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RAILWAY RECRUITMENT BOARD

CIVIL ENGINEERING

CONCRETE TECHNOLOGY

SELF STUDY MATERIAL

CIVIL ENGINEERING FOR ALL

Concrete Technology

CEMENT

The history of cementing material is as old as the history of engineering construction. The natural cement is obtained by burning and crushing the stones containing clay, carbonate of lime and some amount of carbonate of magnesia. The natural cement is brown in colour and its best variety is known as the Roman cement.

(1) **CEMENT AND LIME :** The point of difference between ordinary cement and lime are the following:-

(i) Lime is white in colour whereas colour of cement is greyish.

(ii) Portland/lime blends are manufactured in a blending facility using portland cement and hydrated type 'S' lime,whereas masonry cements are manufactured in a cement plant using portland clinker, plasticizers, and air entraining agent together.

(iii) Cement paste sets quickly than lime.

(2) **COMPOSITION OF ORDINARY CEMENT :** The raw material required for manufacture of portland cement are calcareous materials such as limestone or chalk and argillaceous material such as clay or shale. In calcareous materials, the calcium carbonate predominates and in argillaceous materials, it is clay which predominates. A typical chemical analysos of good ordinary cement is as follows:-

Cement constitutes of Calcarious and Argilaceous compound :	**Average**
Lime (CaO) : 62–65%	63%
Silica (SiO_2) : 17–25%	20%
Alumina (Al_2O_3) : 3–8%	6.3%
Calcium sulphate ($CaSO_4$) : 3–4%	3.5%
Iron oxide (Fe_2O_3) : 3–4%	3.6%
Magnesia (MgO) : 1–3%	2.4%
Sulphur (S) : 1–3%	1.5%
Alkali (Na_2O, K_2O) : 0.2–1%	1%

(1) FUNCTION OF DIFFERENT CONSTITUENTS OF CEMENT :

(i) **Lime (62–65%)** : It imparts strength and soundness, when it makes cement (volume change) unsound causing it to expand and disintegrate.
If it is in deficiency, it reduces strength of cement and causes it to set quickly.

(ii) **Silica (17-25%) :** It also imparts strength to the cement. If in excessm, it increases the strength of the cement but also increases setting time of cement. Cement not set quickly (if batching plant and site are far away).

(iii) **Alumina (3-8%) :** It imparts quick setting property to cement.
It acts as a flux and reduces the clinkering temperature during the burning of cement.
If in excess, it weakens the cement.

(iv) **$CaSO_4$ (3-4%) :** It is generally added in the form of gypsum ($CaSO_4 . 2H_2O$) in cement.
It is used to increase the initial setting time of cement. (Cement start to lose its plasticity with final setting time plasticity is lost completely).

(v) **Iron Oxide (3–4%)**: It imparts strength, hardness and colour to cement (It induces reddish brown tint to the cement).

(vi) **Magnesia (1-3%)** : It also imparts strength and colour. If in excess, it makes the cement unsound.
(It induces yellowish tint to cements).

(vii) **Sulphur (1-3%):** It is also responsible for imparting soundness to cement.
[Soundness due to lime and Magnesia can be measured easily. but no test is available to test soundness and effect of adding sulphur].

(viii) **Alkali (0.2 –1%):** Alkali present in cement causes efflorescence and staining of structure in which it is used for construction. These alkalies react with H_2O resulting in the development of white grey spots over the surface of structure leading to its staining.
The raw materials used for the manufacture of cement consists mainly of lime, silica, alumina and iron oxide These oxides interact with one another in the kiln at high temperature to form more complex compound. The relative proportions of these oxide compositions are responsible for influencing the various properties of cement in addition to rate of cooling and fineness of grinding.
The oxides present in the raw materials when subjected to high clinkring temperature combine with each other to form complex compounds. The identification of major compound is largly based on R.H Bogues's work and hence, called as bogue's compounds. The four compounds usually regarded as major compounds are given below:-

(2) BOGUES COMPOUNDS : When water is added in cement, it chemically reacts with ingradients of cement resulting in formation of complex chemical compounds called Bogues compounds which are not formed simultaneously.

(i) **Tricalcium Aluminate (3 CaO. Al_2O_3) (C_3A) (4–14%) :** It is formed within 24 hrs of addition of water in the cement and is responsible for maximum amount of heat of hydration.

(ii) **Tetracalcium Aluminoferrate (4 CaO. Al_2O_3. Fe_2O_3) (C_4AF) (10-18%) :** It is also formed within 24 hours of addition of water in the cement. The amount of heat evolved during formation of compound which initially is comparitively more goes on decreasing with time.

(iii) **Tricalcium Silicate (3CaO. SiO_2) (C_3S) (45–65%) :**
It is formed within a week or so, after the addition of water in cement.
It is responsible for development of early strength in the cement in its initial stages.

(iv) **Di-Calcium Silicate (2CaO. SiO_2) (C_2S) (15–35%) :**
It is formed very slowly on addition of water in cement. It may require a year or so for its formation.
It is responsible for progressive strength of cement in its later stage.
More for [hydraulic structure, bridges, dams].
If strength in structure is to be developed in its early stages, proportion of C_3S is increased and if required in later stages, proportion of C_2S is increased.

Heat of hydration :

Component	Heat of Hydration (Calories/gm) 3 days		90 days		
1. C_3A	212	=A	310	a = 9	4-14%
2. C_4AF	69	= B	98	b = 14	10-18%
3. C_3S	58	= C	105	c = 55	45-65%
4. C_2S	12	= D	42	d = 25	15-35%

Heat of hydration of cement = $aA + bB + cC + dD$

$$= \frac{9 \times 212 + 14 \times 69 + 55 \times 58 + 12 \times 25}{100}$$

= 63 . 64 Cal/gm

Heat of hydration of cement during 7 days is approximate 89-90 cal/gm and during 28 days is 90-100 cal/gm

About 23% of water by weight of cement is required to carry out the complete hydration.

About 15% of water added to cement is imbibed within the voids of the cement particles. Hence effectively, 38% of water by weight of cement is required to carry out complete hydration.

