of small magnitude and where there is no chance of doing compaction by mechanical means.

(i) Rodding:

→ It is a process of Poking the concrete with 2m long and 16mm diameter rod.

→ It may be of Iron rod or bamboo to remove the entrapped air.

(ii) Ramming:

→ Ramming should be done with care.

→ It is not permitted in R.C.C work because it distrubs reinforcement & form work.

(iii) Tamping:

→ It is one of the usual method adopted in compacting roof or floor slab or road pavement where the thickness of the section is low.

→ It consists of beating the top surface by wooden cross beam of section 10 cm x 10 cm

→ Since the tamping bar is sufficiently long. It not only compact but also levels the top surface

(b) Compaction by vibration:

→ where high strength is required, it is necessary that stiff concrete with lower water cement ratio to be used. To compact such concrete mechanically operated vibrators must be used

→ It is more effective than hand compaction

(i) Internal vibrator [Needle vibrator]:

→ It is most commonly used one, this is also called "Needle vibrator," "Immersion vibrator" or "poker vibrator."

→ This consists of a power unit; flexible shaft and needle.

→ It may be operated by electricity (or) by using petrol engine

→ The needle diameter varies from 20-75mm but 40mm is generally used.

→ The length of needle varies from 25-90 cm & length of shaft 3m.

→ This is portable can be shifted from place to place very easily during concrete operation.

→ This can be used in difficult positions and situations.

(ii) Form work vibrator [External vibrator]:

→ Form work vibrators are used for concreting columns, thin walls (or) in the casting of precast units.

→ The vibrator is clamped on the external surface of form work. the vibration is given to form work so that the concrete in the vicinity of the forms gets vibrated

→ This method of vibrating concrete is particularly useful and adopted where reinforcement, lateral ties and spacers interference too much with the internal vibrator.

→ It produce a good finish to the concrete surface

→ It consumes more power and efficiency is lower than internal vibrator.

(iii) Table vibrator:

→ This is the special case of a form work vibrator where the vibrator is clamped to the table. any article kept on the table gets vibrated.

→ This is adopted mostly in the ~~b~~ laboratories.

(iv) Platform vibrators:

→ This is nothing but a table vibrator but larger in size.

→ This is used in the manufacturing of large pre-fabricated concrete elements such as electrical poles, railway sleepers, roofing elements (tiles)

(v) Surface vibrator (or) slab vibrator:

A small vibrator placed on the plate gives an effective method of compaction and levelling of thin concrete members. such as floor slab and road surfaces.

→ This is not efficient beyond 250mm thickness

(vi) Vibratory Roller:

→ One of the recent developments of compacting very dry and lean concrete is the use of vibratory Roller. Such concrete is known as Roller compacted concrete.

→ This method of concrete construction originated from Japan & spread to USA and other contries mainly for construction of dams and Pavements.

c) Compaction by Pressure & Jolting:

→ This is one of the effective method of compacting very dry concrete.

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→ This method is often used for compacting hollow blocks, cavity blocks and solid concrete blocks.

→ The stiff concrete is vibrated, pressed and also given jolts.

→ With combined action of the jolts vibrations and pressure, the stiff concrete gets compacted to a dense form to give good strength & volume stability

(d) Compaction by Spinning:

→ Spinning is one of the recent methods of compaction of concrete.

→ This method of compaction is adopted for the fabrication of concrete pipes.

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

→ Patented products such as a 'Hume pipes' "Spun pipes" are compacted by spinning process.

(vi) Curing of Concrete:

⇒ For comple and proper strength development the loss of water in concrete from evaporation should be prevented.

⇒ Thus, the concrete continuously gaining strength with time provided sufficient moisture is available for the hydration of cement which can be assured only by creation of favourable conditions of temperature and humidity.

⇒ This process of creation of an environment which is suitable for the 100% compaction of hydration of cement is termed as curing.

* Curing methods:

These are broadly divided into categories

(i) Water curing

(ii) Membrane curing

(iii) Application of heat

(iv) Miscellaneous

(i) Water curing:

This is by far the best method of curing as it satisfies all the requirements of curing, namely. Promotion of hydration, reduction of shrinkage and absorption of heat of the hydration.

⇒ Water curing can be done in the following ways:

(a) Immersion (b) Ponding

(c) Spraying (or) Fogging (d) Wet covering

(a) Immersion: The precast concrete items are normally immersed in curing tanks for a certain duration

(b) Ponding: Pavement and roof slabs are covered under water by making small ponds

(c) Spraying (or) sprinkling:

Vertical retaining wall, plastered surface and concrete columns etc., are cured by sprinkling the water.

(d) Wet coverings: In some cases, wet coverings such as wet gunny bags, Jute bags and straw are wrapped to vertical surface for keeping the concrete wet.

(ii) Membrane curing:

→ Sometimes, concrete works are carried out in places where there is acute shortage of water.

→ The lavish (plenty) application of water for water curing is not possible for reasons of economy. There we are adopting membrane curing.

→ It has been pointed out earlier that curing does not mean only application of water. It means creation of conditions for porimotion of ~~uninterrupted~~ uninterrupted and progressive hydration.

→ It is also pointed out that the quantity of water normally mixed for making concrete is more than sufficient to hydrate the cement, provided this water is not allowed to go out from the body of concrete. For this reason, concrete could be covered with membrane which will effectively seal off the evaporation of water from concrete.

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→ Some of the materials that can be used for this purpose : are Bitumenous compounds, Poly-ethylene, polyester film, water proofing paper, rubber compounds etc.,.

(iii) <u>Application of Heat:</u>

→ The development of strength of concrete is a function of not only time but also that of temperature.

→ When concrete is subjected to higher temperature is accelerates the hydration process resulting in faster development of strength.

→ Concrete can not be subjected to dry heat to accelerate the hydration process as the presence of moisture is also an essential requisite. There fore, concrete subjecting to higher temperature and maintaining the required wetness can be achieved by subjecting the concrete to steam curing.

⇒ Exposure of concrete to higher temperature is done in following manner:

(a) steam curing at ordinary pressure.

(b) steam curing at high pressure

(c) curing by Infra-red radiation

(d) Electrical curing

(a) steam curing at ordinary pressure:

→ This method of curing is oftenly adopted for pre-fabricated concrete elements which are stored in a chamber.

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

→ The door is closed and steam is applied.

→ It may be continuous or intermediately applied.

→ An accelerated hydration takes place at this higher temperature (upto 100 °c).

→ The concrete attains 28 days strength of normal concrete in 3 days. But this method is not suitable for cast-in situ construction.

(b) **High Pressure steam curing:**

→ This is different from ordinary steam curing.

→ The super heated steam at high pressure and high temperature is applied on the concrete.

→ This process is also called auto-claving.

→ In this at atmospheric pressure the temperature of the steam is in between 100-175°c.

→ The steam will get covered into water. Thus, it is also called hot water curing.

→ 28 days strength of normal concrete attained in 1 day.

→ concrete exhibits lower drying shrinkage

→ this type cured concrete is highly resistance to sulphate attack & freezing attack.

(c) **Infra-red Radiation:**

→ It has been practised in very cold climate regions.

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

→ This system is often adopted for the curing of hollow concrete products.

(d) <u>Electrical curing</u>:

→ This type of curing is mostly applicable to very cold climate regions by the use of electricity.

→ Concrete can be cured electrically by passing an Alternating current through the concrete itself between the two electrodes either buried-in (or) applied to the surface of the concrete.

→ Care must be taken to prevent the moisture to going out leaving completely dry.

(iv) Miscellaneous methods of curing:

→ Calcium chloride is used either as a surface coating (or) as an admixture. It has been used satisfactorily as a curing medium.

→ $CaCl_2$ shows affinity for moisture, not only absorbs moisture from atmosphere but also retains it at the surface.

⇒ Form work prevents escaping of moisture from the concrete particularly in the case of beams and columns.

⇒ Sealing the joint with wax (or) any other sealing compound prevents evaporation of moisture. This procedure promoting hydration, can be considered as one of miscellaneous methods of curing.

(VII) Finishing:

→ It is the final operation in manufacturing of concrete.

→ It is essential for concrete road pavement, air field pavement (or) for the flooring of a domestic building

→ surface finishes may be grouped as under:

(a) Formwork Finishes

(b) Surface Treatment

(c) Applied Finishes

* Quality of Mixing Water:

→ Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement.

→ It should be free from harmful material.

→ Water with pH value 6 to 8 also considered in some condition.

→ To find suitable source of water, make concrete with any source of water & compare the strength of 7 days and 28 days with cubes prepared with distilled water.

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→ If the compressive strength is upto 90%, the source of water may be accepted.

→ This criteria may be safely adopted in places like coastal area of marshy area or in other places where the available water is brackish in nature and of doubtful quality.

→ Carbonates and bi-carbonates of sodium and potassium effect the setting time of cement. Tolerence limit is 1000 ppm, In lower concentrations they may be accepted

→ When chloride does not exceed 10,000 ppm and ~~sh~~ sulphate does not exceed 3000 ppm the water is harmless.

→ Salts of Manganese, Tin, Zinc, copper & lead cause a marked reduction in strength of concrete

→ Sodium iodate, sodium phosphate and sodium borate reduce the initial strength of concrete

→ Sodium sulphide even 100 ppm warrants testing

→ Turbidity limit of 2000 ppm has been suggested.

→ Organic material limit 3000 ppm or less is suggested.

Unit-IV

Hardened Concrete

Introduction:

Hardened concrete is a concrete which must be strong enough to withstand the structural and service load which will be applied to it and must be durable enough to the environmental exposure for which it is designed.

→ It will be a strong and durable building material

→ The strength of concrete depends upon

ⓐ Ratio of cement to mixing water

ⓑ Ratio of cement to aggregate

ⓒ Grading, surface texture, shape, strength and stiffness of aggregate particles

ⓓ Maximum size of aggregate

⇒ In the above it can further inferred that Water/cement ratio primarily affects the strength, where as other factors indirectly affect the strength of concrete by affecting the water/cement ratio.

* Water/Cement Ratio:

→ Strength of concrete primarily depends upon the strength of cement paste.

→ The strength of paste increases with cement content and decreases with air and water content.

→ It was Feret who formulated in as early as 1897, a general rule defining the strength of the concrete paste and concrete in terms of volume fractions of the constituents by the equation

$$S = K\left[\frac{c}{c+e+a}\right]^2$$

Where

s = strength of concrete

c = volume of cement

e = volume of water

a = volume of air

K = constant

⇒ strength of concrete not only depends on w/c ratio but also on degree of compaction.

⇒ In this expression, the volume of air is also included because it is not only w/c ratio but also the degree of compaction, which indirectly means the volume of air filled voids in concrete is taken into account in estimating the strength of concrete

Note: ⇒ Low w/c ratio needs - because of stiffness - compaction by vibrators

⇒ High w/c ratio - needs hand compaction - because of fluidity

⇒ As the water cement ratio increasing, the compressive strength value of concrete decreases.

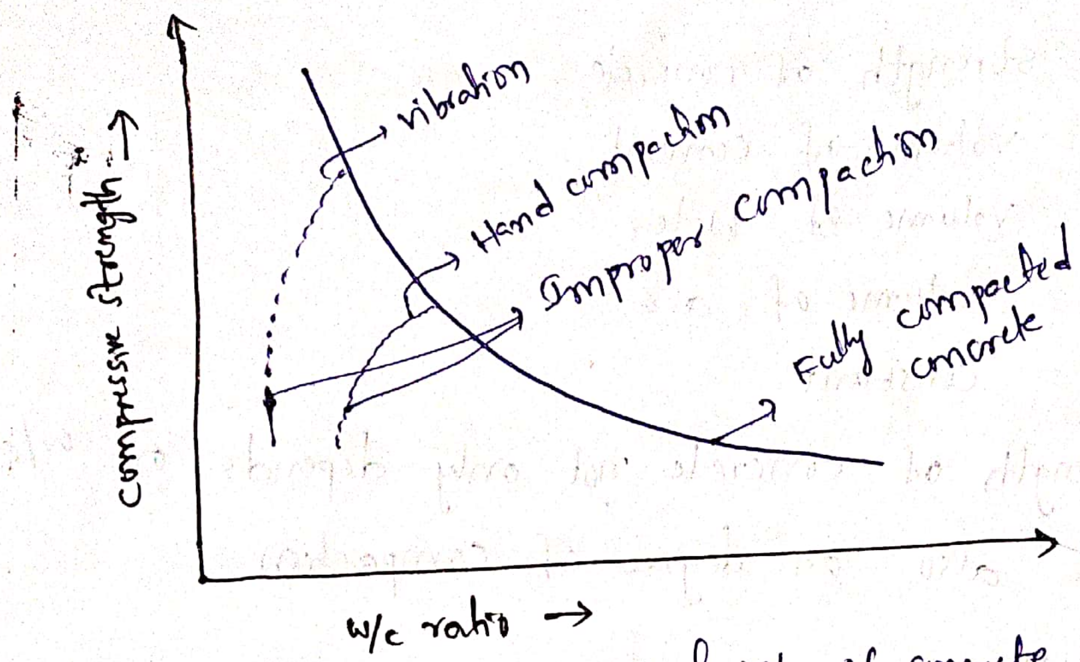
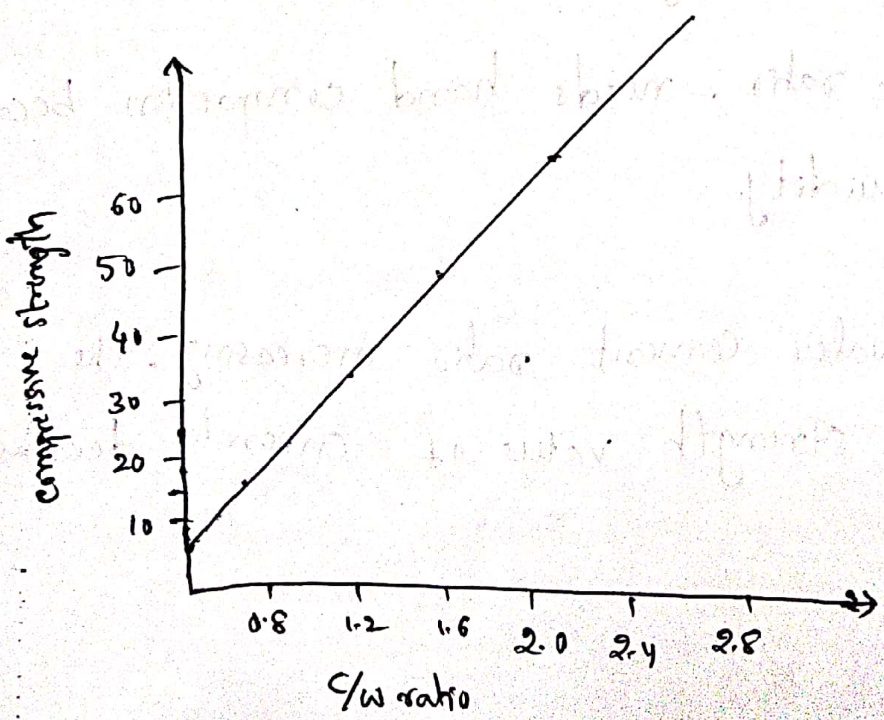


Fig 1: The Relation b/w strength & w/c of concrete

If compaction is not properly done, strength falls down suddenly; Hence in this graph, if we have any w/c ratio value we cannot interpolate the compressive strength value to over come this feret is introduced c/w ratio.



The graph showing the relation b/w strength & W/c ratio is approximately hyperbolic in shape. Sometimes it is difficult to interpolate the intermediate values. Instead the graph between strength and cement water ratio is drawn it is approximately linear, so intermediate values can be easily found.

* Abram's Law (1918):

⇒ This law states that strength of concrete is depending only on w/c ratio provided the concrete mix is workable.

$$S = \frac{A}{B^x}$$

where S = strength of concrete

A, B = constants

x = w/c ratio by volume

$A = 14{,}000$ lbs/sq. in
$B = 7$
} at 28 days.

⇒ The law states that strength of a concrete mix is inversely related to the W/c ratio. As the water content increases, the strength of concrete decreases.

* <u>Gel/space Ratio (x):</u>

⇒ The Abram's statement does not include many qualifications necessary for its validity to call it a law. Some of the limitations are that the strength at any water/cement ratio depends on the degree of hydration of cement and its chemical & physical properties.

⇒ The strength can be more correctly related to the solid products of hydration of cement to the space available for formation of this product

⇒ Powers and Brownyard have established the relationship between the strength and gel/space ratio.

⇒ This ratio is defined as the ratio of the volume of the hydrated cement paste to the sum of volumes of the hydrated cement and of the capillary pores

Power's and Brownyard equation:

$$\text{Gel/space ratio } (x) = \frac{\text{Volume of gel}}{\text{Space occupied volume by gel}}$$

Calculation of gel/space ratio for complete hydration

$$x = \frac{\text{Volume of gel}}{\text{space occupied volume by gel}}$$

→ volume of gel = c × specific volume of cement × 2.06

Assuming that 1 ml of cement of hydration will produce 2.06 ml of gel.

c = weight of cement in grams

V_c = specific volume of cement = 0.319 ml/grams

volume of gel = c × 0.319 × 2.06

Space available = c × 0.319 + W_0

W_0 = Volume of mixing water in ml

$\therefore$ Gel/space ratio(x) = $\dfrac{\text{Volume of gel}}{\text{Space available}}$

$$x = \frac{0.657\,C}{0.319\,C + W_o}$$

* **Calculation of gel/space ratio for partial hydration:**

Let α = Fraction of cement that has hydrated

Volume of gel = $C \times \alpha \times 0.319 \times 2.06$

Space available = $C V_c \alpha + W_o$

$$x = \frac{2.06 \times 0.319 \times C\alpha}{0.319\,C\alpha + W_o}$$

⇒ It is pointed out that the relationship between the strength and w/c ratio will hold good primarily for 28 days strength, for fully compacted concrete where as the relationship between strength and gel space ratio is independent of age.

⇒ The gel space ratio can be calculated at any age and at any fraction of hydration of cement.

Theoritical strength of concrete (S)

$$S = 240x^3$$

where S = theoritical strength

x = gel space ratio.

Ex 1: Calculate the gel space ratio and theoritical strength of a sample of concrete made with 500 grams of cement with 0.5 W/c ratio

(i) on full hydration (ii) 60% hydration

(i) Full hydration

$$x = \frac{0.657C}{0.319 + W_o}$$

$$S = 240x^3$$

$\frac{W_o}{C} = 0.5$, $C = 500$ grams

$W_o = 0.5 \times 500$

$= 250$ ml

$$x = \frac{0.657 \times 500}{0.319 \times 500 + 250}$$

$$x = 0.802$$

Theoritical strength (S)

$$S = 240x^3$$

$$= 240 \times (0.802)^3$$

$$\boxed{S = 123.8\ N/mm^2}$$

(ii) <u>60% hydration:</u>

$$x = \frac{0.657\ C\alpha}{0.319\ C\alpha + W_0}$$

$$= \frac{0.657 \times 500 \times 0.6}{0.319 \times 500 \times 0.6 + 250}$$

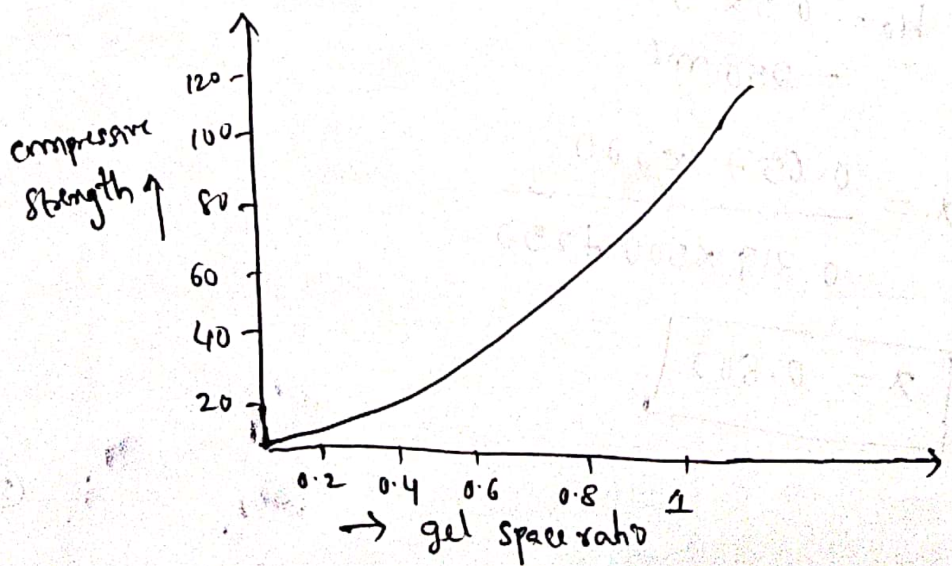
$$x = 0.57$$

$$S = 240 \times (0.57)^3$$

$$\boxed{S = 44.45\ N/mm^2}$$

⇒ Gel space ratio ∝ strength of concrete

W/c ratio $\propto \frac{1}{\text{strength of concrete}}$.



→ There is a lot of difference between the theoritical strength of concrete and actual strength of concrete

→ The actual strength of concrete is much lower than the theoritical strength of concrete estimated on the basis of molecular cohesion and surface energy of a solid assumed to be parfectly homogeneous and flawless.

→ The actual strength reduction is due to the presence of flaws cement paste in concrete contains many discountinuties such as voids, cracks, bleeding channels, rupture of bond due to drying shrinkage and temperature stresses.

It is difficult to explain how exactly these various defects contribute to the reduction in actual strength of concrete

* <u>Gain of Strength with Age</u> :

→ The concrete develops strength with continued hydration.

* Age factors for permissible compressive stress in concrete as per British code

Minimum age of member when full design load is applied in months	Age factor.
1	1
2	1.1
3	1.16
6	1.2
12	1.24

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

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

→ Actually the concrete develops strength beyond ~~immersed with the~~ 28 days. ~~used to get~~ ~~factor of safety~~.

→ This is considered in design of structures to make structure more economical.

* Grades of concrete as per IS 456-2000.

Group	Grade Designation
Ordinary concrete	M10 M15 M20
Standard Concrete	M25 M30 M35 M40 M45 M50 M55 M60
High strength concrete	M65 M70 M75 M80 M85 M90 M95 M100

* Accelerated curing.

⇒ Accelerated curing can be done in 7 hours [casting the cubes, curing & testing]

What for accelerated curing is necessary:

⇒ The strength of concrete is generally estimated at 28 days by crushing field test cubes (or) cylinders made from the representative concrete used for the structure.

⇒ Oftenly it is pointed out about the utility of ascertaining 28 days strength by which time considerable amount of concrete will have been placed and works may have progressed

→ It is too late for remedial measures, if the result of test cube at 28 days is too low. On the other hand the structure will be uneconomical if the result of the test cube is too high.

→ Therefore it is tremendous advantage to be able to predict 28 days strength with in few hours of casting concrete. So that satisfactory remedial measures could be taken immediately before it is too late.

* Accelerated curing Test Procedure :

1) Cast the standard cubes
2) Cubes are covered with top plate and joints are sealed with special grease to prevent drying.
3). Within 30 min of adding water the cubes having sealed effectively are placed in air tight oven which is then switched on.
4) Oven is brought to 93°c in about one hour and it is kept at this temperature for five hours.
5) Then the cubes are removed from oven, stripped, cooled and tested in 30 min.

Note: The strength of concrete is determined within 7 hours of casting introduced by Profs King

⊛ Maturity Concept of concrete :

Since the strength development of concrete depends on both time and temperature. It can be said that the strength is a function of product of time & temperature. This summation is called maturity of concrete.

Maturity = Σ (time)×(temperature)

→ It was experimentally found that the hydration of concrete continuous to take place upto about −11°c. Therefore −11°c is taken as datum line for computing maturity of concrete. Maturity is measured in "°ch".

Note: A sample of concrete cured at 18°c for 28 days is taken as fully matured concrete. Its maturity would be equal to

$$(28\times24)\,[18^\circ-(-11^\circ c)] = 19488\ ^\circ ch$$

↓ exactly ⇒ 19800°ch

⇒ However, in standard calculations the maturity of fully cured concrete is taken as 19800°ch. [The difference is because of datum line not exactly being −11°c]

⇒ Maturity concept is useful for estimating the strength of concrete at any other maturity as a percentage of strength of concrete of known maturity. That means if we know the strength of concrete at full maturity (19,800 °ch).

We can calculate the percentage of strength of identical concrete at any other maturity.

strength at any maturity as a percentage

$$= A + B \log_{10}\left[\frac{\text{Maturity}}{1000}\right]$$

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

strength at 28 days at 18°c [maturity of 19,800°ch] N/mm²	coefficient	
	A	B
< 17.5	10	68
17.5 – 35	21	61
35 – 52.5	32	54
52.5 – 70	42	46.5

Ex:1: The strength of a sample of fully matured concrete is found to be 40 MPa. find the strength of identical concrete at the age of 7 days when cured at an average temperature during day time at 20°c and night time at 10°c.

Strength of concrete at the age of 7 days $= A + B \log_{10}\left(\frac{\text{Maturity}}{1000}\right)$

Maturity = Σ (time) (temperature)

$= [(7 \times 12)\ 20-(-11)] + [(7\times 12)\ 10-(-11)]$

$= 4368$ °ch.

$\Rightarrow$ strength at 28 days = 40 N/mm² (or) 400 kg/cm²

A = 32 , B = 54

~~Maturity~~

$\therefore$ % strength of concrete at maturity of 4368 °ch

$= A + B \log_{10}\left[\frac{4368}{1000}\right]$

$= 32 + 54 \log_{10}(4.368)$

$= 32 + 54 \times 0.6403$

$= 66.5\%$

$\therefore$ strength at 7 days $= 40 \times \frac{66.5}{100} = 26.5$ N/mm²

Ex: 2: Laboratory experiments conducted at Pune on a particular mix showed a strength of 325 kg/cm² for fully matured concrete. Find whether formwork can be removed for an identical concrete placed at Srinagar at the age 15 days when the avg temperature is 5°C.

if the concrete is likely to be subjected to a stripping stress of 250 kg/cm²?

Ans →

$$Maturity = (15 \times 24)\,[5-(-11)]$$
$$= 5760\ °ch$$

strength after 28 days = 325 kg/cm² = 32.5 N/mm²

A = 21 & B = 61

$$\text{Percentage of strength} = A + B \log_{10}\left[\frac{Maturity}{1000}\right]$$
$$= 21 + 61 \times \log_{10}\left[\frac{5760}{1000}\right]$$
$$= 21 + 61 \times \log_{10} 5.76$$
$$= 21 + 61 \times 0.7604 = 67.38\ \%$$

$$\therefore \text{strength of concrete at 15 days} = 32.5 \times \frac{67.38}{100}$$
$$= 21.9\ N/mm^2$$

$$21.9\ N/mm^2 < 25\ N/mm^2$$

∴ It is not advisable to remove the formwork

→ If the strength at a given maturity is known then the number of days required to reach the same strength at any other temperature can be calculated from

$$\frac{M}{24[t-(-11)]}$$

M = maturity for the given strength
t = temperature

Ex:3: In the above example for reaching the same strength, number of days required

Maturity at 28 days at 18°c = 19800 °ch

At 5°c

No. of days required = $\frac{M}{24\,[t-(-11)]} = \frac{19800}{24\,[5-(-11)]}$

$= \frac{19800}{24 \times 16} = 52$ days.

∴ This is to say that the concrete cured at 5°c would take about 52 days to achieve full maturity

* Compressive Strength:

⇒ Among the various strengths of concrete the determination of compressive strength as recieved a large amount of attention because the concrete is primarily meant to withstand compressive stresses. Generally cubes and cylinders specimens are used to determine compressive strength.

Cube sizes:

150 × 150 × 150 mm → standard [100%]

100 × 100 × 100 mm → 90% of standard strength

Cylinder → 150 × 300 mm → 75% to 85% of standard strength (80%)

The specimens are casted and cured & tested as per standards prescribed for such tests.

⇒ Compressive strength given by different specimens for the same concrete mix are different.

* Tensile Strength of Concrete:

(i) Direct Method:

→ Direct measurement of tensile strength of concrete is difficult.

→ This method suffers from the number of difficulties related to holding the specimen properly in the testing machine without introducing stress concentration and to the application of uni-axial tensile load [free from eccentricity]

(ii) Flexural * strength:

→ The determination of flexural, tensile strength is essential to estimate the load at which the concrete members may crack.

→ As it is difficult to determine the tensile strength of concrete by conducting a direct tension test & it is computed by flexural testing of concrete

→ The flexural tensile strength at failure [This is also called modulus of rupture] is determined and used when necessary.

→ This is very much useful in the case of design of pavement slab and runways as flexural tension is critical in these sections.

⇒ Standard size of specimen:

150 × 150 × 700 mm → for ≥ 20 mm size Aggregates used

150 × 150 × 500 mm → ≤ 20 mm size aggregates used

⇒ The value of modulus of rupture depends on the dimension of the beam & manner of loading

⇒ Flexural test on concrete can be conducted using

① Three-point loading test [ASTM C78]

② center point load test [ASTM C293]

⇒ Under symmetrical two point loading [third point] the modulus of rupture is determined from the moment at failure $\boxed{M = f \times Z}$

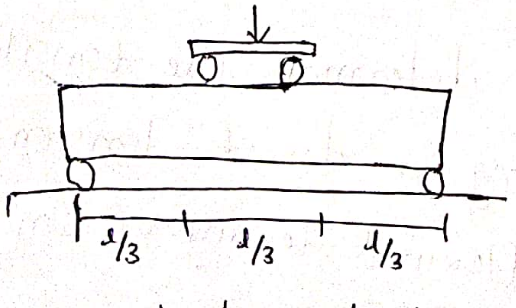


Fig: 3-point loading method

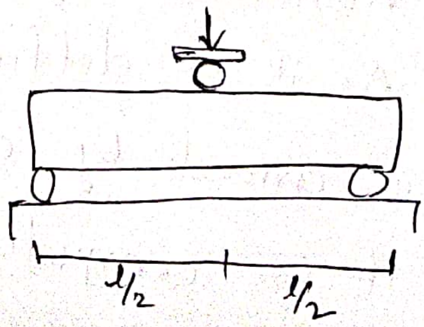


Fig: center point loading method

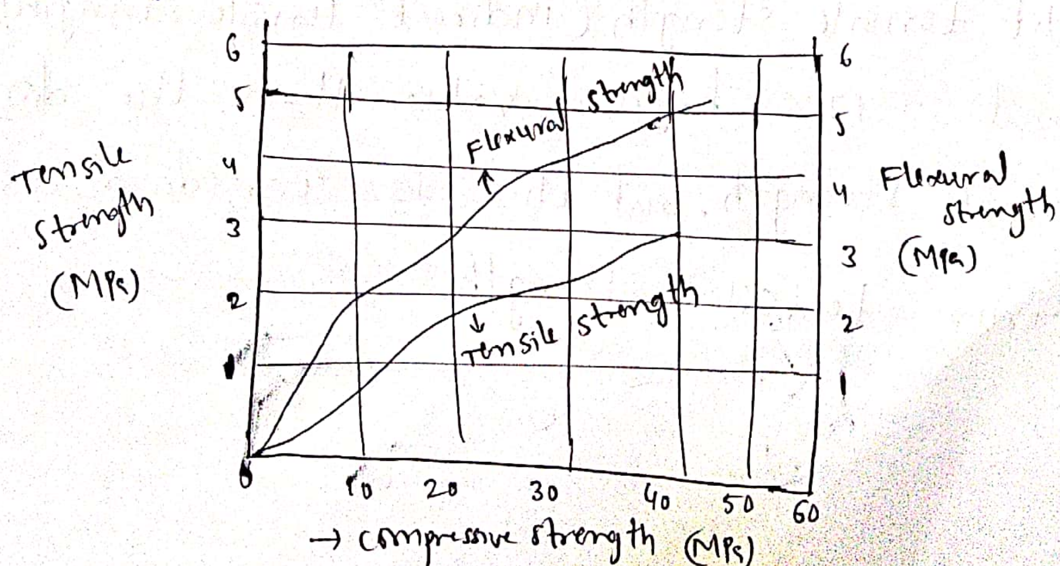
→ The modulus of rupture value obtained by center point load test is higher than the three point load test.

⇒ The computation of rupture stress assumes a linear behaviour of material upto failure which is only a rough estimation. The results are effected by the size of specimen, casting, curing, manner of loading & rate of loading.

⇒ The strength estimated by flexure test is higher than the tensile strength of concrete because of the assumption of linear behaviour.

(iii) Indirect Method:

To overcome the difficulties in direct methods the number of indirect methods have been developed to determine the tensile strength of concrete.



In these test in general a compressive force is applied to a concrete in such a way that the specimen fails due to tensile stresses induced in the specimen.

→ The tensile stress at which failure occurs is the tensile strength of concrete

Advantages of Indirect Method:

1) The test is simple to perform and gives more uniform results
2) The strength determined is closer to the actual strength of concrete than that given by the modulus of rupture test
3) The same moulds can be used for casting specimen for both compression & tension.

Note:

⇒ split tensile stength (indirect tensile strength) gives about 5-12% higher value than the direct tensile strength, but this is considered as true tensile strength.

* Relation b/w compressive & Tensile strength:

→ The reinforced concrete construction the strength of the concrete in compression is only taken into consideration.