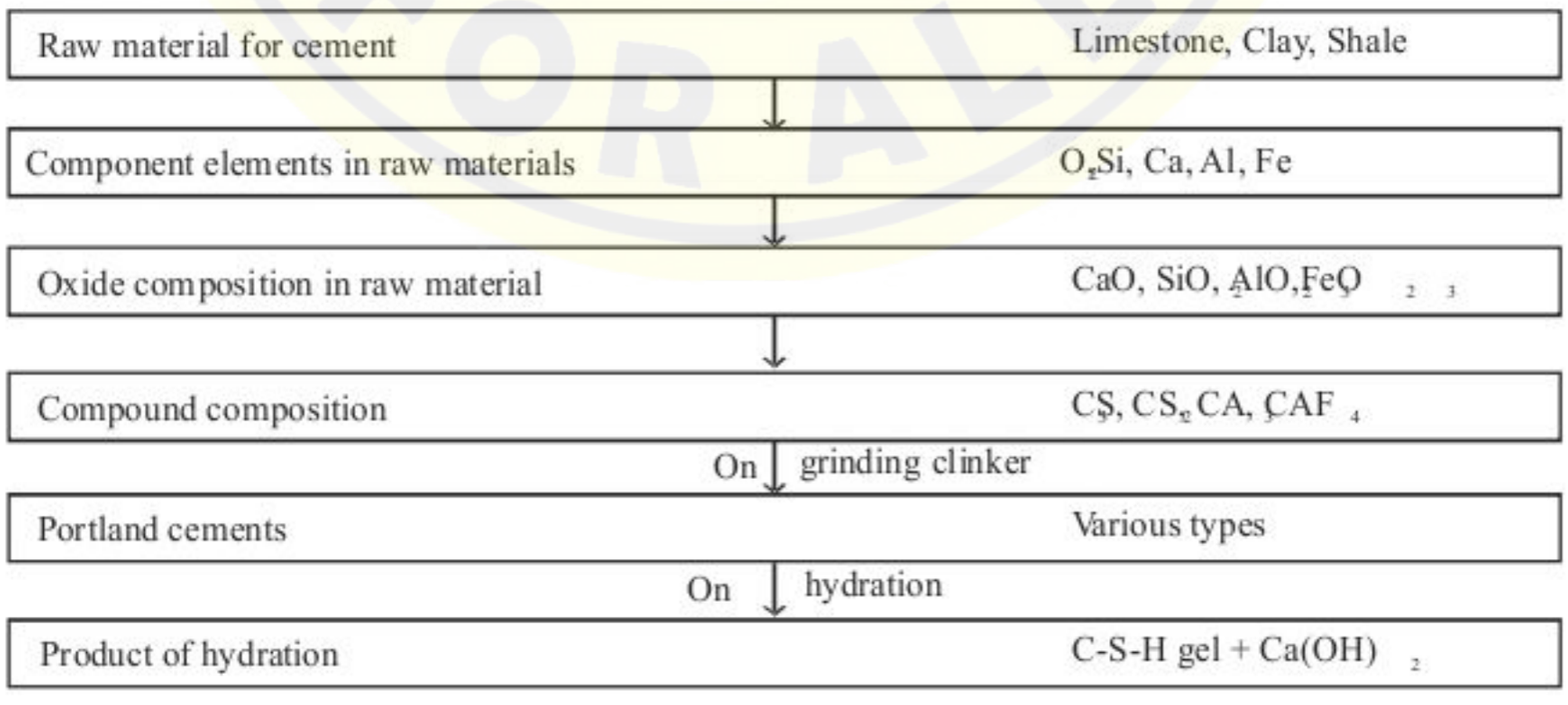
Water Cement ratio = 0.4

Therefore, when water Cement ratio decreases → Strength of concrete increases.

In addition to the four major compunds, there are many minor compunds formed in the kiln. the influence of these minor compounds on the properties of hydrated compounds is not significant. Two of the minor oxides namely K_2O and Na_2O referred to as alkalis in cement are of some importance.

Both le chatelier and Torrebohm observed four different kinds of crystals in thin section of cement clinkers. Torrebohm called these four kinds of crystals as slite,Belite, celite and felite. Torrebohms description of the minerals in cement was found to be similar to bogues description of the compounds. Therefore, Bogue's C_3S, C_2S, C_3A and C_4AF are sometimes also called Alite, Belite, Celite, ande felite respectively.

Cement and hydration of portland cement can be schematicaly represented as given below:-



(3) **Hydration of cement :**

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

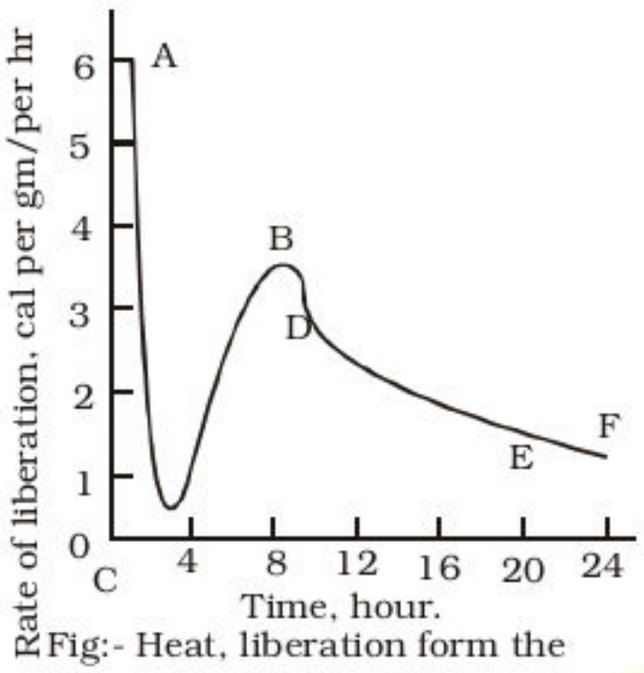


Fig:- Heat, liberation form the setting cement

(4) **TYPE OF CEMENT :**

(i) Ordinary Portland cement

(a) OPC 33 grade :- IS 269 : 1989

(b) OPC 43 grade :- IS 8112 : 1989

(c) OPC 53 grade :- IS 12269 : 1987

(ii) Rapid hardening cement :- IS 8041 : 1990

(iii) Extra Rapid hardening cement :- __ ?

(iv) Sulphate Resisting cement :- IS 12330 : 1988

(v) Portland slag cement :- IS 455 : 1989

(vi) Quick setting cement :- _____ ?

(vii) Super sulphated cement :- IS 6909 : 1990

(viii) Low Heat cement :- IS 12600 : 1989.

(ix) Portland pozzolana cement :- IS 1489 (part1) 1991 (flyash based):- Is 1489 (part -II) 1991(calcined clay based)

(x) Air entraining cement:- _____ ?

(xi) Coloured cement(white cement) :- Is 8042 : 1989

(xii) Hydrophobic cement :- IS 8043 : 1991

(xiii) Mosonry cement :- Is 3466 : 1988

(xiv) Expensive cement :- ___ ___ ?

(xv) Oil well cement :- Is 8229 : 1986

(xvi) Rediset cement :- ___ ?

(xvii) Concrete sleeper grade cement :- IRS - T40 : 1985

(xviii) High alumina cement :- IS 6452 : 1989

(xix) Very high strength cement :- _____ ?

(A) RAPID HARDENING CEMENT :

- This type of cement shows higher rate of development of strength that sets quickly. (However, it must not be confused with quick setting cement).
- The strength of the cement at the age of 3 days is same as the strength of OPC in 7 days. (Strength magnitude is same as that of OPC).
- This rate of gain of strength in Rapid Hardening cement gradually subsicides and at the age of 90 days, strength of rapid hardening cement is almost same as that of simple cement.
- Rapid hardening cement is produced by "fine grinding" the cement clinker, increasing the proportion of C_3S and reducing the proportion of C_2S. Specific surface area of the cement should not be less than 3250 cm^2/gm.

Proportion of C_3S is approximately 56% and that of C_2S is approximately 9 to 10%.

Application :

* Pre–fabricated concrete construction.
* Emergency Road repair work.
* Cold weather concrete.