→ The tensile strength of concrete is generally not taken into consideration. But the design of concrete pavement slabs it is necessary.

→ As mesurement and control of compressive strength in field are easier and more convenient, it has been customary to find compressive strength for different conditions and to correlate this to flexural strength.

→ For higher compressive strength concrete shows higher tensile strength.

→ The use of pozzolanic material increases the tensile strength of concrete.

⇒ Central Road Research Laboratory (CRRI) given following statistical Relationship

(i) $Y = 15.3x - 9$ for 20mm max size crushed Agg

(ii) $Y = 14.1x - 10.4$ for 20 mm max size natural Aggregate

(iii) $y = 9.9x - 0.55$ for 40mm max size crushed Agg

(iv) $y = 9.8x - 2.52$ for 40mm max size natural Agg

where y = compressive strength of concrete (MPa)
x = flexural strength of concrete (MPa)

⇒ flexural to compressive strength ratio was higher with Aggregates of 40mm size than 20mm size

→ The ratio was found to be higher for natural gravel than crushed stone.

⇒ For higher strength ($\geq 25\ N/mm^2$) & 20mm aggregates the flexural strength is equal to 8 to 11% of compressive strength of concrete

→ For lower strength ($< 25\ N/mm^2$), the flexural strength is equal to 9 to 12.8% of compressive strength of concrete

* Factors influencing the strength of concrete:

→ There are two types of factors which effect the strength of concrete.

(a) Factor's depending on testing method

(b) Factor's independent on the type of test.

(a) Factor's depending on testing method

⇒ Following are the factor's which affect the strength of concrete based on testing method.

(1) Size of test specimen:

→ When the strength of 15cm size cube is considered as standard, then the strength of 10cm cube is to be reduced by 10%

150 × 150 × 150 mm → is standard

100 × 100 × 100 mm → 90% of standard

150 × 300 mm (cylinder) → 80% of standard

→ The shape and size of specimen affect the strength of concrete

(2) Moisture condition of specimen:

→ It is highly influence the strength of concrete

→ Dry specimen gives more strength

→ Wet specimen gives less strength

→ Dry cubes undergo drying shrinkage & develop crack.

③ <u>size of specimen in Relation to size of Aggregate</u>:

→ Maximum size of aggregate responsible for lowering the strength of concrete

→ Larger aggregates provide maximum surface area for development of gel bonds, which effect strength.

Aggregate strength > concrete > cement mortar

(4) <u>Support condition of specimen</u>:

→ Presence of lubricating materials at the bearing surface of sample affect the strength.

(5) <u>Type of loading adopted</u>:

→ strength of concrete depend on type of loading

→ uniaxial tensile load, tends to decrease the strength of concrete

⑥ <u>Rate of loading of specimen</u>:

→ Low rate of application of load reduces the strength of concrete due to creep

→ Due to creep, the strain in the specimen is increased which affect strength

(7) Type of Testing Machine:

→ Destructive & non-destructive type of testing machine effects the strength of concrete

(8) Assumptions made in the analysis relating stress to failure load.

→ All the assumptions we made are effecting the strength of concrete.

(b) Factors independent of type of test:

→ Following are factors which are independent of the test type

(1) Type of cement with age

→ Increase in age of cement tends to increase water cement ratio, due to which the strength of the concrete decreases.

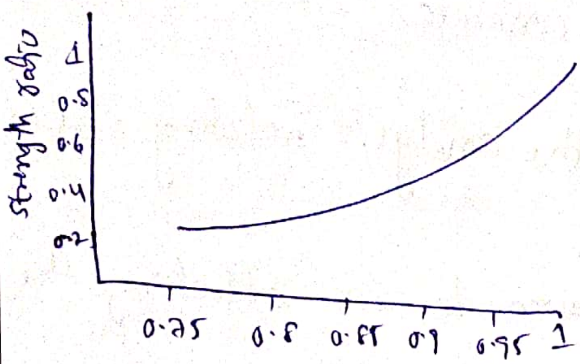
(2) Type of Aggregate & admixture

→ Type of aggregate & admixture are effecting the strength of concrete

(3) Degree of compaction.

→ Process of removing entrapped air from concrete called compaction

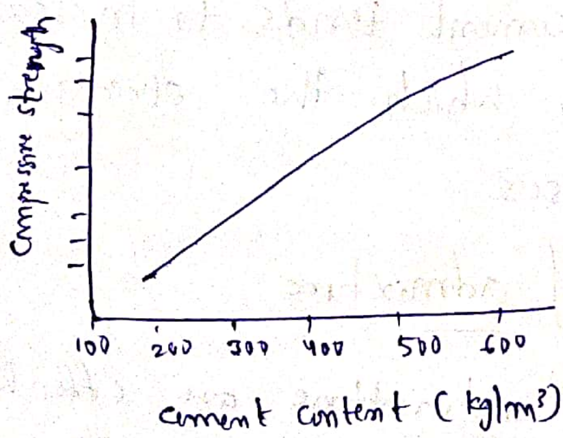
→ If air is not removed, strength of concrete decreases



④ Concrete mix proportions:

→ Increase in mix proportion decreases the strength of concrete

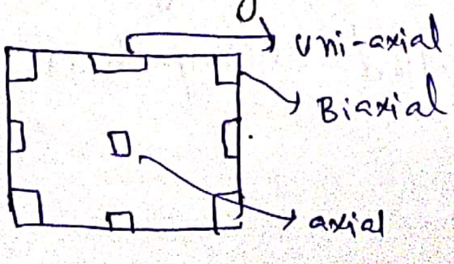
→ cement content, aggregate/cement ratio, amount of air voids, & water cement ratio



⑤ Type of curing & temperature of curing

⑥ Nature of loading to which specimen is subjected i.e static or Dynamic

⑦ Type of stress that may exist like uniaxial (or) Biaxial



* Compression Test :

→ Compression test is the most common test conducted on hardened concrete.

→ It is carried out on specimens cubical (or) cylindrical in shape

→ cube specimen size 150 × 150 × 150 mm
100 × 100 × 100 mm

cylinder specimen size 150 mm diameter & 300 mm long

→ A steel bar 16 mm diameter, 600 mm long tamping rod used

→ Prepare representative concrete sample

→ Fill the concrete in 3 layers & we can do Hand compaction (or) vibration for compaction.

→ After casting remove the mould after 24 hours & keep the mould in water upto testing time

→ Keep the mould in compression testing machine & Apply the load. note down the failure load.

$$\text{compressive strength} = \frac{\text{Compression load}}{\text{area of specimen}} \quad (1)$$

* Procedure for conducting flexural strength of concrete:

1). The bearing surfaces of supporting and loading rollers are wipped clean

2) Any loose sand or other material removed from the surface of specimen

3) The specimen size

150 × 150 × 700 mm → 600mm span

100 × 100 × 500 mm → 400 mm span

4) The specimen is then placed in the machine in such a manner that the load is applied to the upper most surface as cast. in the mould along two lines spaced 20 cm or 13.3 cm apart

5). The axis of the specimen is carefully aligned with the axis of the loading device [no packing is used b/w the bearing surface of the specimen and rollers]

6). Apply the load uniformly and increase continuously at a rate of 400 kg/min (4kN/min) for 150 mm specimen & 180 kg/min [1.8 kN/min] for 100 mm specimen

7). The load is increased until the specimen fails and the maximum load applied to the specimen during the test is recorded

8) The appearance of the factured faces of concrete and any unusual features in the type of failure is noted.

Flexural strength is expressed as modulus of rupture (f_b)

$$f_b = \frac{Pl}{bd^2}$$

a > 20 cm for 150 mm specimen

a > 13.3 cm for 100 mm specimen

$$f_b = \frac{3P \times a}{bd^2}$$

If a < 20 cm for 150 mm specimen

a < 13.3 cm for 100 mm specimen

Where

a = the distance b/w line of fracture and the nearest support

b = width of specimen in cm

d = depth of specimen in cm at the point of failure

l = length of specimen

P = maximum load in kg

(2)

* Indirect tensile test [Split tensile test]

* Procedure:

1). This is carried out by placing a cylindrical specimen horizontally b/w the loading surfaces of a compression testing machine and the load is applied uniformly. until the failure of the cylinder along the vertical diameter.

2). Size of specimen 150mm ϕ & 300mm long

3). The loading condition produces a high compressive stress immediately below the two generatrix (place of loading) to which load is applied.

4). It is estimated that the compressive stress is acting for about $1/6^{th}$ depth & Remaining $5/6^{th}$ depth is subjected to tension.

Note: Split tensile strength gives about 5 to 12% higher value than the direct tensile strength.

→ cylinder subjected to a vertical compressive stress of

$$= \frac{2P}{\pi LD}\left[\frac{D^2}{r(D-r)} - 1\right]$$

& Horizontal stress of

$$= \frac{2P}{\pi L D}$$

where
P = compressive load on cylinder
L = Length of cylinder
D = diameter

⇒ r & (D-r) are the distances of the elements from the two loads respectively.

* Test cores:

→ The test specimen, cube or cylinder is made from the representative sample of concrete used for a particular member. the strength of which we are interested.

⇒ It is to be understood that the strength of cube specimen can not be same as that of the concrete member because of the diference with respect to the degree of compaction, curing standards, uniformity of concrete, evaporation causes lose of mixing water etc.

③ → At best result of the cube or cylinder can give only a rough estimate of the real strength of member.

→ To get the best results attempts made to cut the core from the parent concrete and test the ~~cut~~ core for strength. Perhaps this will give a better picture about the strength of actual concrete.

* Disadvantages:

1) while cutting the core the structural integrity of the concrete across the full cross section may be effected to some extent.

2) H/D ratio cannot be obtained as cylinder or cube

3) Existing reinforcement will also make difficulty in cutting core.

* Non-Distructive Testing Methods (NDT):

The development of these methods have taken place to such an extent that these are now considered as powerful methods for evaluating existing concrete structures with regard to strength & durability. Some times this method can also be used for the investigation of crack depth, micro cracks and progressive detorioration of concrete.

In this testing the specimen's are not loaded to failure and as such the strength estimated can not be expected to yield absolute values of strength. Therefore, these methods attempt to measure some other properties of concrete from which an estimate of its strength, durability and elastic parameters are obtained. some such properties of concrete are hardness, rebound number, resonant frequency and pulse velocity. though these methods are relatively simple to perform, the analysis & interpretation of test results are not so eesy. These are need special knowledge is required to analyses hardness properties of concrete.

*Types of NDT methods:

① Surface Hardness Test

② Rebound Test

③. Penetration & Pull out. Techniques

④ Dynamic (or) vibration Tests

⑤ Combined methods

⑥ Radio active & Nuclear methods

⑦ Magnetic & Electrical Methods

⑧ Acoustic emission techniques.

④

① Surface Hardness Test (Strength):

These are of identation type, include the williams testing pistol & impact hammers and are used only for estimation of concrete strength.

→ The fact that concrete hardness increese with age, the measure of hardness of surface may indicate the strength of concrete.

② Rebound test:

→ The rebound hammer test measures the elastic rebound of concrete & is primarily used for estimation of concrete strength & for comparative investigations.

→ Schmidt's rebound hammer developed in 1948 is one of the commonly adopted equipments for measuring the surface hardness.

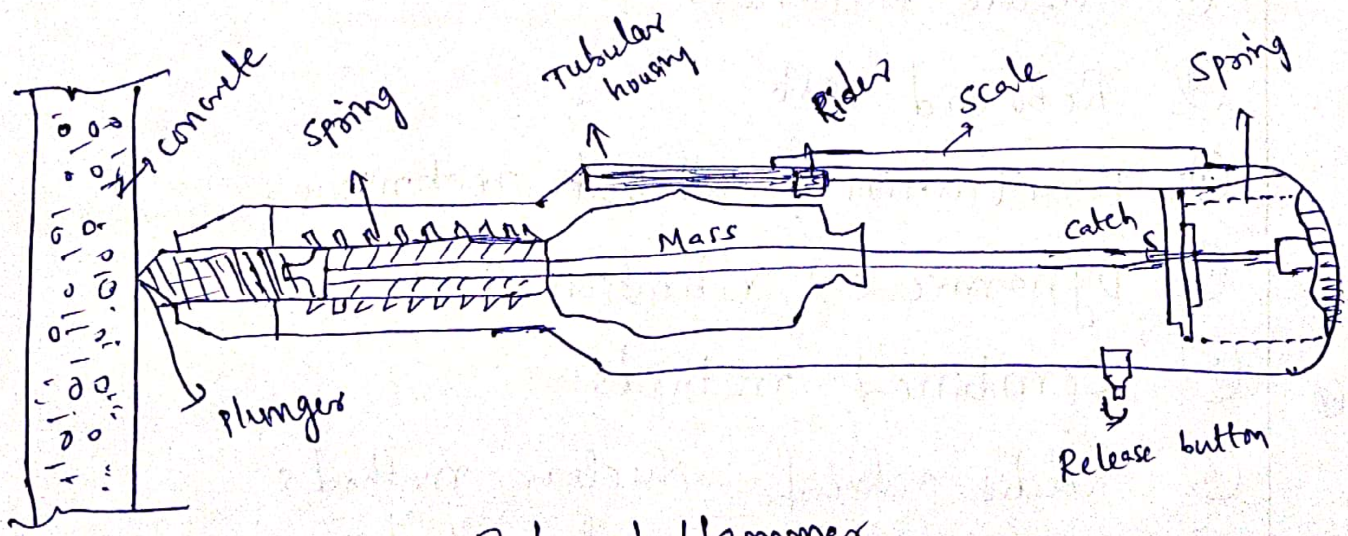


Fig: Rebound Hammer

It consists of a spring control hammer that slides on a plunger within a ~~ta~~ tubular housing. When the plunger is pressed against the surface of the concrete, the mass rebound from the plunger. It retracts against the concrete and the spring control mass rebounds, taking the rider with it along the guide scale.

The distance travelled by the mass, is called the rebound number. It is indicated by the rider moving along a graduated scale.

The test can be conducted horizontally, vertically upward (or) downwards (or) at any intermediate angle. At each angle the rebound number will be different for the same concrete and will require seperate correction (or) calibration chart.

Limitations: Test results are affected by

(a) smoothness of surface under test

(b) size & shape & rigidity of the specimen

(c) Age of specimen

(5)

(d) surface & internal moisture condition of concrete.

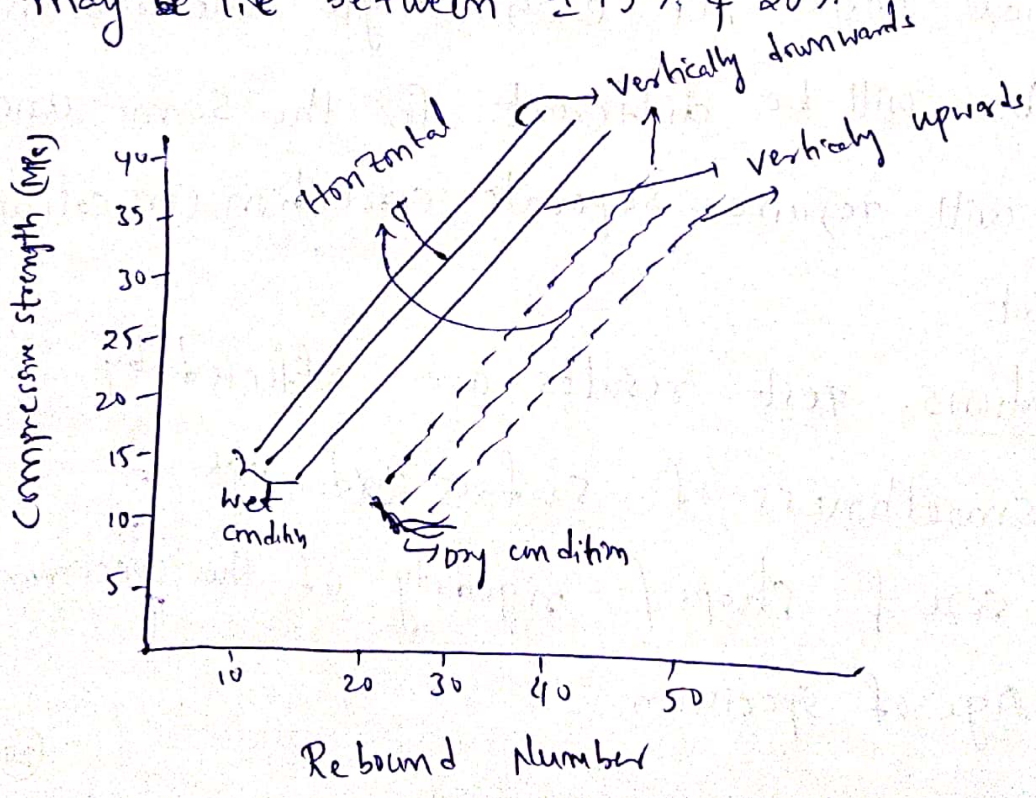
(e) Type of coarse aggregate

(f) Type of cement

(g) Type of mould.