(B) EXTRA RAPID HARDENING CEMENT:

(i) This cement is manufactured by intergrinding rapid hardening cement clinkers with calcium chloride, proportion of which should not be 'greater than 2% by weight of cement.

(ii) This cement should be mixed, transported, placed, compacted and finished within 20mins of its formation.

(iii) This cement has approximately 20-25% higher strength than Rapid Hardening cement at the age of 1-2 days & 10-15% higher strength at the age of 7 days than rapid hardening cement.

(iv) This rate of gain of strength decreases with time and the strength of the cement is same at the age of 90 days to that of OPC.

(v) Application :

- Same as that of rapid hardening cement is used.

(C) SULPHATE RESISTING CEMENT :

(i) OPC is highly susceptible to the attack of Sulphate specially to that of Magnesium Sulphate that reacts with both calcium Hydroxide to form $CaSO_4$ and with calcium Aluminate to form calcium Sulpho Aluminate; volume of which is approximately 227% more than the original constituent.

Sulphur attacks on structures like, sewage treatment plant, sewers, marine structure, foundation structure etc.

(ii) This cement is manufactured by reducing the proportion of C_3A & C_4AF such that :
$C_3A \not> 5\%$; $2C_3A + C_4AF \not> 25\%$

(iii) **Application :**

* Foundation works
* Sewage treatment works
* Marine structure
* Construction of pipes to be layed in Marshy area.

This type of cement has low heat of hydration and less rate of gain of strength as (C_3S and C_4 AF is decreased).

(iv) Sulphate contact can be reduced by use of polymer (costly) or network wall around foundation.

(D) SUPER – SULPHATED CEMENT :

(i) This type of cement is manufactured by intergrinding 80-85% granulated blast furnace slag, 15% hard burnt gypsum and 5% cement clinkers.

Gypsum → Increases the setting time (so it is increased), slag (particle size are less) → permeability decreases. Hence, it can be used in water retaining structure. (Economical).

Application :

Same as that of sulphate Resisting cement.

(E) PORTLAND SLAG CEMENT:

(i) Manufactured by intergrinding, granulated blast furnace slag with gypsum and cement clinker in definite proportion.

Sulphate, resisting cement is a type of Portland slag cement.

(ii) This cement offers, higher resistance against the attack of chlorides & sulphates.

(iii) It possess higher water tightness due to its reduced permeability that is achieved by the refinement of porous structure.

(F) QUICK SETTING CEMENT :

(i) This cement is produced by adding small quantity of Aluminium sulphate, fine grinding the cement and reducing the proportion of gypsum.

Aluminium imparts initial setting grinding fine which leads to quick formation of C_3S strength easily. It is not other wise easy to be gained.

(ii) Application generally used in granting operation and under water concrete.

(G) LOW HEAT CEMENT :

(i) The cement is produced by reducing the proportion of C_3A and C_3S and increasing the proportion of C_2S

$$C_3A \simeq 5\% \;/\; C_3S \simeq 45\% \;/\; C_2S \simeq 46\%$$

(ii) The cement shows slow rate of development of strength because of reduced C_3A and C_3S_1. They slow down the process of hydration.

(iii) Heat of hydration of the cement during first seven days is limited to 65 cal/grams and during 28 days is limited to 75 cal/grams.

(iv) **It is used for bulking of concrete in hydraulic structure.**

(H) PORTLAND POZZOLANA CEMENT :

(i) This cement is manufactured by intergrinding cement clinker with 10-25% Pozzolanic material.

(ii) Pozzolanic material are essentially silicious and aluminious compounds which donot posses any cementious property but when finely divided in the presence of water reacts with $Ca(OH)_2$ formed during hydration of cement resulting in the formation of compound which posses cementious property.

(Non-cementious material)→ (Cementious material)

Pozzolanic + Water + $Ca(OH)_2$ ⟶ C – S – H (Gel)

material

(Non-cementious material)→ (Cementious material)

This cement is found to have properties like

* High tensile strength and resistance against attack of chloride & sulphate.
* Higher resistance against expansion.
* More economical.
* Offers higher water tightness.
* Evolves less heat during setting.
* Attains compressive strength with age.

(I) HYDROPHOBIC CEMENT :

(i) This type of cement is manufactured by intergrinding cement with water repelant film forming substances like oelic Acid and steric Acid.

(ii) These water repellent which are formed around each cement particle reduces the rate of deterioration of cement due to storage of avoids for the absorption of moisture from the atmosphere. Absorption of moisture from the atmosphere is not there, but when we put water into it, the water repellent film breaks.

(iii) This type of cement is generally used where transportation period and storage period is more.

(J) IRS – T – 40 CEMENT :

(i) It is a special type of cement that is manufactured by fine grinding the cement clinker and increasing the proportion of C_3S in order to increase the rate of gain of strength (Pre-fabricated structures).

(ii) This type of cement is used for the manufacturing of concrete sleeper for Indian Railways.

(K) HIGH ALUMINA CEMENT :

(i) This cement is manufactured by intergrinding clinkers of Bauxite (Ore of Aluminium) and $CaCO_3$ (Ore of lime) obtained during calcination.

(ii) In this type of cement percentage of alumina should not be less than 32% and the percentage of Alumina to lime should be in the range of 0.85 to 1.3.

(iii) This cement offers initial setting time of approximately 3.5 hours and final setting time of approximately 5 hours, Hence, more time is available for placing of this cement.

(iv) This cement can withstand high temperature and resists the action of acids.

(v) The rate of development of strength of this cement is also comparatively high as it attains 20% of ultimate strengthing in 1 day and substantial strength within 6 to 8 hours.

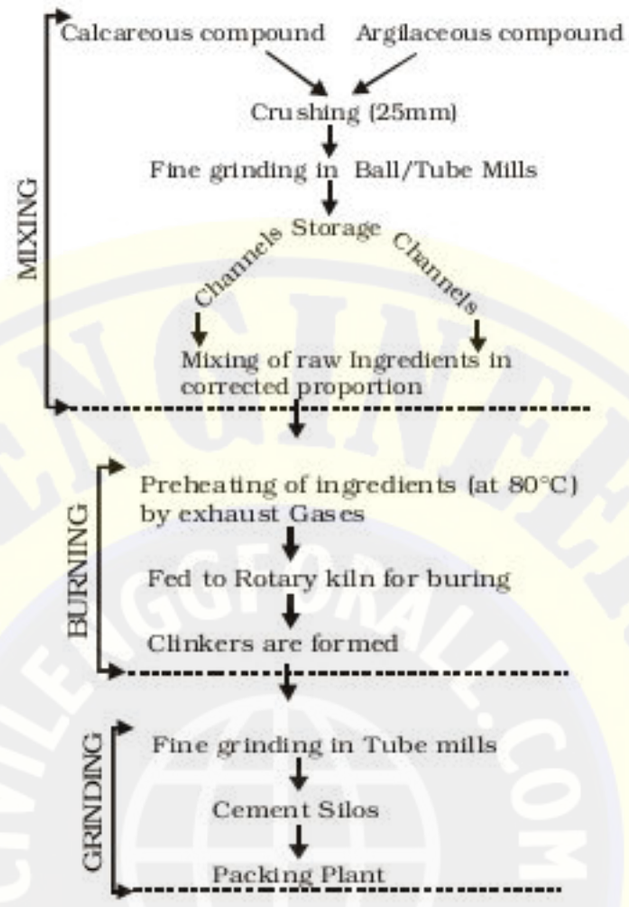
(5) **MANUFACTURING OF CEMENT :**

Manufacturing includes 3 – basic operations

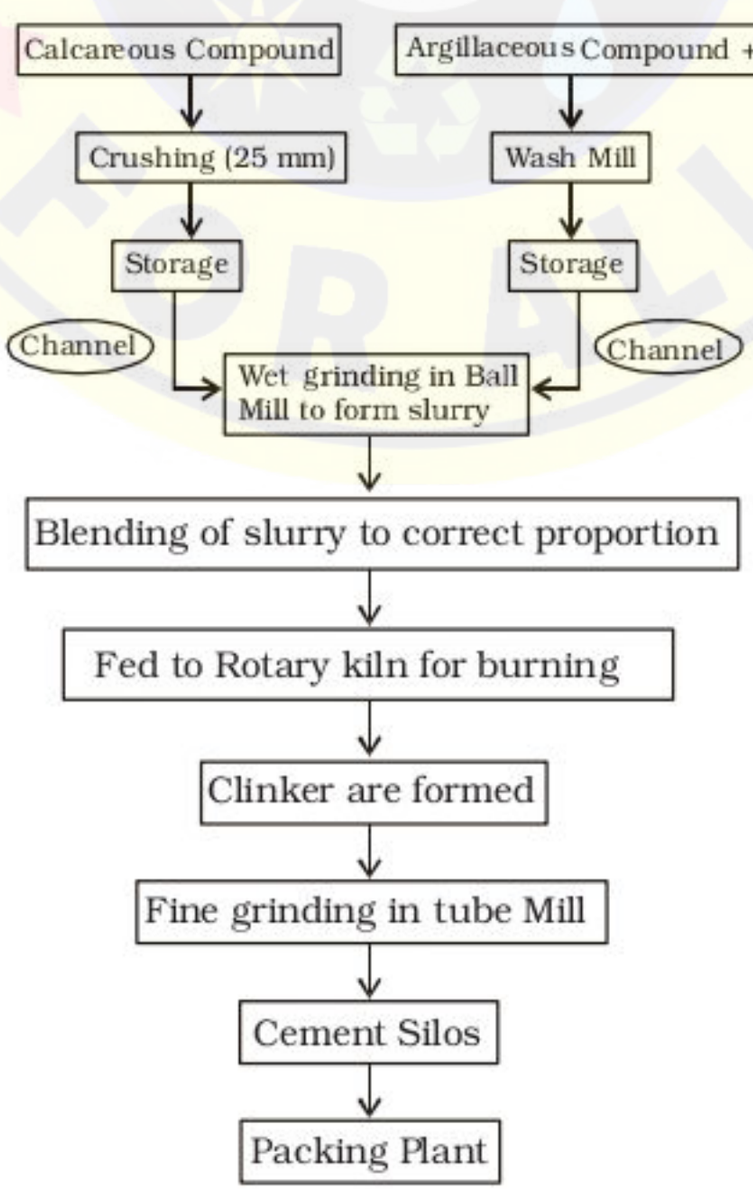
1. Mining of raw material
2. Burning
3. Grinding

Manufacturing can be done by any of following two methods :

1. DRY PROCESS :



2. WET PROCESS :



Cost is more as No PREHEATING is done and the ingredients are heavy.

(6) TESTING OF CEMENT

Testing of cement is carried out to analyse the presence of desirable properties in it.

Generally two class of test are available.

Field Test and Laboratory test

(A) FIELD TEST

(1) **COLOUR TEST :** Cement should posses uniform grey colour.

(2) **PHYSICAL PROPERTY TEST :** Cement should feel smooth when rubbed in between the fingers.

When small sample of cement is thrown in bucket of water, it should sink and not float over the surface.

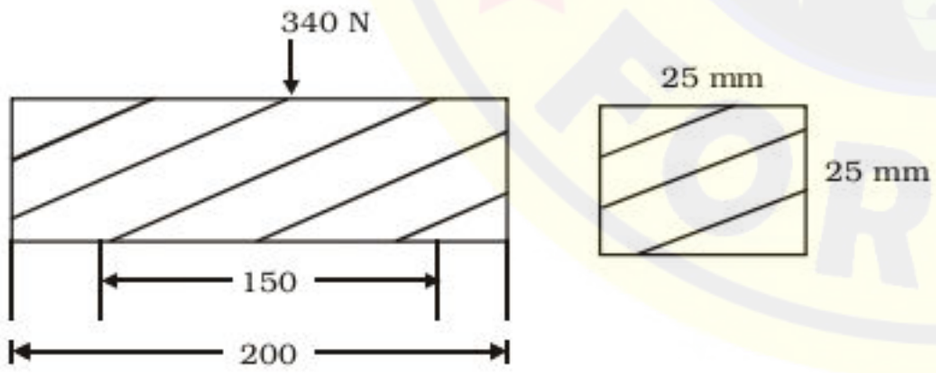
The sample should be free from lumps. Lumps are formed due to absorption of moisture by cement from air that results in its deterioration.

[Only 90 days old cements are permitted by IS : 456].

(3) STRENGTH TEST : Prepare a block of cement to be tested of size 75mm × 75mm × 200mm and immerse it in water for 7 days for curing.

Remove the mould from water and subject it to a point load of 340N by placing it over supports 150mm apart.

The mould should show no sign of failure under the application of this load.



(B) LABORATORY TEST :

(1) FINENESS TEST :

(Measured in terms of area) fineness of cement is tested to check its proper grinding which has direct impact over the rate of hydration, rate of gain of strength and rate of evolution of heat.

Fineness of cement is tested by any of following methods.

(i) SIEVE TEST :

1. Take 100gm of cement to be tested and place it over standard Indian Standard sieve No.9 (90 micron).
2. Perform the sieving for atleast 15 mins along with the continuous breaking of air set lumps.
3. Note the weight of residue left over the sieve. For OPC it should not exceed 10% of original weight of cement.

(ii) STANDARD CONSISTENCY TEST :

In order to find the initial setting, final setting time, soundness, a parameter termed as standard consistency should be known.

Standard consistency is consistency of cement paste that permits the penetration of Vicats plunger of size 10mm and height 50mm upto the depth of 33 to 35 mm from top into a mould prepared from the paste of cement to be tested.

The test is concerned with finding of the water content at which cement paste of Standard consistency is produced.

In order to perform this test take 500gm of cement and add 23% by weight water in the first trail for preparation of cement paste lower the plunger gently upto to the top surface of the mould and release it quickly. Repeat the test upto penetration of 33 to 35 mm from top is observed.

The moisture content at which the cement paste of standard consistency is produced is denoted by P. This test is performed at 27 ± 2°C and at relative humidity of 90%.

(iii) SETTING TIME TEST :

This test is performed to check the deterioration of cement due to storage.

Generally 2 times are associated with setting of cement.

(a) Initial setting time (b) Final setting time.