⇒ The investigations have shown that there is a general correlation between compressive strength and rebound number. However there is a wide degree of disagreement among various research workers regarding the accuracy of estimation of strength from rebound readings.

→ The variation of properly calibrated hammer may lie between ±15% & 20%.



(3) Penetration & Pull out Techniques:

* Penetration Technique:

→ The measurement of hardness by probing techniques was first reported during 1954.

There are two tests

① Simbi hammer test
② Windsor probe test.

⇒ In one case a hammer known as 'Simbi' was used to perforate concrete and depth of bore hole was correlated to compressive strength of concrete cubes.

- In the other technique, the probing of concrete was achieved by blasting with split pins & the depth of penetration of the pins was correlated with compressive strength of concrete.

* Pullout Test:

A pullout test measures the force required to pull out from the concrete a specially shapped rod whose enlarged end has

⑥ been cast into the concrete.

⇒ A steel disc, dimensions 25 mm diameter & depth is 25 mm.

⇒ The stronger the concrete, the more is the force required to pullout.

⇒ The ideal way to use pullout test in the field would be to incorporate assemblies in the structure. These standard specimens could then be pulled out at any point of time. The force required denotes the strength of concrete.

④ Dynamic (or) Vibration Method:

The fundamental principle on which the dynamic methods are based on velocity of sound through a material. This can be measured by determining the resonant frequency of specimen or by recording the time of travel of sharp pulse of vibration passing through the concrete.

They are

① Resonant frequency

② Time of pulse (or) Pulse velocity methods

ⓐ Mechanical sonic pulse velocity method

(b) Ultra sonic pulse velocity method

Scanned by CamScanner

① Resonant frequency:

⇒ This method is mostly used in laboratory and the equipment used for this method is known as 'Sonometer.'

⇒ This method is based on the determination of the fundamental resonant frequency of vibration of a specimen.

⇒ The Resonance is indicated by the point of maximum amplitude for the various driving frequencies generated

⇒ The test results are offenly used to calculate dynamic modulus of elasticity of concrete

② Time of pulse (or) pulse Velocity Methods:

(a) Mechanical sonic pulse velocity method:

⇒ which involves measurement of the time of travel of longitudinal (or) compressional waves generated by a single impact hammer blow (or) repeated blows.

(7)

⇒

→ When mechanical impulses are applied to a solid mass, three different kind of waves are generated. These are generally known as

(i) longitudinal (compression waves)

(ii) Transverse (shear waves)

(iii) surface waves

⇒ These three waves travel at different speeds. The longitudinal waves travel about twice as fast as the other two types.

⇒ The shear waves are not so fast, the surface waves are the slowest.

⇒ The pulses can be generated either by hammer blows (or) by the use of an electroacoustic transducer. Electroacoustic transducers are preferred as they provide better control on the type & frequency of pulses generated.

→ The instrument used is called 'soniscope'.

(b) <u>Ultrasonic pulse velocity Method</u>:

→ which involves measurement of the time of travel of electronically generated mechanical pulses through the concrete.

→ Apparatus: One electrical pulse generator, a pair of transducer, an amplifier, an electronic timing device

⇒ An ultrasonic pulse is generated by electronic Acoustical transducer when the pulse is introduced to the concrete it undergoes multiple reflections and a complex system of wave is developed which includes longitudinal, transverse & surface waves.

→ The receiving ~~to~~ transducer detects a set of the longitudinal waves which is the fastest after traversing a known path (l) in the concrete. The vibration pulse is converted into an electrical signal by a second transducer held in contact with other surface of the concrete member.

→ An electronic timing circuit enables the transit time (T) of the pulse to be measured from which the ultrasonic pulse velocity can be found.

(8)

* Methods of Measuring pulse velocity:

There are three ways of measuring pulse velocity through concrete. They are

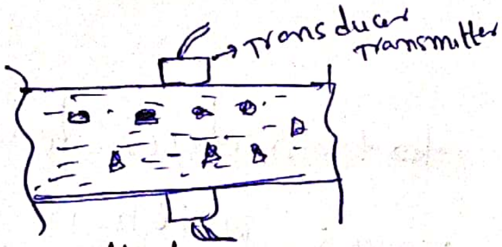
(a) Direct transmission [Direct method]

(b) Indirect transmission [Indirect method]

(c) surface transmission [surface method]

(a) Direct Method:

→ This method is preferred whenever the axis to opposite sides of the component are possible



(b) Indirect Method:

→ This method is used whenever axis for one side but not possible for opposite sides of the component

(c) surface Method:

→ This is least satisfactory

→ It should be used when axis to only surface is possible

* Table: Quality gradings for concrete

Velocity determination by cross-probing (As per IS: 13311 - Part I)		Velocity determination by surface-probing [As per NCBM]	
Pulse Velocity (km/sec)	Quality of concrete	Pulse velocity (km/sec)	Quantity of concrete
Above 4.5	Excellent	Above 3.5	Excellent
3.5 to 4.5	Good	3.0 to 3.5	Good
3.0 to 3.5	Medium	2.5 to 3.0	Medium
Below 3.0	Doubtful	Below 2.5	Poor

* Factors Affecting the Measurement of Pulse Velocity (or) Limitations:

(1) Smoothness of contact surface under test

— Very smooth surface is suitable & gives good results.

(2) Any variation in temperature of concrete b/w 5° & 30°c does effect the pulse velocity measurement

⇒ At temperatures b/w 30°c & 60°c, there is upto 5% reduction in pulse velocity

⇒ < 5% temperatures, an increase of upto 7.5% in pulse velocity.

> 30°c – upto – 60°c

reduction 5% (−)

< 5°c → increase 7% (+).

(9)

(3) The pulse velocity of concrete increases with an increase in the moisture content of concrete

(4) The pulse velocity is measured in reinforced concrete in the vicinity of reinforcing bars is usually higher than in plane concrete of the same composition. This is because the pulse velocity through steel is 1.2 to 1.9 times higher than the velocity through concrete

Note: when the axis of the reinforcing bars is parallel to the direction of pulse is important. if it is parallel to then it is negligible.

⇒ when the concrete is subjected to stress which is abnormally high for the quality of concrete. The pulse velocity may be reduced due to development of micro cracks.

(5) ~~Combined methods:~~

⑤ Combined Methods:

→ Use of any one method may not give reliable results.

→ Using more than one method at the same time has been found to give reliable results regarding the strength of structure.

→ The combined methods involving ultrasonic pulse velocity and rebound hammer have been used to estimate strength of concrete

⑥ Radioactive & nuclear Methods:

→ These include the x-ray and Gamma-ray penetration tests for measurement of density and thickness of concrete.

→ Also, the neutron scattering & neutron activation methods are used for moisture and cement content determination

⑦ Magnetic & Electrical Methods:

→ The magnetic methods are primarily concerned with determining cover of reinforcement in concrete

→ Whereas the electrical methods, including microwave absorption ~~ten~~ techniques, have been used to measure moisture content & thickness of concrete.

⑩

⑧ Acoustic emission techniques:

⇒ These have been used to study the initiation and growth of cracks in concrete.

* Elastic Properties of concrete:

→ In theory of reinforced concrete, it is assumed that concrete is elastic, isotropic, homogenous & that it conforms to Hook's law.

→ When reinforced concrete is designed by elastic theory it is assumed that a perfect bond exists between concrete & steel.

→ Modulus of elasticity is a property of ~~reset~~ concrete

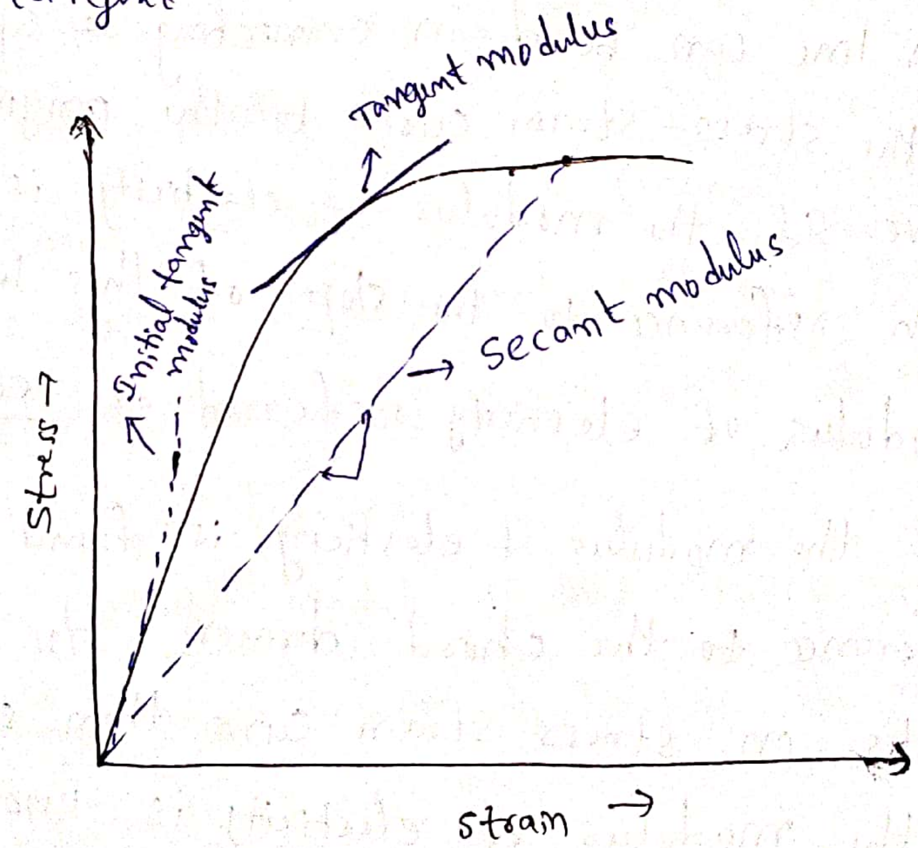
→ The modulus of elasticity is determined by subjecting a cube (or) cylinder specimen to uniaxial compression and measuring the deformations by means of dial gauges fixed b/w certain gauge length.

→ Dial gauge reading divided by gauge length will give the strain & load applied divided by area of cross-section will give the stress.

→ The modulus of elasticity so found out from actual loading is called static modulus of elasticity

→ The term young's modulus of elasticity can strictly be applied only to the straight part of stress-strain curve

→ In case of concrete, since no part of graph is straight, the modulus of elasticity is found out with reference to the tangent drawn to the curve at the origin. The modulus found from this tangent is referred as initial tangent modulus



→ Initial tangent modulus gives satisfactory results only at low stress value. But for higher stress values it gives a misleading picture.

(11)

→ Tangent can also be drawn at any point on the stress-strain curve. The modulus of elasticity calculated with reference to this tangent is then called tangent modulus.

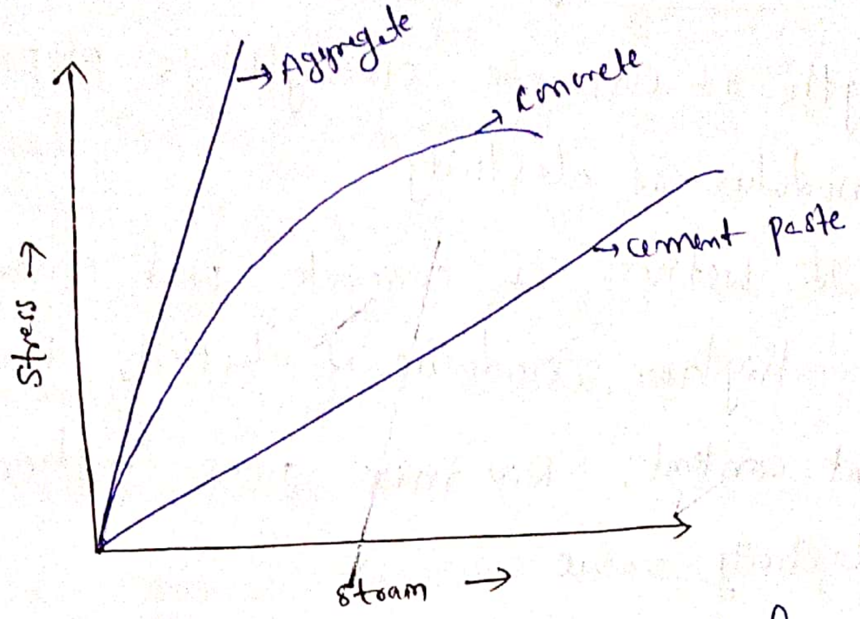
→ The value of modulus of elasticity will be satisfactory only for stress level in the vicinity of the point considered.

⇒ A line can be drawn connecting a specified point on the stress-strain curve to the origin of the curve. If the modulus of elasticity is calculated with reference to the slope of this line, the modulus of elasticity referred as <u>Secant modulus</u>.

⇒ If the modulus of elasticity is found out with reference to the chord drawn b/w two specified points on stress-strain curve then such value of the modulus of elasticity is known as chord modulus.

⇒ The modulus of elasticity most commonly used in practice is secant modulus.

* stress/strain curve for Aggregate, cement paste & concrete



→ stress-strain relationship of aggregate & cement paste alone shows fairly good straight line.

→ But combination of aggregate & cement paste together shows a curved relationship. Perhaps this is due to the development of micro cracks at the interface of aggregate & paste.

* Relation between Modulus of Elasticity & strength:

⇒ stronger the concrete, higher is the modulus of elasticity

⇒ Modulus of elasticity of concrete increases approximately with the square root of the strength

As per IS 456: 2000

$$E_c = 5000\sqrt{f_{ck}}$$

E_c = short term modulus of elasticity in N/mm²

f_{ck} = characteristic compressive strength of concrete (N/mm²)

(19) (12)

* Factors influencing modulus of Elasticity:

① strength of concrete, strength is proportional to modulus of elasticity

② State of wetness of concrete, wet concrete will show higher modulus of elasticity than dry concrete

③ Cement content, Rich mix gives higher modulus of elasticity value

④ Age of concrete is more modulus of elasticity of that concrete is increased

⑤ Quantity & quality of Aggregate: It is not having much effect on strength but it is having more significance on the modulus of elasticity

$$\frac{1}{E_c} = \frac{V_p}{E_p} + \frac{V_a}{E_a}$$

E_a, E_p, E_c are → Modulus of elasticity of Aggregate, paste & concrete

V_a & V_p → volume of aggregate & paste

⑥ Temperature, steam cured concrete shows lower modulus than water cured concrete of same strength

⑦ The modulus of elasticity is almost same in compression, tension & shear

* Dynamic Modulus of Elasticity:

→ The value of modulus of Elasticity found by actual loading of concrete known as static modulus of elasticity

→ The static modulus of elasticity does not truly represent the elastic behaviour of concrete due to the phenomenon of creep

⇒ The dynamic modulus of elasticity obtained by vibration tests on concrete prisms or cylinders

⇒ By using NDT, the modulus of elasticity can be determined by subjecting the concrete member to longitudinal vibration & resonance frequency of specimen is determined.

⇒ The dynamic modulus of elasticity can be calculated from the following relation

$$E_d = K \rho n^2 L^2$$

where

E_d = Dynamic modulus of elasticity

K = constant

n = resonant frequency

L = length of specimen

ρ = density of concrete

(14) (13)

* Poisson's Ratio (μ)

⇒ It is determined as the ratio of lateral strain to longitudinal strain. It is denoted by 'μ'

⇒ For normal concrete the value of poisson's ratio lie's in the range of 0.15 to 0.2 when actually determined from strain measurements.

⇒ As an alternative method, Poisson's ratio can be determined from ultrasonic pulse velocity method and by finding out the fundamental resonant frequency of longitudinal vibration of concrete beam.

⇒ The Poisson's ratio 'μ' can be calculated from

$$\left[\frac{V^2}{2nL}\right]^2 = \frac{1-\mu}{(1+\mu)(1-2\mu)}$$

where

V = pulse velocity (mm/s)

n = resonant frequency of longitudinal vibration (Hz)

L = Length of beam (or) distance b/w transducers (mm)

μ = poisson's ratio

Dynamic modulus of Elasticity can be found by

$$E_d = \rho V^2 \frac{(1+\mu)(1-2\mu)}{1-\mu}$$

V = pulse velocity

ρ = density

μ = poisson's ratio

* Creep:

→ Creep can be defined as "the time-dependent" part of the strain resulting from stress

→ It is the function of time and load

→ It is defined as the increase in strain under sustained stress with time.

→ The gradual increase in strain, without increase in stress, with the time is due to creep.

→ We know that the stress-strain relationship of concrete is curved one. The degree of curvature of the stress-strain relationship depends upon many factors amongst which the intensity of stress & time for which the load is acting are significant

→ Therefore, it clearly shows that the relation between stress and strain for concrete is a function of time.

* Creep recovery: When the sustained load is removed the strain decreases immediately by an amount equal to the elastic strain at the given age.

Note: It is about only 15%

(14)

* Factors Affecting Creep:

① Influence of Aggregate:

⇒ Aggregate undergoes very little creep. It is really the paste which is responsible for creep

⇒ The paste which is creeping under load is restrained by aggregate which do not creep.

⇒ The stronger the aggregate the more is the restraining effect & less is the creep

⇒ Modulus of elasticity of aggregate is one of the important factors influencing creep. Higher the modulus of elasticity the less is the creep

② Mix proportions:

⇒ The amount of paste content & its quality is one of the most important factors influencing creep

→ A poorer paste structure undergoes higher creep.

→ It can be said that creep increases with increase in water/cement ratio

→ As the grade of concrete is increasing the strength of concrete increases thus creep decreases.

③ Age of concrete:

Age of concrete is more → strength increases

→ creep reduces.

→ In the absence of experimental data, the ultimate creep strain may be estimated from following values of creep coefficients

* Table: Values of creep coefficients at age of loading

Age at loading	Creep coefficient
7 days	2.2
28 days	1.6
1 year	1.1

* Measurement of Creep:

→ Creep is usually determined by measuring the change with time in the strain of specimen subjected to constant stress and stored under appropriate condition.

→ It is generally assumed that the creep continues to assume a limiting value after an infinite time under load. It is estimated that

26% of 20 years creep occurs in 2 weeks

(15) 55% of 20 years creep occurs in 3 months

76% of 20 years creep occurs in one year

If creep after one year taken as unity, then the average value of creep at later ages are

After 2 years → 1.14

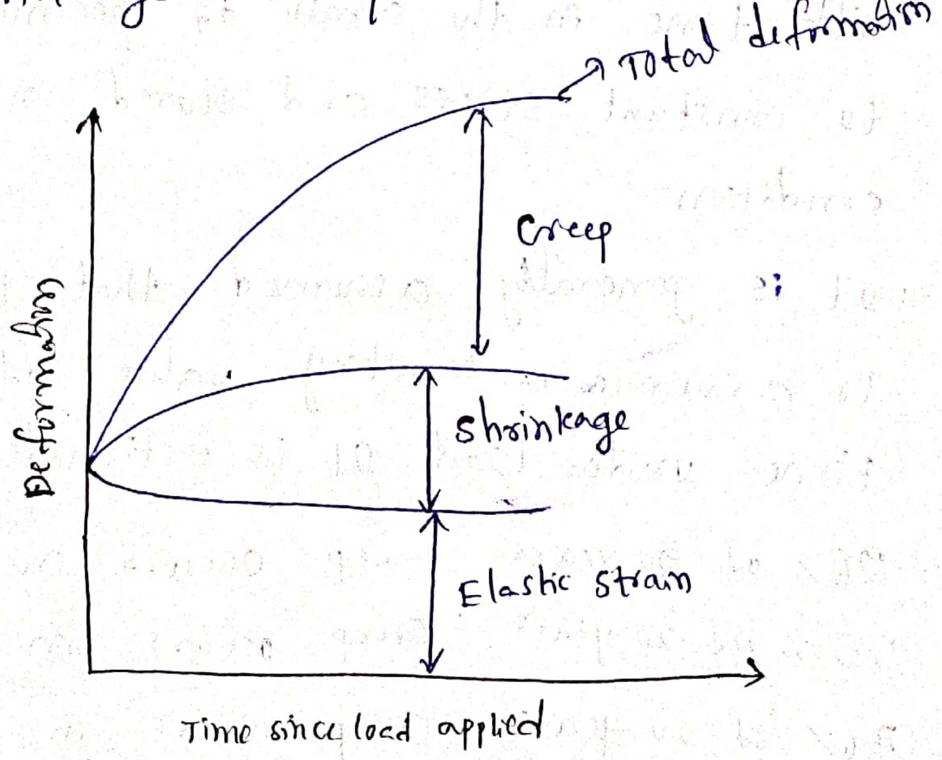
After 5 years → 1.20

After 10 years → 1.26

After 20 years → 1.33

After 30 years → 1.36

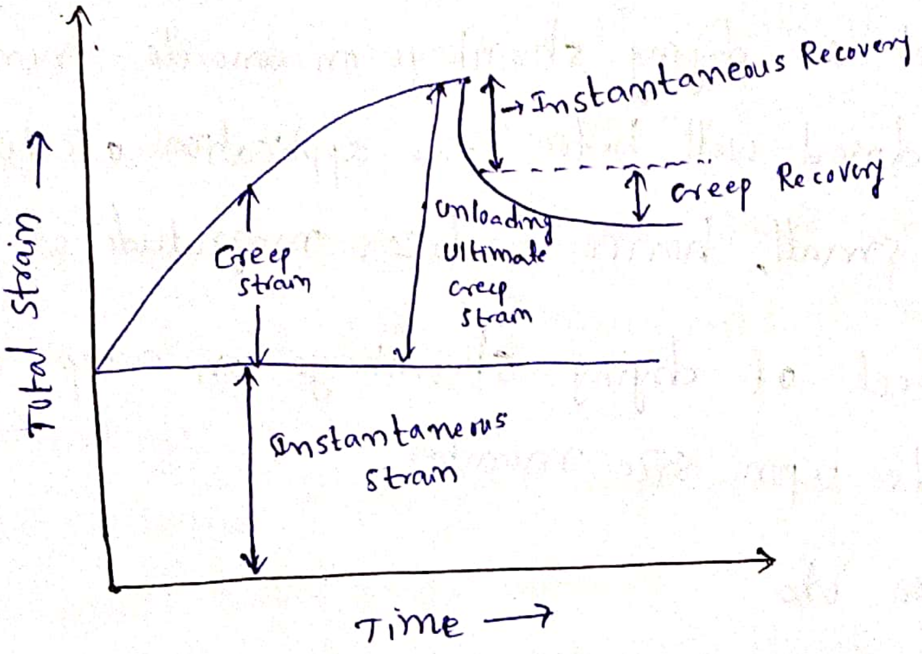
- The total deformation of member is the sum of deformation due to elastic strain + shrinkage + creep



* Nature of Creep:

⇒ Creep of concrete is generally related to the internal distubance of absorbed water, viscous flow etc.

⇒ For drying of creep, it is essential that the water is moved out of the concrete



⇒ It is studied that empty pores are much responsible for the basic creep as it depends upon porosity or strength of the concrete.

⇒ Viscous flow or sliding between gel particles causes creep.

15(1)

* **How does drying shrinkage effect creep?**

→ Drying shrinkage and creep are assumed to be proportional to each other

→ If relative humidity at the site is mantained at 100% then the drying shrinkage reduces to zero, hence reducing the creep.

→ Effect of drying shrinkage on concrete member which are dried well before the application of load is very small, hence reduces magnitude of creep

→ Effect of drying shrinkage on creep also depends upon size member

→ [illegible]

* Shrinkage :

⇒ Decrease in volume due to loss in water

⇒ So the cracks will be occured which leads to reduction in strength.

Defination: The term shrinkage is used to describe various aspects of volume changes in concrete due to loss of moisture at different stages due to different reasons.

⇒ One of the important factor that contribute to the cracks in floors & Pavements. is due to shrinkage.

⇒ The "volume change is one of the most detrimental (harmful) property of concrete which effects the long term strength and durability of concrete.

* Types of shrinkage:

Shrinkage can be classified in the following way

1. plastic shrinkage
2. Drying shrinkage
3. Autogeneous shrinkage
4. Carbonation shrinkage
5. Thermal shrinkage

(16)

① Plastic shrinkage:

→ It appears when concrete is still plastic form, first few hours after placing

→ It is caused due to loss of water by evaporation or by the absorption by aggregate (or) subgrade.

→ The loss of water decreases the volume of concrete

→ plastic shrinkage is ~~absorbed~~ observed when large surface of concrete is exposed to sun and drying wind

→ The performance of concrete highly subjected to plastic shrinkage

* plastic shrinkage can be controlled by.

→ cover the slabs with polythene bags

→ Do the concrete work during night time

→ Aluminium powder will reduce the shrinkage

→ Use the expansive cement

→ Avoid over sanded mix

* ② **Drying shrinkage:**

→ It occurs when concrete attains its final set

→ hydration of cement is an ever lasting process, the drying shrinkage is also an ever lasting process when concrete is ~~w~~ subjected to drying conditions.

→ Water contained in hardened concrete, does not result in any appreciable dimension change.

⇒ It is the loss of water held in gel pores that causes the change in the volume

⇒ cement paste shrinks more than mortar and mortar shrinks more than concrete.

cement paste > cement mortar > concrete

⇒ shrinkage is more in small size aggregates compared to large size aggregate

⇒ Finess of gel is increasing the effect of shrinkage is more

⇒ In the absence of test data, approximate value of total shrinkage strain for design may be taken as 0.0003.

⇒ The rate of shrinkage decreases with time.

⇒ The tests indicate that

⇒ 14 - 34% of 20 years shrinkage occurs in 2 weeks

⇒ 40 - 70% of 20 years shrinkage occurs in 3 months

⇒ 66 - 80% of 20 years shrinkage occurs in 1 year

③ Autogeneous shrinkage:

⇒ In a conservative system i.e where no moisture movement to or from the paste is permitted, when temperature is constant some shrinkage may occur. The shrinkage of such a conservative system is known as a autogeneous shrinkage.

⇒ It has minor importance, may be consider in the case of mass concrete in the interior of a concrete dam.

⇒ The magnitude of autogeneous shrinkage is in the order about 100×10^{-6}

④ Carbonation shrinkage:

→ The carbon dioxide (CO_2) present in atmosphere reacts in the presence of moisture with the hydrated cement minerals.

→ The $Ca(OH)_2$ get converted to calcium carbonate [$CaCO_3$].

⇒ The carbonation penetrates beyond the exposed surface of concrete only slowly.

⇒ Carbonation is accompanied by increase in weight and shrinkage.

⇒ The shrinkage due to carbonation occurs mainly at intermediate humidities.

⇒ Carbonation also ~~resut~~ results in increased strength and reduced permeability.

⇒* The only advantage of shrinkage is that it causes the concrete to grip the steel tightly, thus increasing the bond.

④ **Thermal shrinkage:**

→ Like any other materials, concrete can be subjected to volumetric changes with decrease in temperatures.

→ Thermal shrinkage is of physical nature.

→ Decrease in temperature may take place when the early thermal temperature is

(17)

fully depleted and go below the ambient temperatures. Another examples is that a roof slab or road pavement expands during the day & undergoes thermal shrinkage during night.

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UNIT-V

Mix Design & Special Concretes

* Introduction:

⇒ The concrete mix design is a process of selecting suitable ingredients for concrete and determining their proportions which would produce, as economically as possible, a concrete that satisfies the job requirements i.e concrete having a certain minimum compressive strength, workability and durability.

⇒ The proportioning of the ingredients of concrete is an important phase of concrete technology as it ensures quality and economy.

⇒ The design of concrete mix is not a simple task on account of the widely varying properties of the constituents materials, the condition that prevail at the site of work, in particular the exposure condition and the condition that are demanded for a particular work for which the mix is designed.

* Factors influencing the choice of mix proportions

⇒ According to IS: 456-2000 & IS: 1343-1980, the design of concrete mix should be based on the following factors

1. Grade designation
2. Type and grade of cement
3. Maximum nominal size of Aggregates
4. Grading of combined aggregates
5. Water - cement ratio
6. Workability
7. Durability
8. Quality control

1. Grade designation :

→ The grade designation gives characteristic compressive strength requirements of the concrete

→ As per IS: 456-2000, the characteristic compressive strength is defined as that value below which not more than five per cent of the test results are expected to fall.

→ It is the major factor influencing the mix design.

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→ The mix of concrete should be designed for a target mean compressive strength which should be greater when compared to characteristic strength.

(2) Type and Grade of cement:

→ The type of cement is important mainly through its influence on the rate of development of compressive strength of concrete.

→ Selection of cement based on necessity of performance required.

→ A good quality cement shows minimum standard deviation

→ Minimum standard deviation for different grade of concrete are given below

Grade of cement	Minimum Standard deviation (N/mm^2)
33	2.5
43	1.5
53	1.0

(3) Maximum nominal size of Coarse Aggregate:

→ The maximum nominal size of the aggregate to be used in concrete is governed by the size of the section & spacing of the reinforcement.

→ According to IS 456-2000, the maximum nominal size of the aggregate should not be more than one-fourth of the minimum thickness of the member.

→ The workability also increases with an increase in the maximum size of the aggregate.

→ For the concrete with higher W/c ratio, the larger maximum size of aggregate may be beneficial whereas for high strength concrete, 10-20 mm size of aggregate is preferable

(4) <u>Grading of Combined Aggregates</u>:

→ The relative proportions of the fine and coarse aggregates in a concrete mix is one of the important factors affecting the workability & strength of concrete.

→ Proper grading of fine and coarse aggregate is necessary for dense concrete

→ this proper grading will increase the strength, reduced shrinkage & decrease concrete cost

(5) Water-Cement Ratio:

→ The compressive strength of concrete at a given age and under normal temperature depends primarily on the water-cement ratio

⇒ The lower the water-cement ratio greater is the compressive strength & vice versa.

⇒ In so far as the selection of the water-cement ratio for the target compressive strength at 28 days is concerned.

(6) Workability:

⇒ It can be controlled by shape & size of cross-section spacing and amount of reinforcement, transportation method, placing and compaction method

⇒ Insufficient workability resulting in incomplete compaction may severely affect the strength, durability & surface finish of concrete

→ Different works require different workability

→ So, the process may become expensive if desired workability is not provided for the mix.

⑦ <u>Durability</u>:

→ The durability of concrete can be defined and interpreted to mean its resistance to deteriorating influences which may reside inside the concrete itself or to the aggressive environments.

→ ~~It~~ The requirements for durability are achieved by restricting the minimum cement content & maximum water-cement ratio.

→ The portland slag cement & Portland pozzolana cement are the blended cements, which contributes higher durability to the concrete in sea water & sulphatic environment.

⑧ <u>Quality control</u>:

→ The strength in every batch of concrete varies over a course time

→ It is due to change in quality of constituents elements change in quality of battening & mixing apparatus, change in mix proportion & expertise skills.

→ This variation should be controlled to reduce the difference between characteristic mean strength & minimum strength of concrete mix & hence reducing the cement content

* Durability of concrete:

→ The property of resisting the chemical attack weathering action, abrasion and potentially deterious substance is known as durability of concrete.

→ The used mix proportion and materials should preserve the reinforcement from getting corroded.

→ Even though concrete is a durable material requiring a little or no maintenance in normal environment but when subjected to highly aggressive environment require some maintenance.

→ The presence of aggressive environment is requires expensive repairs due to deterioration

→ Durability of concrete is affected by its permeability to the ingress of water, Oxygen, CO_2, chloride, sulfate & other potentially deleterious substances.

⇒ Most of durability problems in the concrete can be attributed to the volume change in the concrete

⇒ change in volume caused due to sulphate attack, affect of chlorides, heat of hydration, steel reinforcement corrosion & carbonation process.

* Factors Affecting Durability:

There are mainly two factor's affect durability

① Internal causes &

② External causes

① Internal Causes:

It includes:

Ⓐ Change in volume of concrete:

→ It is actually internal change in concrete volume

→ Permebility is one of causes for change in volume

→ It results in cracks in the concrete member

→ Carbonation, Rusting of steel reinforcement are the some factor responsible for change in volume

(B) Alkali – Aggregate Reaction (AAR)

→ Due to presence of silica in aggregate is ~~also~~ reacting to the other substances is called AAR.

→ Due to this reaction, expansion and cracking of concrete take place, crack width range from 0.1 mm to 10 mm

(2) External Causes:

It includes:

(A) physical and Mechanical Causes:

→ It includes the occurrance of electrostatic actions, high temperature & abrasion

(B) Chemical causes:

→ It consists:

(a) sulphate attack:

→ sulphates are harmful to concrete as they can lead to increse in the concrete volume and consequent cracking.

→ Use of pozzolana cement has better resistance to sulphate attack.

(b) Acid Attack:

→ The solutions of acid will damage cement concrete slowly (or) quickly based on acid concentration

→ There are some harmless acids such as phosphoric acid & oxalic acids

→ If solution of acid comes in contact with the reinforcement steel, then the corrosion occurs & resulting in cracking

(c) chloride attack:

→ It is highly affect the durability of concrete.

→ Corrosion of steel is due to chloride

→ Due to chloride, protective oxide film lost which are shielded on steel reinforcement

(d) Salt Water (or) Marine Water effects:

→ When concrete is subjected to salt water, it undergoes in many reaction

→ The concrete in salt water is subjected to freezing & thawing abrasion

→ A concrete of less dimensions exposed to salt water can show the result of leaching. Chemical attack increases in high temperature zones.