(a) Initial Setting Time : It is regarded as the time which is being measured from instant water is added to the cement to cement starts losing its plasticity.

In order to perform this test take 500gm cement and gauge it with 85 P (add 85% of water that is required to prepare the cement paste of standard consistency). Lower the square needle gently over the mould and release it quickly. Note the time required by needle to show the penetration of 33-35 mm into the mould from the top. This time taken by needle is regarded as initial setting time for OPC IST = approximately 30mm.

(b) Final Setting Time : It is the time measured from the instant water is added into the cement upto the time it completely loses its plasticity and attains sufficient firmness. So that it can resist a definite pressure.

In order to perform this test prepare the cement paste as above, lower the annular collar with needle at its centre gently upto the top surface of mould and release it quickly. Final setting time is taken as time at which annular collar fails to make the impression over the mould. But needle does so.

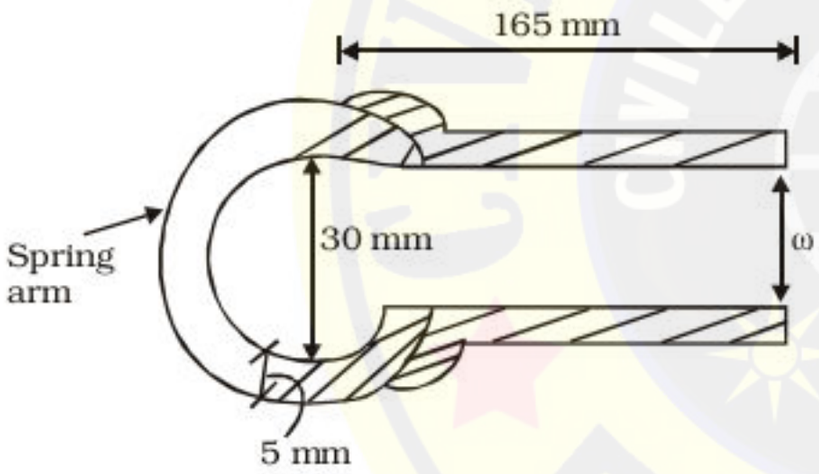
For OPC – Final setting time is approximately 10 hrs.

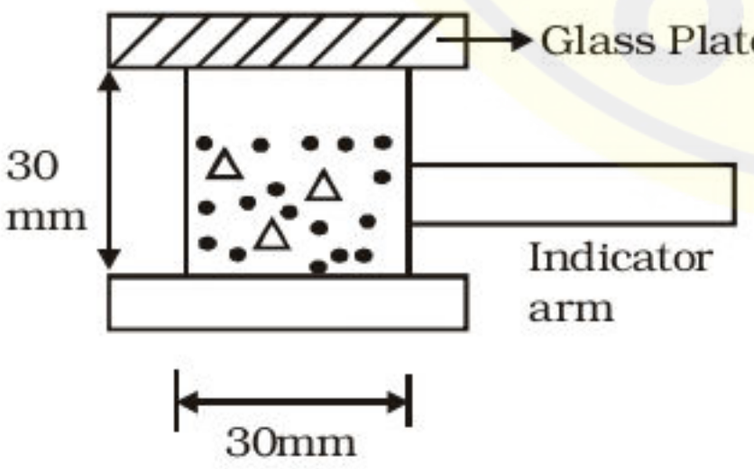
(c) SOUNDNESS TEST : Cement after setting does not show appreciable change in volume as it seriously effect the durability of structure in which it is used for construction.

The soundness of cement is due to the presence of time, Magnesia, Sulphur.

Soundness due to lime :

It is tested using Le-chatelier's Apparatus that consists of small split cylinder of spring brass of size 30mm and diameter of 30mm.





The apparatus has also 2 indicator arms provided on either side of split having length of 165mm.

In order to perform this test gauge the cement, 78(P) and fill the cement paste in mould.

Cover the mould from top and bottom with the help of glass plate and immerse the entire assembly in water having the temperature in range of 27°C–32°C for 24 hours.

Remove the mould from the water and note the displacement of the split with help of indicator arms.

Reimmerse the entire assembly in the water. Temperature of which is increased upto boiling point in 25-30min and is maintained for further 3 hours. Note the displacement of the split again with the help of indicator arms. The difference of reading in both the part of test should not exeed 10mm for OPC.

This test is sensitive to both time and magnesia.

In order to perform this test, prepare a mould of lean cement of size of 25mm (cube) and place it in autoclave in which steam pressure is increased upto 21kg/cm^2 and is maintained for next 3 hours. The mould is removed from autoclave and the percent expansion of the mould is noted in each direction which should not exceed 8% for OPC.

★ Autoclave test is also used to test for soundness of cement for both lime and magnesium.

The chief test for soundness are the Le-chatelier and autoclave tests.

(d) STRENGTH TEST

(i) Compressive Strength Test : In order to check the compressive strength cement, cement mortar with standard sand [Ennore Sand] of proportion 1:3 is also prepared (weight of standard sand is generally kept 550gms and Water Cement ratios of 0.4).

This mortar is filled in mould of size 75mm and immersed in water for required duration.

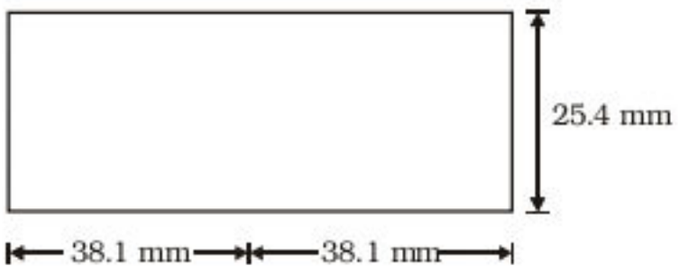
Compressive strength of cement is tested in universal testing machine.

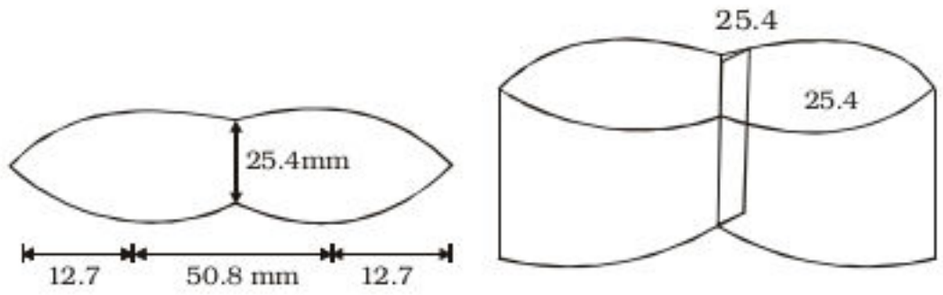
$$7 \text{ days strength} = \frac{2}{3} \text{ characteristic strength}$$

3 days strength = 50% of 28 days characteristics.

(ii) Tensile Strength Test : Tensile Strength of cement or concrete cannot be measured directly as there is no shape of mould or apparatus available that leads to development of uniform tensile stress across any section.