* Quality Control of Concrete:

→ The quality control available materials are tested for behaviour and are used in the best efficient way

→ This helps in reducing the cost of extra material.

→ The maintenence cost can be reduced by quality control

→ It ensure checking of work and correcting defect at the same time

→ It also reduces time of completion of construction

→ By quality contol economical design is achieved

* Acceptance Criteria:

⇒ In order to ensure proper quality control, IS 456-2000 requires that a minimum number of random samples from the fresh concrete of each grade should be taken & cubes should be made, cured and tested as described in IS: 516-1959.

→ The minimum number of samples of concrete shall be in accordance with table below.

Table: Frequency of sampling of concrete

Quantity of concrete at job (m^3)	Number of samples
1 – 5	1
6 – 15	2
16 – 30	3
31 – 50	4
51 & Above	4 plus one additional sample each additional 50 m^3 or part thereof

⇒ The average of the strengths of three specimens is the test strength of any sample.

Note: At least one sample shall be taken from each shift.

⇒ The acceptance criteria given in IS 456: 2000 stipulates that the strength requirement is satisfied if

① Every sample has a test strength not less than (f_{ck}-3) MPa for M15 concrete and (f_{ck}-4) MPa for M20 or higher grade concrete

② For M15 grade concrete, the mean strength of the group of 4 non-overlapping consecutive test results is greater than $f_{ck} + 0.825 \times S$ or $(f_{ck} + 4)$ MPa which ever is grater.

where

f_{ck} = characteristic strength

S = established standard deviation

⇒ <u>For Flexural strength</u>:

⇒ when both above conditions are met, the concrete complies with the specified flexural strength.

ⓐ the mean strength determined from any group of four consecutive test results exceeds the specified characteristic strength by at least 0.3 N/mm^2

ⓑ the strength determined from any test result is not less than the specified characteristic strength less 0.3 N/mm^2

* Proportioning of Concrete Mixes :

⇒ Following are the various methods adopted for Proportioning of concrete mix

1) Bureau of Indian standard Method (BIS)
2) American concrete Institute Method (ACI)
3). Trial mixes
4). Department of environmental method (DOE)
5). Road Research Laboratory Method (RRL)
6). Maximum Density Method
7). Nominal mixes.
8) Minimum voids Method.
9) Fineness modulus method

* Indian standard concrete mix proportioning

BIS Method :

→ Indian standard Recommeded Method of concrete Mix Design IS 10262-1982 & it is revised in 2009.

⇒ The guidelines given in Indian standard IS-10262-2009 for concrete mix proportioning

① ⑧

*1. Data Required for Mix proportioning:

- → Grade of concrete
- → Maximum size of aggregate
- → Minimum cement content
- → Maximum w/c ratio
- → workability in terms of slump
- → Exposure conditions
- → Maximum temperature at the pouring point
- → Early age strength (if required)
- → Grading zone of fine aggregate
- → Type of aggregate
- → What kind of admixture used – Brand name
- → specific gravity of all the materials used & dosage etc

2. Target Mean strength:

→ Assuming 5% of the site results are allowed to fall below the characteristic strength.

The target mean strength is given by following relation

$$f'_{ck} = f_{ck} + t \times s$$

$$\boxed{f'_{ck} = f_{ck} + 1.65\, s}$$

Where f'_{ck} = Target mean compressive strength at 28 days

f_{ck} = Characteristic compressive strength at 28 days

S = standard deviation

t = tolerance factor

⇒ standard deviation indicates the level of Quality control exercised at the site.

⇒ It should be worked out by conducting trails by adopting possible control. The number of trails to be conducted not less than 30.

* Table 1: Assumed standard Deviation:

Grade of concrete	standard Deviation (N/mm²)
M10 M15	3.5
M20 M25	4.0
M30, M45 M35, M50 M40, M55 M60	5.0

② 3. Selection of Water-cement Ratio:

→ As per IS 456-2000 minimum cement contents & maximum water cement ratio is taken

Table 2: Minimum cement content & Maximum water content ratio of concrete of 20mm nominal maximum size (Adapted from IS 456-2000)

S. No	Exposure condition	Plain concrete			Reinforced concrete		
		Minimum cement content (kg/m³)	Maximum free water cement ratio	Minimum grade of concrete	Minimum cement content (kg/m³)	Maximum free-water cement ratio	Minimum grade of concrete
1	Mild	220	0.6	—	300	0.55	M20
2	Moderate	240	0.6	M15	300	0.6	M25
3	Severe	250	0.5	M20	320	0.45	M30
4	Very severe	260	0.45	M20	340	0.45	M35
5	Extreme	280	0.4	M25	360	0.40	M40

⇒ Adjustments to minimum cement content for Aggregates other than 20mm nominal maximum size

Nominal maximum size (mm)	Adjustments to minimum cement contents (kg/m³)
10	+40
20	0
40	-30

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* Maximum water content for nominal maximum size of Aggregates:

* Table 3

S.No	Nominal maximum size of aggregate, mm	Maximum Water content (kg)
1	10	208
2	20	186
3	40	165

* change in conditions stipulated above

(A) Shape of Aggregate

reduction in water

1. Sub-angular Aggregates → -10 kg
2. Gravel with some crushed particles - 20 kg
3. Rounded gravel - 25 kg

(B) Workability:

→ For the required workability (other than 25 to 50mm slump), the required water content may be established by trail (or) can be estimated by an increase in 3% of water for every 25mm increased slump

(3)

4. Selection of cement content:

→ cement plus supplementary cementitious materials content per unit volume of concrete may be calculated from free water ~~content~~ cement ratio and the quantity of water per unit volume of concrete

5. Estimation of volume proportion of coarse aggregate in total Aggregate

→ The volume proportion of coarse aggregate (P) of given ~~on~~ nominal maximum size is estimated from below table.

→ Table-4

S.No	Nominal maximum size of Agg, mm	Volume of fraction of coarse aggregate to total aggregate (P)			
		Zone IV	Zone III	Zone II	Zone I
1	10	0.5	0.48	0.46	0.44
2	20	0.66	0.64	0.62	0.60
3	40	0.75	0.73	0.71	0.69

→ For more workability, e.g. pumpable concrete ~~on~~ congested reinforcement → coarse aggregate content may be reduced up to 10%.

⑥ Computation of total absolute volume of Aggregates (V_a)

total absolute volume of Aggregates (V_a) in m3

$$V_a = 1 - \left[v + \frac{C}{S_c \times 1000} + \frac{W}{1000} \right]$$

Where

W = mass of water (Kg)

C = mass of cement (kg)

v = air content (m3) per cubic meter of concrete

S_c = specific gravity of cement = 3.15

⑦ Determination of absolute volumes of fine aggregate & coarse aggregates

$$V_{ca} = p V_a \quad \& \quad V_{fa} = (1-p) V_a$$

Where

p = ratio of coarse agg in the total absolute volume of Aggregates

V_{ca} = absolute volume of coarse aggregate

V_{fa} = absolute volume of fine aggregate

∴ contents of fine aggregate & coarse aggregate by mass are

(4)

$$C_{fa} = (S_{fa} \times 1000) V_{fa} \quad \& \quad C_{ca} = (S_{ca} \times 1000) V_{ca}$$

S_{fa} & S_{ca} are specific gravities of saturated surface dry fine & coarse aggregate, in kg/liter)

⇒ Thus the concrete mix proportions for the first trail mix by mass (kg) are

Cement		Water		Fine Agg		Coarse agg
C	:	W	:	$V_{fa} S_{fa} (1000)$	:	$V_{ca} S_{ca} (1000)$

⇒ Above concrete mix proportions can be expressed by volume (m^3)

Cement		Water		Fine agg		Coarse Agg
$\frac{C}{\gamma_c}$	:	$\frac{W}{1000}$	:	$\frac{V_{fa} S_{fa} (1000)}{\gamma_{fa}}$	:	$\frac{V_{ca} S_{ca} (1000)}{\gamma_{ca}}$

Where

γ_c, γ_{fa} & γ_{ce} are bulk densities (kg/m^3) of cement, fine aggregate & coarse aggregate respectively

(8) Adjustments for aggregate moisture & determination of final proportions

(9) preparation of trail batches & testing

(10) Final mix proportions

Example 1 :

Design a concrete mix of M45 grade of concrete with the following data

(a) Type of cement - OPC 43 grade

(b) Maximum size of Agg - 20 mm

(c) Exposure condition - severe (RCC)

(d) Workability - 125 mm slump

(e) Minimum cement content - 320 kg/m³

(f) Maximum W/c ratio - 0.45

(g) Method of placing concrete - pumping

(h) Degree of supervision - good

(i) Type of aggregate - crushed Angular Agg

(j) Super plasticizer will be used.

(k) Sp. gr. of Fine Agg - 2.70

(l) Sp. gr. of coarse Agg - 2.80

(m) Water absorption

Coarse Agg - 0.5%

Fine Agg - 1%

(n) Free surface Moisture

Coarse Agg - Nill

Fine Agg - Nill

(o) Grading of coarse aggregate conforming to table 2 of IS 383

(p) Grading of Aggregate conforming to Zone II.

Target Mean Strength:

Characteristic Strength $f_{ck} = 45\ N/mm^2$

Target Mean strength $f'_{ck} = f_{ck} + 1.65 \times S$

$= 45 + 1.65 \times 5$

$= 53.25\ N/mm^2$

Where 'S' is the standard deviation taken as $5\ N/mm^2$

Water/Cement Ratio:

Water/cement ratio is taken from the experince of the mix designer based on his experience of similar work elsewhere.

W/C ratio = 0.42

This water cement ratio is to be selected both from strength consideration and the maximum W/C denoted in Table 5 of IS456 and lesser of the two is to be adopted for durability requirement.

W/C ratio mentioned in Table 5 of IS 456 is 0.45. W/C proposed is 0.42. This being lesser than 0.45, we should adopt W/C ratio as 0.42.

Slection of Water Content:

Maximum water content as per table-3 is 186 litre. This is for 50 mm slump.

Estimated water content for 125 mm slump $= 186 \times \frac{9}{100} + 186$

(3% increase for every 25mm slump over and above 50mm slump) = 203 litre.

In the absence of such trial, it is assumed that the efficiency of super plasticizer used as 25 percent.

∴ Actual Water to be used = 203 × 0.75 = 152 litre.

Calculation of Cement Content

W/c ratio = 0.42

Water used = 152 litre

$\therefore$ Cement content $= \frac{W}{C} = 0.42$

$$C = \frac{152}{0.42} = 362 \text{ kg/m}^3$$

This cement content is to be checked against minimum cement content given in Table-5 of IS 456 for durability requirement.

As the calculated cement 362 kg/m³ is more than minimum cement mentioned in Table-5 of IS 456 i.e., 320 kg/m³, the cement content of 362 kg/m³ should be accepted. Adopt cement content of 362 kg/m³.

Calculation of Coarse and Fine Aggregate Content

From Table-4 volume of coarse aggregate corresponding to 20mm size aggregate and fine aggregate zone II, for w/c ratio of 0.50 is found out to be 0.62.

In the present case w/c 0.42 i.e., it is less by 0.08. As the w/c is reduced it is desirable to increase the coarse aggregate proportion to reduce the fine aggregate content.

The Coarse aggregate is increased at the rate of 0.01 for every decrease in w/c ratio of 0.05.

$$\therefore \frac{0.01}{0.05} \times 0.08 = 0.016$$

Volume of C.A = 0.62

$$= \frac{0.016}{0.636}$$

$\therefore$ Corrected proportion of volume of CA = 0.636

Since it is angular aggregate and the concrete is to be pumped, the coarse aggregate can be reduced by 10%.

∴ Final volume of coarse aggregate $= 0.636 \times 0.9$

$= 0.572$

say $= 0.57$

∴ Volume of fine aggregate $= 0.43$

Calculation of Mix Proportions:

Volume of concrete $= 1\ m^3$

Absolute volume of cement $= \dfrac{362}{3.15} \times \dfrac{1}{1000}\ m^3$

$= 0.115 m^3$

Volume of water $= 152$ litre $= 0.152 m^3$

Volume of chemical admixture $= \dfrac{1.2 \times 362}{100 \times 1.1} \times \dfrac{1}{1000}$

$= \dfrac{362 \times 1.2}{110 \times 1000}$

$= 0.004 m^3$.

(assuming dosage of 1.2% by weight of cementitious material and assuming specific gravity of admixture as 1.1)

Absolute volume of all the materials except total aggregates

$= 0.115 + 0.152 + 0.004$

$= 0.271 m^3$

Absolute volume of Total Aggregate $= 1 - 0.271$

$= 0.729 m^3$

Weight of coarse aggregate $= 0.729 \times 0.57 \times 2.80 \times 1000$

$= 1163\ kg/m^3$

Weight of fine aggregate $= 0.729 \times 0.43 \times 2.70 \times 1000$

$= 846\ kg/m^3$

2. Mix proportions for Trial Number 1

Cement —— 362 kg/m^3

Water —— 152 kg/m^3

Fine aggregate —— 846 kg/m^3

Coarse aggregate —— 1163 kg/m^3

Chemical admixture —— 4 kg/m^3

Wet density of concrete —— 2527 kg/m^3

Site Correction:

Absorption of fine aggregate = 1.0%

$= \frac{1}{100} \times 846$

= 8.46 litre

Absorption of coarse aggregate = $\frac{0.5}{100} \times 1163$

= 5.82 litre

Total absorption = 14.28 litre

∴ Actual amount of water to be used = 152 + 14.28

= 166.28 litre

Actual weight of F.A to be used = 846 − 8.46

= 837.5

Actual weight of C.A to be used = 1163 − 5.82

= 1157.20

∴ Proportion of materials at the site

Cement	362 kg/m^3
Water	166.28 kg/m^2
C.A	1157.2 kg/m^3
F.A	837.5 kg/m^3
Admixture	4.0 kg/m^3

Mix proportion

Cement	:	FA	:	CA	:	Water
362	:	846	:	1163	:	152
or 1	:	2.34	:	3.21	:	0.42

Site proportion

362	:	838	:	1157	:	166
or 1	:	2.31	:	3.2	:	0.46

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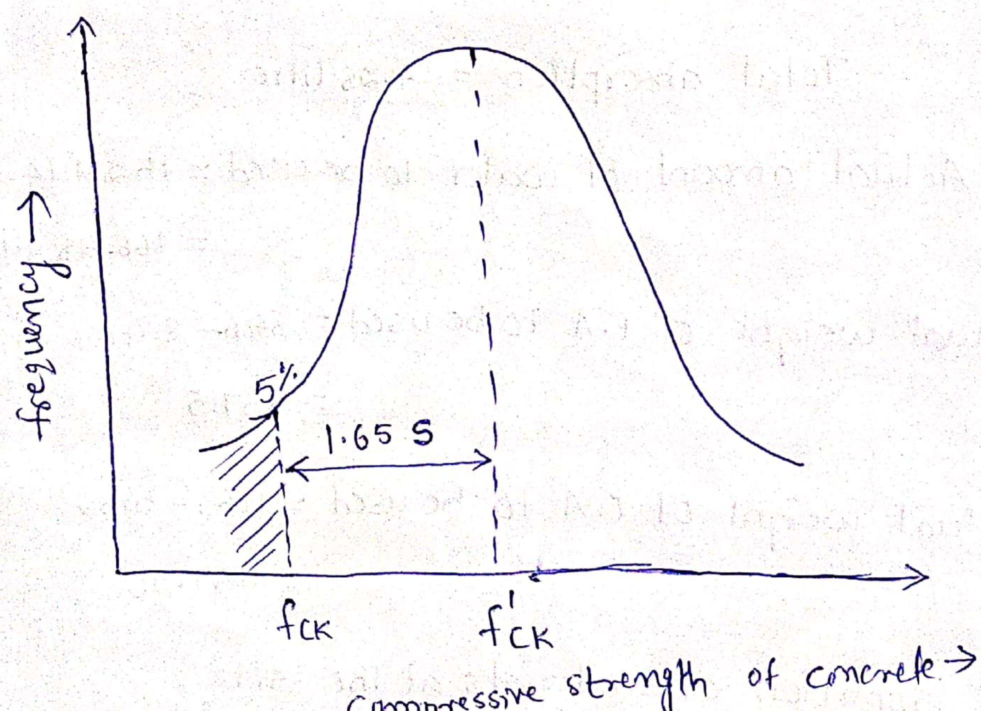
* Important Topic:

⇒ Probability Distribution Curve:



Where:

f_{ck} = cherecteristic compressive strength at 28 days

f'_{ck} = Target mean strength at 28 days

S = standard Deviation

Special Concretes

* **Introduction:**

→ cement concrete suffers from several drawbacks, such as low tensile strength, permeability to liquids and consequent corrosion of reinforcement, susceptibility to chemical attack and low durability.