Tensile strength of cement is calculated by preparing cement as above & placing it in standard Briquettes having following dimensions.





$$\text{Tensile Strength} = \frac{\text{Failing load}}{25.4 \times 25.4} = \frac{\text{Failing load}}{6.45\ \text{cm}^2}$$

(E) **CHEMICAL COMPOSITION TEST :**

The ratios of Alumina to Iron Oxide should not be less *than* the ratios of lime to silica, Alumina & Iron oxide should not be greater than 1.02 & should not be less than 0.66.

This ratiois termed as *lime saturation* factor.

$$1.02 \leq \frac{CaO - 0.7SO_3}{2.8\ SiO_2 + 1.2\ Al_2O_3 + 0.65\ Fe_2O_3} \leq 0.66$$

Total weight of Magnesia $\leq$ 5%.

Total loss on ignition $\leq$ 4%

Total sulphur content $\leq$ 2.75%

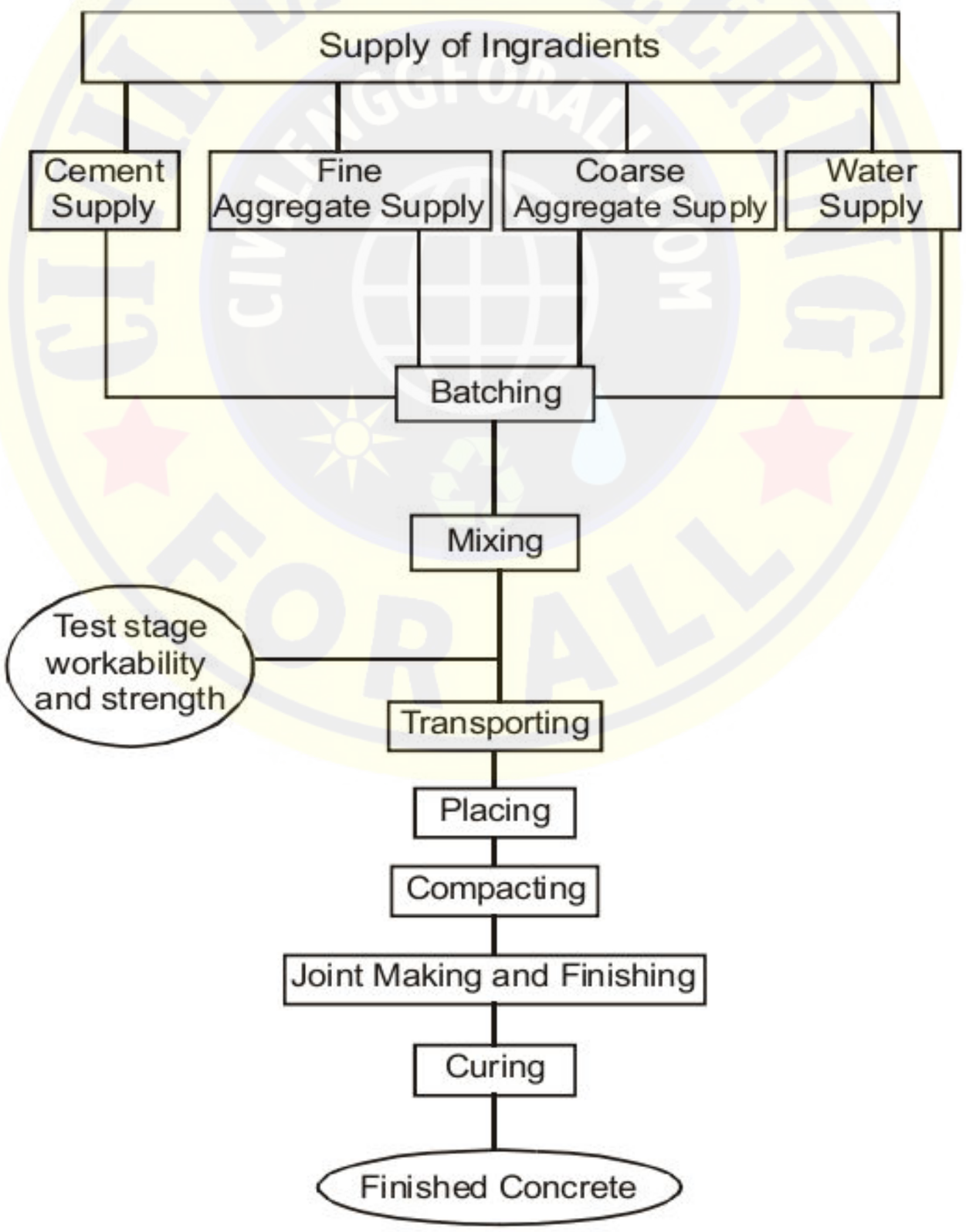
Weight of insoluble residue $\leq$ 1.5%.

CONCRETE

Concrete is the most widely man made construction material. It is a mixture of cement, water, sand and gravel or crushed aggregates. The mixture when placed in forms and allowed to cure becomes hard like stone. Concrete is also known as an artificial stone as it possesses many similar characteristics of a natural stone.

The process of making concrete is called concreting. In order to obtain finished concrete, the process in sequence is known as concrete chain.

Each concreting operation (process) should be carefully done and controlled to obtain the desired strength and durability of concrete.



Concrete Chain Final

Fig. (1)

Properties of concrete

Concrete has to pass through two stages before it is used as structural member. These two stages of concrete are plastic stage and hardness stage.

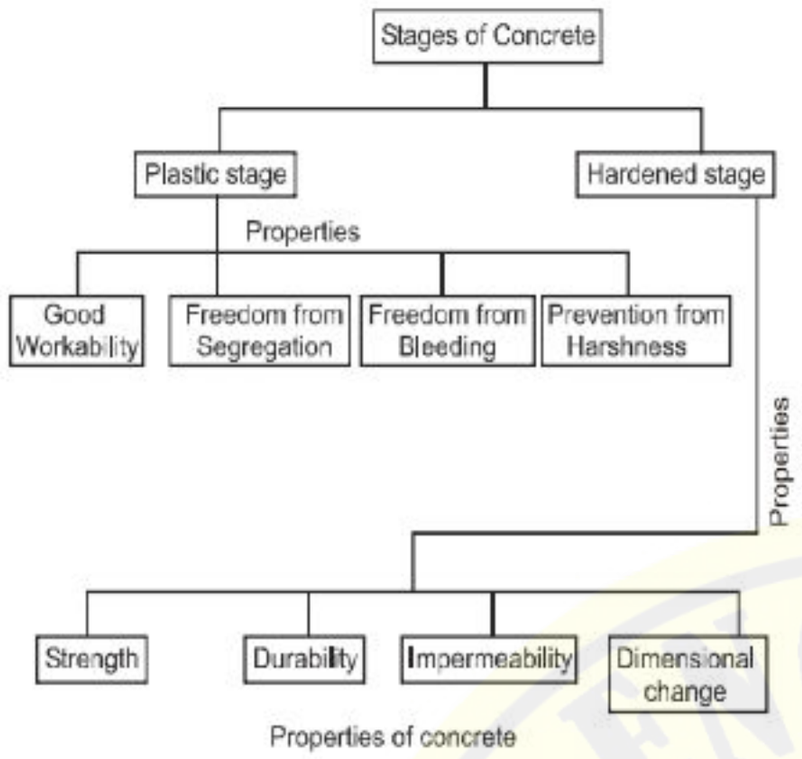


Fig. (2)

1. Properties of concrete in Plastic stage

(a) Good workability : Workability in simple term can be defined as "the ease with which the concrete can be mixed, transported, placed and compacted. A workable concrete mix does not result in bleeding or segregation.