→ In order to overcome the dificiencies of cement concrete special concretes are come into exisistance.

⇒ There are so many types of special concretes, in that we are going to discuss some special concretes. They are

* **Light Weight Concrete:**

→ The conventional cement concrete is heavy material having a density of 2400 kg/m³ & high thermal conductinty.

→ The relatively small reduction in dead weight, Particularly for members in flexure e.g highrise

(i) buildings, can save money and manpower considerably.

→ If floors & walls are made up of light-weight concrete will result in considerable economy.

There are three methods for making concrete light, They are

ⓐ By replacing the usual mineral aggregate by cellular porous (or) light weight aggregate

ⓑ By introducing gas (or) air bubbles in mortar This is known as aerated concrete

ⓒ By omitting sand fraction from the aggregate. This is called "no-fines concrete"

* ⓐ Classification of light weight Aggregates

These are classified into two groups

* ① Natural ~~Ag~~ light weight Aggregates:

ⓐ Sawdust ⓓ Pumice
ⓑ Rice husk ⓔ Diatomite
ⓒ volcanic ciders ⓕ Scoria

② Artificial light weight Aggregates:

ⓐ Artificial cinders ⓕ Expanded slate
ⓑ Foamed slag ⓖ Expanded clay
ⓒ sintered fly ash ⓕ Exfoliated vermiculite
ⓓ thermo code beads ⓖ Expanded perlite
ⓔ Expanded shale ⓗ Coke breeze

* Light-weight Aggregate concrete:

→ light weight concrete is made by the use of light weight aggregates.

→ This concrete has different densities.

→ The strength of light weight aggregate concrete may also vary from about 0.3 N/mm² to 40 N/mm²

→ A cement content of 200 kg/m³ to about 500 kg/m³ may be used.

* ~~[struck out]~~

(b) Aerated concrete [Cellular Concrete]:

→ Aerated concrete is made by introducing air (or) gas into a slurry composed of portland cement & finely crushed siliceous fillers so that when the mix sets & hardens, a uniformly cellular structure is formed

→ Aerated concrete also referred as gas concrete, foam concrete, cellular concrete.

→ In India few factories manufacturing aerated concrete

⇒ There are several ways in which aerated concrete can be manufactured

(i) By the formation of gas by chemical reaction within the mass during liquid or plastic state.

(ii) By mixing preformed stable foam with the slurry

(iii) By using aluminium powder with the slurry and made to react with the calcium hydroxide [CaOH] liberated during the hydration process, to give out large quantity of hydrogen gas. This hydrogen gas when contained in the slurry mix, gives the cellular structure.

⇒ The aerated concrete density range from 400 kg/m³ to about 800 kg/m³

⇒ It has good thermal insulation property.

© <u>No-fines Concrete</u>:

→ The third method of producing light concrete is to omit the fines from conventional concrete.

→ In this concrete fine aggregate fraction has been omitted.

→ This Concrete is made up of only coarse aggregate, cement & water

CA + Cement + Water → No. FA.

→ very often only single sized coarse aggregate of size passing through 20 mm retained on 10 mm is used. It offers architecturally attractive look.

→ Here strength of the concrete not only depends on W/c ratio but also Aggregate/cement ratio & unit weight of concrete.

→ We use W/c ratio → 0.38 – 0.52

Agg/Co ratio → 6:1 to 10:1

unit weight of concrete < 18.5 kN/m^3

⇒ The compressive strength of no-fines concrete
(iii) varies between 1.4 MPa to 14 MPa

⇒ Bond strength is very low.

* Applications of No-fines concrete:

1. It is used in large scale for load bearing cast in-situ external walls for single storey & multistoried building.
2. It has been used for temporary structure because of low initial cost & also for the ease with which it can be broken & reused as aggregate.
3. Architects consider this as an attractive construction material
4. It can be used for external walls for heat insulation
5. Because of rough texture it gives a good base for plastering
6. When sand is not available this type of concrete should become a popular construction material.
7. Low thermal productivity, drying shrinkage also low
8. ~~[illegible]~~

* Limitations of No-fines concrete :

→ It requires long time for formwork removal

→ It is more permeable than conventional concrete. Therefore walls constructed with no fines concrete needs an extra coat of mortar from durability point of

→ There is no standard test method to measure the consistency or workability of no-fines concrete

* High Density Concrete :

→ Density of normal concrete is in the order of about 2400 kg/m³.

→ To call the concrete as high density concrete, it must have unit weigh ranging from about 3360 kg/m³ [33.6 kN/m³] to 3840 kg/m³ [38.4 kN/m³]

in which is about 50% higher than the unit weight of conventional concrete

→ The heavy weight aggregates are used for producing high density concrete

→ If we use iron in place of coarse aggregate & fine aggregate we can produce high density concrete of density upto 52.8 kN/m^3.

⇒ High density concrete is used in the construction of radiation shields

⇒ Use of nuclear reactors, industrial radiography, x-ray & gamma ray therapy require need of shielding material for protection of operating personnel against the biological hazards of such radiation

→ Used in Ballast blocks construction at at solar installations

→ Counter weight

→ used as Sea Walls.

* Characteristics of light weight concrete

① **Low density**: The density of concrete varies from 300 to 1200 kg/m³. The lightest grade is suitable for insulation purposes.

→ The low density of cellular concrete makes it suitable for precast floor and roofing units

② **High strength**: Cellular concrete has high compressive strength in relation to its density. The compressive strength of such concrete is found to increase with increasing density.

⇒ Tensile strength of cellular concrete is 15 to 20% of its compressive strength.

③ **Thermal insulation**: The insulation value of light weight concrete is about 3 to 6 times of that of brick & about 10 times that of concrete.

(V) ⇒ A 200 mm thick wall of aerated concrete of density
② 800 kg/m³ has the same degree of insulation as a 400 mm thick brick wall of density 1600 kg/m³

④ Fire resistance: Light weight concrete has excellent fire resisting properties.

→ It has low thermal conductivity

⑤ Sound insulation: Sound insulation in cellular concrete is normally not as good as in dense concrete

⑥ Shrinkage: Light weight concrete is subjected to shrinkage but to a limited extent

⑦ Repairability: Light weight products can be easily sawn, cut, drilled or nailed. This makes construction easier. ~~~~

⑧ Durability: Aerated concrete is only slightly alkaline. Due to its porosity and low alkalinity it does not give rust protection to steel which is provided by dense compacted concrete.

→ The reinforcement used, therefore, requires special treatment for protection against corrosion

⑨ Speed of construction: with the adoption of prefabrication, it is possible to design the structure on the concept of modular coordination which ensures a faster rate of construction.

⑩ Economy: Due to light weight & high strength to mass ratio of cellular concrete products, their use results in lesser consumption of steel.

→ Saving 15 to 20% in cost of construction of floors & roofs compared to conventional concrete.

⑪ Quality control: A better quality control is exercised in the construction of structure with light weight concrete products owing to the use of factory made units.

(vi)

③

* Some Important points:

1. Sorptivity:

→ concrete takes water by capillary suction. The rate at which water enters into concrete is called sorptivity

2. Permeation:

→ The ease with which fluid passes through concrete usually under a pressure differential is referred as permeation.

3. Diffusion:

→ Vapour (or) gas ions are sucked through concrete under the action of ion concentration differential is known as diffusion

Fibre Reinforced Concrete (FRC) :-

Concrete is mostly used construction Material.
Mostly used Man-Made material. and Second Only to
the Water. Ordinary portland Cement Concrete is very
good in Compressive Strength. It is Weak in Tension.
So, in Order to improve the tensile Strength of the Concrete. we
are using FRC

⇒ Plane concrete possess a Very low Tensile strength
limited ductility & little resistance to Cracking. Internal micro
cracks are inherently present in the Concrete & it's poor tensile
Strength is due to the propogation of Such micro Cracks eventually
Leading to brittle fracture of the concrete. It has been recon-
gnized that the addition of small closely spaced & uniformly
dispersed fibre's to Concrete would act as crack arrester &
would substaintly improve its static & dynamic properties this
type of Concrete is called fibre reinforced Concrete.

It can also be defined as a Composite material
Consisting of mixture of cement, mortar (or) Concrete & discontinuous
discrete, Uniformly dispersed Suitable fibres.

Fibre :- It is a small piece of reinforcing material possesing
certain characteristic properties they can be Circular (or) flat.
The fibre is often discribed by a Convinent parameter is called
aspect ratio.

(vii) **Aspect ratio:-** It is the ratio of its length to its diameter.

Generally We Use (30 to 150) in ranges.

① **Types of Fibres:-**

→ **Steel fibre:-** It is one of the most Commonly used fibre.
Generally round fibre's are used the diameter vary from
0.25 to 0.75mm.

Use of steel fibres makes significant improvement in flexural & impact strength of concrete. It is used in air filled pavements, bridge deck, thin shells, plates & particularly used in overlays of roads.

→ **Asbestos:-**

It is a mineral fibre & has proved to be most successfull of all fibre as it can be mixed with portland cement. The tensile strength varies between 560 to 980 N/mm².

→ **Glass fibre:-**

It is originally used in conjunstion with cement was found to be effected by alkaline condition of cement. The alkali resistant fibre reinforced concrete shows considerable improvement in durability when compared to conventional concrete.

→ **Nylon:-**

It is found to be suitable to increase the impact strength it passes very high tensile strength but low modulous of elasticity & higher elongation donot contribute to flexural strength.

Factors Effecting proportion of fibre Reinforced Concrete:-

1. **Relative Fibre Matrix Stiffness:-**

The modulous of elasticity of matrix much lower than that of fibre for efficient stress transfer. low modulous of elasticity of fibre such as nylon's & polypropylene are therefore unlikely to give strength improvement where as high modulas fibres such as steel, glass & carbon import strength & stiffness to composite.

2. **Volume of fibres:-** ($\leq 2.5\%$)

The strength of composite largely depends on the quantity of fibres used in it.

The increase in the volume of fibres increases approximetely linearly the tensile strength & toughness of the composite.

The max % of fibres used is 2.5% of volume. If it Exceeded leads to segregation & bleeding.

3. Aspect ratio:-

Strength of the concrete increases upto aspect ratio 75 & then decreases. Beyond 75 relative strength & toughness decreases.

4. Orientation of fibres:-

It was observed that the fibres aligned parallel to the applied load offered to more tensile strength & toughness than randomly distoributed or ⊥lar fibres.

5. Workability & Compaction of concrete:-

In Corporation of steel fibres decreases the workability considerably it is because of non-Uniform of distoribution of fibres. Generally the workability & compaction can be improved by increasing w/c ratio (or) By the use of some kind of water reducing Admixtures.

6. Size of Coarse aggregate:-

Several investigators suggested that the max size of C.A should be restricted to 10mm to avoid appreciable reduction in strength of composite.

(viii)

7. Mixing of Concrete:-

(2)

Mixing of F.R.C needs carefull condition to avoid segregation & bleeding.

Typical proportion of FRC

C.C = 325 to 550 kg/m3.

w/c = 0.4 to 0.6

% of sand to total aggregate = 50 to 100%

Max. Size of Course Aggregate = 10mm

Air Content = 6 to 9%

Volume fibres = 0.5 to 2.5% of its volume.

Density

Steel = 7840 kg/m3

Glass = 2500 kg/m3.

Nylon = 1100 kg/m3.

Advantages of fiber reinforced Concrete :-

→ It reduces brittleness of plain Concrete.

→ It is Utilized in low cost and light wt structure.

→ It protects and strengthens the skin of Concrete members.

→ It improve the impact strength, reduces shrinkage.

Application of Fibre Reinforced Concrete :-

1. Road Pavements.
2. Industrial flooring.
3. Bridge Decks
4. canal lining.
5. Explosive resistant Structures.
6. pre-cast works like pipes, boats, beams, staircase steps, Wallpanels, roof panels & manhole Covers etc.

Self-Compacting Concrete (SCC):-

The Self Compacting Concrete first time developed by Japan in the University of Tokyo (1980's).

Self-compacting Concrete is generally defined as Concrete that can fill formwork and encapsulate reinforcing bars through the action of gravity only, while maintaining homogeneity. Self-Compacting concrete therefore achieves full compaction without externally or internally applied vibration energy and de-aerates by itself. It is characterized by its Excellent flow properties, Combined with a high resistance to Segregation. The Quantity of Course aggregates is reduced and a higher dosage of Superplacticizer is added to the mix. The Segregation resistance and stability of the Mix is achieved by using a high fines Content. Mix design procedures for Self Compacting Concrete differ from Conventional Concrete and mainly rely on trial mixes in Order to decide Optimum mix ratios for the specific material used. Self-Compacting Concrete has proved very beneficial from the following points.

The ability of Concrete to undergo Compaction by its Own Weight without any vibration is called Self-compacting Concrete.

Advantages of Self-Compacting Concrete:-

(3)

1. Faster Construction.
2. Reduction in site-manpower.

3. Better surface finish

4. Easy to place

5. Improved durability

6. Greater freedom in design ["NANSU" Method]

7. Thinner concrete section

8. Reduce noise level

9. Safer working environment.

* Material for SCC :

1. Cement
2. Aggregates → Maximum size of Aggregate limited to 20mm.

   Aggregates of size 10 to 12mm is desirable for structures having congested reinforcement.
3. Water
4. Chemical admixtures
5. Mineral admixtures
   - a) Fly ash
   - b) GGBS
   - c) Silica fume
   - d) Stone powder
6. e) Fibers → Fibers may be used to ~~each~~ enhance the property of SSC in the same way as for normal concrete.

* Appropriate Composition :

Traditional concrete		SCC
Trace	Admixture	0.01%
18%	Water	20%
46%	CA	28%
24%	Sand	34%
12%	Fines	18%

* Requirements of SCC:

The main characteristics of SCC are the properties in the fresh state. The mix design is focused on

1. Filling ability: The ability to flow under its own weight without vibration
2. Passing ability: The ability to flow through heavily conjusted reinforcement under its own weight
3. Segregation Resistance: The ability to retain homogenity without segregation

Note: The workability of SCC is higher than very high degree of workability mentioned in IS 456 : 2000.

* Filling ability:

1. slump flow by Abrams cone
2. T_{50cm} slump-flow
3. V-funnel
4. Orimet

* Passing ability:

1. L-box
2. J-Ring
3. V-box

* Resistance to Segregation:

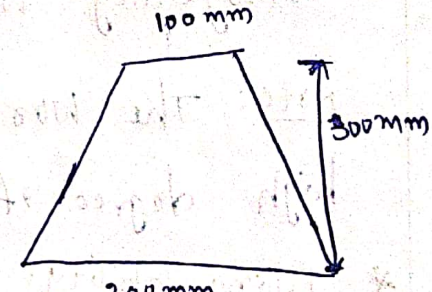
1) V-funnel T_5 minutes
2. GTM Screen stability Test

* Test Methods:

1. Slump flow Test:

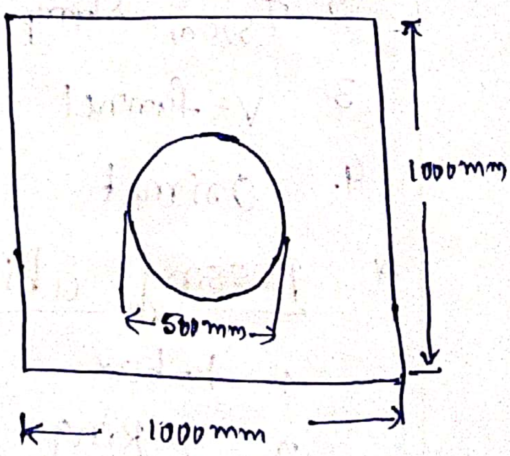
→ The slump flow test is done to assess the horizontal flow of concrete in the absence of obstructions
→ It is most common method of filling ability.
→ It can be used at site & this test also indicate the resistance to segregation

* Equipments:



Slump cone

1. slump cone
2. stiff. base plate [1000x1000 mm]
3. A trowel
4. Scoop
5. Measuring tape
6. stop watch.



* Procedure:

→ About 6 litre of concrete needed.
→ Keep the base plate on level surface
→ Keep the slump cone centrally on the base plate.
→ Fill the cone with scoop. do not tamp.

→ simply strike off the concrete with the trowel.

→ Raise the cone vertically and allow the concrete to flow freely.

→ Measure the final diameter of the concrete in two perpendicular directions & calculate the avg of the two diameters. This is the slump in mm

→ Normal range of flow recommended are 650 mm to 800 mm.

2. T_{50cm} Slump Flow Test:

→ The procedure for this test is same as for slump flow test.

→ When the slump cone is lifted, start the stop watch and find the time taken for the concrete to spread 500mm mark.

→ This time is called T_{50} time. This is an indication of rate of spread of concrete.

→ A lower time indicates greater flowability

→ It is suggested that T_{50} time may be 2 to 5 sec.