(b) Freedom from Segregation : Segregation means separation of coarse aggregates from concrete in its Plastic Stage.

(c) Freedom from bleeding : The appearance of water along with some particles of cement and very fine sand on the surface of freshly placed concrete is known as bleeding. The term 'water gain' also means the same.

(d) Prevention from harshness : The concrete mix that does not give smooth surface with a certain amount of trowelling is known as harsh mix.

2. Properties of concrete in Hardness Stage.

In hardness stage, the properties of concrete are :

(a) Strength : The ability of concrete to resist load is called strength. Stronger concretes are stiffer, impermeable and durable. The strength of concrete may be :

(1) Crushing Strength
(2) Tensile Strength
(3) Bond Strength
(4) Shear Strength

(i) Lime is white in colour whereas colour of cement is greyish.

(b) Durability : Durability of concrete is the resistance to deterioration and disintegration due to temperature change variations in moisture content, action of water containing chemicals and weathering.

(c) Impermeability : Impermeability is the resistance of the concrete to the flow of water into the pre-space in it. Impermeability of concrete should be high.

(d) Dimensional changes : The following are the properties involving dimensional changes.

(i) Shrinkage : Shrinkage in concrete should be minimum.

(ii) Elasticity : A good concrete should have adequate elasticity or plasticity.

(iii) Thermal expansion : A good concrete should have minimum thermal expansion.

(iv) Creep : Creep concrete is sometimes beneficial and sometimes disadvantageous.

Advantages of Concrete

As compared to other construction materials, concrete has the following advantages.

1. Green or freshly prepared concrete can easily be moulded in any desired shape.
2. The materials used in the manufacture of concrete are easily available.
3. It is more durable, free from corrosion and weathering if properly designed.
4. It is not liable to rot or decay.
5. It is fire resistant.
6. It is almost impermeable to moisture.
7. It provides good architectural appearance to the structure.
8. The concrete can be pumped and hence can be used in difficult positions.
9. It is economical in the long run because of low maintenance cost of structures made from it.
10. Concrete can even be sprayed on and filled into fine cracks or voids for repairs by gruting process.
11. The concrete become stronger with age.
12. Construction of all types of structure is possible by reinforcing the concrete with steel. Even earthquake resistant structures can be constructed.

Uses of concrete in comparison to other building materials

The uses of concrete in comparison to other building materials are :

1. It is used for the construction of structure, especially for foundation in wet location.
2. It is used for providing damp-proof course. For this purpose, rich mix of plain cement concrete is generally used.
3. It is used for the construction of structural members subjected to bending or shear stresses. For this purpose, reinforced or prestressed concrete is used.
4. It is used for the construction of bridges, water tank industrial buildings etc.

5. It is used for the construction of concrete pipes, poles, sleepers, piles, etc. For this purpose, prestressed concrete is used.
6. It is used for the construction of thin shells, shelled roots (dome shaped), swimming pool etc.
7. It is used for the construction of fire proofing and insulation applications. For this purpose, light weight concrete is commonly used.

Ingredients of Concrete

The materials used in the manufacture of concrete are known as ingredients of concrete. The various materials used as ingredients of concrete are :

1. Cement
2. Aggregates
3. Water

These ingredients can be classified into two groups.

1. **Active Group :** The active group consists of cement and water.
2. **Inactive Group :** The inactive group consists of fine and coarse aggregates.

Cement

Cement is the most important ingredient of concrete and acts as a binding material. Cement has adhesive and cohesive properties. Cement is a material which possesses cementatitious, properties.

Functions of cement in concrete

(i) Cement binds the coarse and fine aggregates by filling the voids and chemically reacting with water.

(ii) It provides strength, durability and water tightness to the concrete. Cement is only about 10% of the volume of concrete mix.

Aggregates

Generally 85% of the volume of concrete is occupied by the aggregates. Aggregates are those inert material, which when bound together by cement form mortar or concrete. Aggregates are known as inert materials because they remain chemically inactive giving settings and hardening to cement. Aggregates mostly used for the manufacture of concrete are sand, gravel, broken bricks, blast furance slag, saw dust, crushed rock etc.

The aggregates are cheaper than cement and a concrete mix which makes use of maximum quantity of aggregates is economical. Aggregates provide, volume stability and better durability to concrete.

Requirement of Good Aggregate : A good aggregate should be chemically inert, sufficiently strong, durable and hard. Along with this :

(i) Lime is white in colour whereas colour of cement is greyish.

(i) It should be of limited porosity.

(ii) It should preferably be cubical or spherical in shape.

(iii) It should have rough surface.

(iv) It should be free from coatings or clay and other materials.

Water

Water is an important and the least expensive ingredient of concrete.

Functions of water : The function of water in the concrete are :

1. Chemical : For chemical reaction of cement for hydration of cement.

2. Physical :

(a) It distributes the cement evenly so that every particle of gravel and sand is coated by it and brought into intimate contact with each other.

(b) It acts as a lubricant and gives workability to mixture. Cement needs about 0.25 times its weight of water for chemical reaction. But some more water is required for proper workability of concrete.

Quality of Water : The quantity of water is also important as it affects the quality of the resulting concrete. For example impurities in the water affect the setting time of cement, strength of concrete and may cause corrosion of the reinforcement.

Water used for both mixing and crusing gives be free from injurious amount of deleterious materials. If a water is potable, it is generally accepted as suitable for mixing and curing of concrete.

(i) The pH value in water suitable for concrete construction shall generally between 6 to 8.

(ii) The water received from a tube-well is more suitable than that received from pond, river or lake.

The common impurities in water along with their permissible limits as specified in IS : 456-2000 are given in table below.

Table

Permissible limits of some common Impurities in Mixing Water

(As specified in IS : 456-2000)

S.No.	Impurities in Mixing water	Maximum Permissible Limits
1.	Organic	200 mg/litre
2.	Inorganic	3000 mg/litre
3.	Sulphates (as SO_4)	400 mg/litre
4.	Chlorides (as Cl)	(i) 2000 mg/litre for plain cement concrete. (ii) 500 mg/litre for rein forced cement concrete
5.	Suspended matter	2000 mg/litre

(iii) The water containing large quantities of chloride tends to cause dampness and surface efflorescence.

Curing Water : The water which is satisfactory for mixing concrete can also be used for curing it.

Water - Cement Ratio (w/c Ratio)

It is the ratio of weight of water in concrete mixed (exclusive of water absorbed by the aggregates) to the weight of cement.

$$\text{Water-cement ratio} = \frac{\text{Weight of water}}{\text{Weight of cement}}$$

It is usually expressed in litres of water required per bag (50 kg) of cement.

For example, if water - cement ratio is specified as 0.5, the weight of water required per bag (50kg) of cement is 25kg (0.5 × 50 = 25) = 25 litres.