→ T_{50} time is also used to evaluate the viscosity of concrete

3. V- Funnel Test:

→ This test was developed in Japan.

→ The equipment consist of V-shaped funnel.

→ This test is used to find the filling ability [flowability] & viscosity of the concrete with max size of Agg 20mm size

* Equipment:

1. V-funnel
2. Bucket [12 liters]
3. Trowel
4. Scoop
5. Stop watch

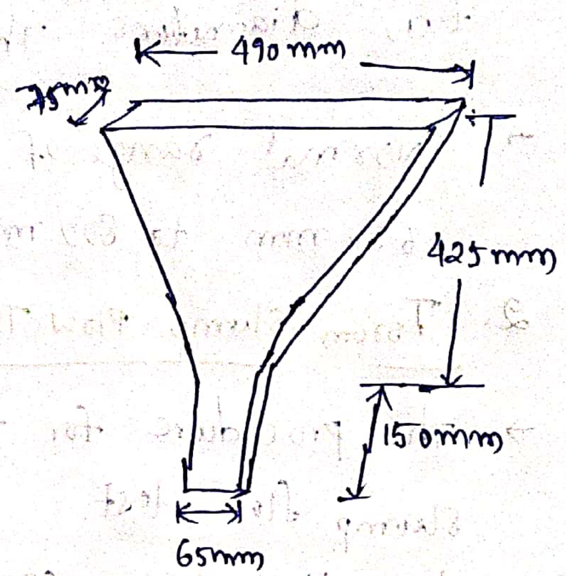


Fig: V-Funnel test equipment.

* Procedure:

→ About 12 liter of concrete is needed for the test

→ Set the V-funnel on firm ground

→ Close the trap door & place a bucket underneath.

→ Fill the apparatus completely with concrete - no compaction (or) tamping is done

→ Open with in 10 seconds the trap door and record the time taken for concrete to flow down.

→ Record the time for emptying

→ The typical range values 8 to 12 sec is ok

*4. V- Funnel T_5 minutes:

→ Do not clean (or) moisten the inside surface of the funnel. Close the trap door & refill the V-funnel immediately after measuring the flow time

→ Fill the apparatus with concrete without tamping.

→ Open the trap after 5 minutes after the second fill of the funnel & allow the concrete to flow.

→ Calculate the time taken for complete discharge

→ For V-funnel flow time at T_5 min +3 sec is allowed.

*5. L-Box test method:

→ This test was developed by in Japan

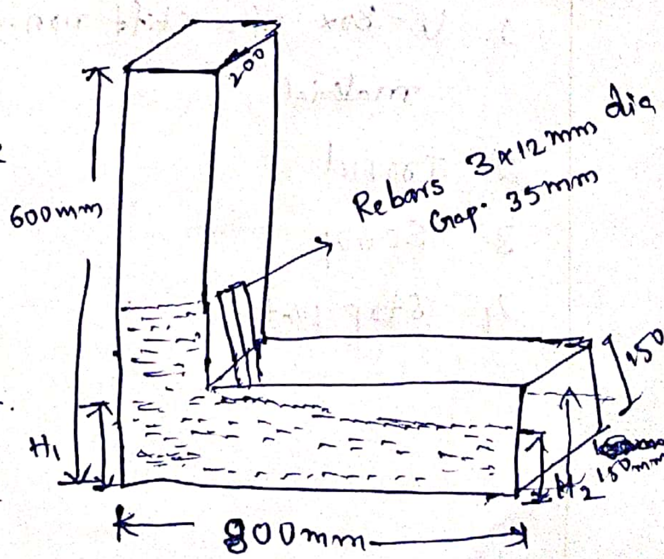
→ The test assesses self levelling properties of concrete and also the extent to which the concrete is having resistance to blocking by reinforcement.

* Procedure:

→ About 14 liters of concrete is required for test

→ Ensure that sliding gate can open freely & then close it.

→ Fill the vertical section of the aparatus with concrete.



→ Leave it standing for 1 minute.

→ Lift the sliding gate and allow the concrete to flow out into the horizontal section.

→ Simultaneously start stop watch & record the time taken for the concrete to reach 200 & 400mm marks.

→ When the concrete stops flowing, the height H_1 & H_2 are measured.

→ Calculate H_2/H_1, the blocking ratio. The whole test has to be performed within 5 min.

→ The minimum acceptable value ≥ 0.8

→ T_{20} and T_{40} time can give some indication of ease of flow, but no suitable value have been suggested

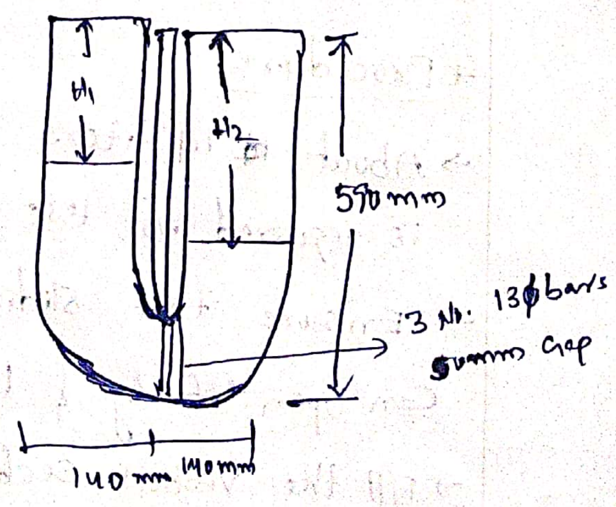
6. U-Box test Method:

→ The test was developed in Japan

→ The test is used to measure the filling ability of SCC.

Equipment:

1. U-Box of a stiff non-absorbing material
2. Trowel
3. Scoop
4. Stop watch



* **Procedure:**

→ About 20 liter of concrete is needed for this test

→ Ensure that sliding gate can open freely and then close it.

→ Fill the one compartment of the apparatus with about 20 litre concrete. Leave it to stand for 1 min

→ Lift the sliding gate and allow the concrete to flow to the other compartment.

→ Once the concrete has come to rest, measure the height of concrete in the second compartment in two places & take mean let it be H_2.

→ The height of concrete in the 1st compartment be H_1

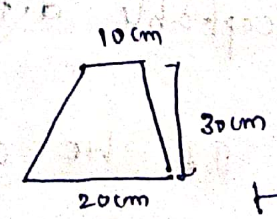
→ Calculate $H_1 - H_2$, the filling height. The whole test has to be completed within 5 min

→ Recomended values < 30 mm

7. J-Ring Test:

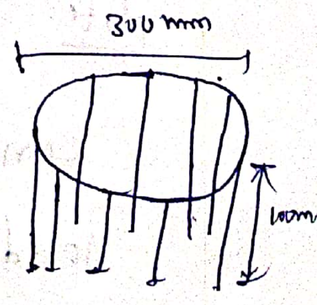
→ J-ring test denotes the passing ability of concrete.

Equipment:



slump cone

1. Slump cone
2. Base plate at least 700mm square
3. Trowel
4. Scoop
5. Tape
6. J-ring [300mm dia & height 100mm, gap 50mm]



J-ring

Scanned by CamScanner

Procedure:

→ About 6 litres of concrete is needed for the test

→ Plate the J-Ring centrally on the base plate & slump cone centrally inside the J-ring.

→ Fill the slump cone with scoop, do not tamp

→ Raise the cone vertically and allow the concrete to flow out through the J-ring

→ Measure the final diameter in two perpendicular directions. Calculate the average diameter

→ Measure the difference in height between the concrete just inside J-Ring bars and just outside the J-Ring bars.

→ Calculate the average of difference in height at four locations in mms.

→ Acceptable difference in height $H_2 - H_1$ b/w 0-10mm.

Note: If we observe more coarse aggregate at center and water, cement around ring it leads to segregation.

* Acceptance of SCC:

⇒ Combinations may be

→ slump flow, V-funnel & U-box test [Japan]

→ slump flow & L-Box (Sweden)

→ J-ring & U-Box

→ slump flow, U-Box/L-Box, V-funnel at 5 min

* characteristics of SCC in Hardened state:

⇒ Typical properties of hardened SCC.

Items	SCC
Water binder Ratio (%)	25 to 40
Compressive strength [28 days], MPa	40 to 80
Compressive strength [90 days], MPa	55 to 100
Spit tensile strength (28 days) MPa	2.4 to 4.8
Elastic modulus (GPa)	30 – 36
shrinkage strain ($\times 10^{-6}$)	600 – 800

* Suggested Values of Acceptance for different methods of SCC - EFNARC - 2002

[EFNARC - European Federation of National Associations Representing for Concrete]

S.No	Method	Units	Typical range of values	
			Minimum	Maximum
1	Slump Flow	mm	650	800
2.	T_{50cm} slump Flow	sec	2	5
3.	J - ring	mm	0	10
4.	V- Funnel	sec	8	12
5.	V-Funnel at T_5 min	sec	8	15
6.	L- Box	h_2/h_1	0.8	1
7.	U- Box	(h_2-h_1) mm	0	30
8	Fill Box	%	90	100
9	GTM Screen stability test	%	0	15
10	Orimet	sec	0	5

* Summary of SCC:

→ One of the out comes of using high strength concrete is slender members & consequently very dense reinforcement. Normal methods of vibration are not effective. Hence SCC.

→ SCC has various other applications. It is especially suited to pre cast/pre fabricated products. In Japan, they now use for casting composite columns. Steel tubes with shear lugs inside filled with SCC and no other reinforcement very tall columns have been made

→ Very few national standards exists as of now for SCC [Japan, Europe, Italy etc]

→ SCC mixes are very sensitive to variation in water

→ water curing is absolutely necessary for 3-7 days

→ SCC should be treated as high quality concrete & not meant for low strength applications

→ SCC can be advantageously used for all types of work with proper understanding of its behaviour

→ It is a matter of time SCC replacing Normal concrete even in India.

* High performance Concrete [HPC]:

⇒ A performance enhanced concrete (or) HPC is a specialized series of concrete designed to provide several benefits in the construction of concrete structures that cannot always be achieved routinely using conventional ingredients, normal mixing and curing practices.

→ * In other words, a HPC is a concrete in which certain characteristics are developed for a particular application and environment, so that it will give excellent performance in the structure in which it will be placed, in the environment to which it will be exposed and with the loads to which it will be subjected during its design life.

⇒ The American concrete comittee on HPC includes the following six criteria for material selections, mixing, placing & curing procedure of concrete.

1. Ease of placement
2. Long term mechanical properties
3. Early-age strength

4. Toughness

5. Life in severe environments

6. volumetric stability

The above mentioned performance requirements can be grouped under the following three general categories

(a) Attributes that benefit the construction process

(b) Attributes that lead to enchanced mechanical properties

(c) Attributes that enhance durability & long term performance.

* According to R.N SWAMY:

A high performance concrete element is that which is designed to give optimized performance characteristics for a given set of load, usage & exposure conditions, consistent with requirement of cost, service life & durability.

* Requirement of HPC:

- → Water (Cement + mineral admixture) ratio
- → strength
- → Densification of cement paste
- → Elimilation of bleeding
- → Homogeneity of the mix
- → Particle size distribution
- → Dispersion of cement in fresh mix
- → stronger transition zone
- → Low free lime content
- → very little free water in hardened concrete

* In HPC:

→ High C_3A content in cement generally leads to a rapid loss of flow in fresh concrete. therefore high C_3A content should be avoided in cements used for HPC

→ The total amount of soluble sulphate present in cement is a fundamental considerable for HPC.

* Superplasticizers:

→ Induced electrostatic repulsion b/w particles

→ Dispersion of cement grains & consequent release of water trapped within cement flocks

→ Reduction of surface tension of water

→ Development of lubrication film b/w particles

* HPC (Vs) Conventional mix design:

→ The compressive strength levels covered by conventional mix design are far less than those usually obtained by HPC

→ The strength developed in case of HPC after conventional 28 days is quantitatively considerable; hence later age strength [say 90 day] is better criterion for design of HPC mixes.

* Advantages of HPC:

→ Very low porosity through a tight and refined pore structure of the cement paste.

→ very low permeability of concrete

→ High resistance to chemical attack
→ Low heat of hydration
→ High early strength and continued strength development
→ High workability & control of slump
→ Low water-binder ratio
→ Low bleeding & plastic shrinkage

Note: HPC is often of high strength concrete but high strength concrete can not be a HPC.

Applications of HPC :

→ pavements
→ Bridges
→ High rise buildings
→ Miscellaneous applications :- bridge decks overlays, floor slabs, pavements & pavement overlays, Hydraulic structures, thin shells, rock slope stabilization, mine tunnel linings & many precast products.

* Polymer Concrete :

→ Polymer concrete is a composite wherein the polymer replaces the cement-water matrix in the cement concrete.

⇒ It is manufactured in a manner similar to that of cement concrete

⇒ Monomers (or) pre-polymers are added to the graded aggregate and the mixture is thoroughly mixed by hand (or) machine

⇒ The thoroughly mixed polymer concrete material is cast in moulds of wood, steel (or) aluminium etc.. to the required shape or form

⇒ Mold releasing agents can be added for easy demolding.

⇒ This is then polymerised either at room temperature (or) at an elevated temperature

⇒ The polymer phase binds the aggregate to give a strong composite.

→ Polymerization can be achieved by any of the following methods

1. Thermal - catalytic reaction
2. Catalyst - promoter reaction
3. Radiation

* **Features of polymer concrete:**

→ High strength → as high as 140 MPa with a short curing period.

→ Greater resistance to chemical attack.

→ It has lower water absorption.

→ High density

→ Higher freezing & Thawing stability

→ Less shrinkage

Note: The main technique in producing PC is to minimize void volume in the aggregate mass as to reduce the quantity of polymer needed for binding the aggregates.

Note: It is used in selected situations & has very restricted use due to high cost.

* Types of Polymer Concrete:

→ Four types of polymer concretes are there

(a) Polymer cement concrete (P.C.C)

(b) polymer concrete

(c) Polymer Impregnated concrete (PIC)

(d) Partially Impregnated & surface coated Polymer concrete

(a) Polymer cement concrete:

→ polymer cement concrete is made by mixing cement, aggregates, water and monomer. Such plastic mixture is cast in moulds, cured, dried & polymerized.

→ The monomers used in PCC are

(i) polyester-styrene

(ii) Epoxy-styrene

(iii) Furans

(d) vinylidene chloride

→ These are added to mix by 2 to 20% by mass.

⇒ Results obtained by PCC are disappointing many times & shown relatively modest improvement of strength & durability

ⓑ Polymer concrete: (PC)

→ Polymer concrete in an aggregate bound with a polymer binder instead of portland cement in conventional concrete

→ The main technique in PC is to minimize void volume in the aggregate mass so as to reduce the quantity of polymer needed for binding the aggregates.

⇒ This composition based on synthetic resins (or) monomers with chemically stable fillers and aggregates.

⇒ the main properties of polymer concrete are exhibited by chemical nature of synthetic resins & the finely dispersed filler fraction

→ The strength obtained with PC can be as high as 140 MPa with a short curing period.

ⓒ Polymer Impregnated Concrete [PIC]

→ PIC is one of the widely used polymer composite.

→ It is nothing but a precast conventional concrete cured & dried in oven.

→ Then a low viscosity monomer is diffused through the open cell & polymerized by using radiation, application of heat or by chemical initiation.

⇒ Monomers used are.

(i) Methyl methacrylate (MMA)

(ii) Styrene

(iii) Acrylonitrile

(iv) t- butyl styrene

(v) other thermoplastic monomers

⇒ These are cement concrete which after placing drying & curing are impregnated with various monomers which fill the pores of concrete to produce a non-porous concrete

Ⓓ Partially Impregnated & Surface Coated concrete

→ partial impregnation may be sufficient in situations where the major requirement is surface resistance against chemical & mechanical attack in addition to strength increase

→ Even with only the partially impregnated concrete could be produced significant increase in the strength of original concrete has been obtained.

→ The potential application of polymer impregnated concrete surface treatment [surface coated concrete (SC)] is in improving the durability of concrete bridge deck.

→ Monomer → benzoyl peroxide used as catalyst

* Polymer Concrete (Vs) Normal concrete:

→ Compressive strength is 4 times higher than normal concrete

→ Tensile strength is also 4 time higher than normal concrete

→ modulus of elasticity is 2 times than N.C

→ modulus of rupture is also 4 times than N.C

→ creep deformation is about 10% only

→ The water permeability becomes negligeable.

* Applications of Polymer concrete:

→ construction of under ground engineering structures

→ Covering floors & making roads

→ Sound insulating material

→ Agriculture & Horticulture in pipe construction

→ Load bearing structures like props & ties in industrial structures

→ polymer plaster for interior decoration

→ Residential & other civil engineering constructions.

* Limitations of Polymer Concrete:

→ Low thermal stability

→ Uneconomical