Relation between water-cement ratio and strength of concrete

The compressive strength of concrete decreases with the increase in water-cement ratio. It can be seen that lower water-cement ratio could be used when the concrete is vibrated to achieve higher strength. Comparatively higher water-cement ratio is required when the concrete is hand-compacted. Each per cent of air voids decrease the strength by about 5%. Relationship between the strength of concrete and water - cement ratio gives approximately hyperbolic shape.

Hydration of Cement

The chemical reaction between cement and water is called hydration of cement. The chemical reaction take place between final compounds of cement tricalcium silicate (C_3S), dicalcium silicate (C_2S), tricalcium aluminate (C_3A) and tetracalcium aluminoferrite (C_4AF).

Out of these three active compound C_3A is the most active and reacts first with water. The reaction of C_3S is slower than that C_3A, but is faster than C_2S. The reaction of C_3S is responsible for the development of strength for the first 28 days, C_2S reacts slowly and reaction continues for years. It is responsible for ultimate strength of concrete. During the hydration of cement, the reaction product consists of 20 to 30% of calcium hydroxide $Ca(OH)_2$ which is crystalline. These crystalline products are surrounded with the hydrated calcium silicate and aluminates and the entire composition is called cement gel.

Case-I. Hydration of Cement with insufficient w/c ratio : With insufficient w/c ratio. it is found that water is not normally sufficient to hydrate each cement particle fully. It produces weak physical structure of hydrated cement and thus the strength of concrete is reduced.

Case-II. Hydration of cement with just sufficient w/c ratio : With just sufficient w/c ratio, the water available is just sufficient to hydrate each cement particle fully and the cement gel occupies all the space previously occupied by water and thus there are no voids. This is the stage when cement paste gives maximum strength.

Case-III. Hydration of cement with water is more than required w/c ratio : In this case, the water available is more than required for full hydration and even when full hydration takes place, the free water occupies a certain space in the concrete. The excess water leaves pores behind on evaporation. This reduces the strength.

Workability

Workability in simple terms can be defined as "the ease with the concrete can be mixed, transported placed and compacted". The workability of concrete has also been defined as the amount of work required to place concrete and to compact it throughly, it is the amount of energy required to overcome internal friction and cause full compaction.

1. Ease of flow (Internal Friction)
2. Prevention of segregation
3. Prevention of bleeding

When the mix acquires all these properties, it said to be workable.

Ease of flow (Internal Friction)

The ease with which the concrete flows depends upon the internal friction between the particular of concrete. To improve workability, therefore, it is necessary to reduce the internal friction. The internal friction can be reduced by the lubrication of the surface of aggregates. The lubrication can be improved in two ways:

(a) By increasing the quantity of water in a concrete mix. Greater the quantity of water in a concrete mix. more is the area it can be improved.

(b) The second way is to reduce the total surface area of the aggregates by adopting coarse aggregate. But coarse aggregate should not be used too much otherwise segregation will take place.

Segregation

The separation of coarse aggregate from the concrete mix in plastice stage is called segregation.

Causes of segregation : Segregation takes place when

(i) there is too much of water in the mix.

(ii) there are badly graded aggregates.

(iii) there are too much shocks to a concrete mix due to transport over longer distances, discharge of concrete from a considerable height (more than 1 m), pumping of concrete.

(iv) leakage of mortar from formwork.

(v) concreting is done under - water.

Prevention of Segregation

(i) The mix should be designed correctly and minimum amount of water should be used for mixing.

(ii) The height of free fall of concrete should not exceed 1 m in any case.

(iii) The air-entraining agents should be used for reducing segregation as these reduce the quantity of mixing water.

Harshness

The concrete mix which does not give smooth surface with a certain amount of trowelling is known as harsh mix.

Causes of Harshness

(i) The cement mortar not sufficient to fill the voids in the coarse aggregate.

(ii) The presence of excessive proportion of one particle size in an aggregate grading.

Bleeding

The appearance of water along with some particles of cement and very fine stand on the surface of freshly placed concrete after compaction is called bleeding. The term 'water grain' is also sometimes used instead of bleeding. Due to bleeding, water scum (Water + Particles of fine sand and cement) is formed on the concrete surface. This scum layer is known as maintenance.

Causes of bleeding

(i) Presence of excess water.

(ii) Deficiency of fine aggregate.

(iii) Excessive finishing.

Prevention of bleeding: Bleeding can be prevented by:

(i) Controlling the water content.

(ii) Providing finer grading of fine aggregate.

(iii) Using finely ground cement.

(iv) Controlling compaction.

(v) The air-entertining agents should be used to prevent bleeding.

Factor affecting workability

1. **Water Content :** With the increase in water content, the workability also increases. But too much water results into concrete of low strength poor durability.
2. **Size of Aggregate :** Workability increases with the aggregate. Large size particle provide less surface area as compared to surface area provided by smaller size particles. Hence, for same degree of workability less water is required for large size aggregate. This also reduce the quantity of cement for given water-cement ratio and is therefore economical.
3. **Shape of Aggregate :** Workability increases with round and smooth surface aggregates. Crushed or angular aggregate has less workability because of higher and rough surface area.
4. **Grading of Aggregate :** Grading is more important when lean mixes of high workability are required than rich mixes. For lean mixes, the grading should be continuous, whereas for rich mixes the grading should be rough and discontinuous.
5. **Porosity and absorption of Aggregate :** Porous and non-saturated aggregate will require more water than a non-porous and saturated aggregate. For same degree of workability, the latter will requires less quantity of water.
6. **Admixtures :** Workability also increases with the addition of admixtures such as air entraining agent which will depressed air bubbles. These air bubbles act as rollers thus increasing the workability but of course reduce the strength.
7. **Mixing Time :** With the increase in mixing time upto certain limit (say 2 minutes) workability increases.
8. **Temperature :** The slump of concrete mix decreases as the temperature of mix increases. Thus, the normal temperature help in the improvement of workability of concrete.

Measurement of Workability

The following are the method of measurement of workability :

Slump Test

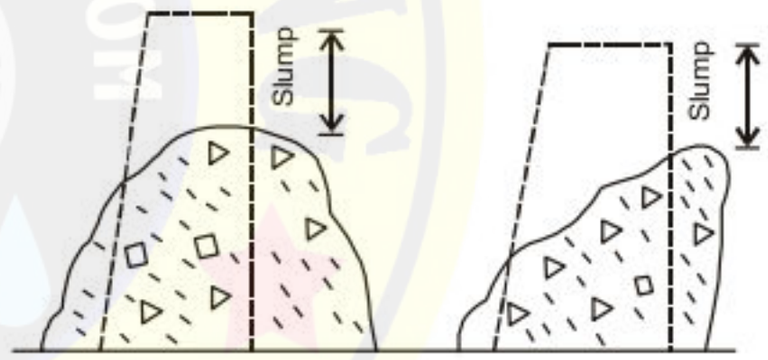
Slump is measured immediately by determining the vertical distance (in mm) between the height of the mould and that of height point of the specimen being tested.

The slump which is the subsidence of the concrete cone after the mould is lifted up can given the following three results.

(a) **True Slump :** If the concrete subside evenly it is known as true slump.

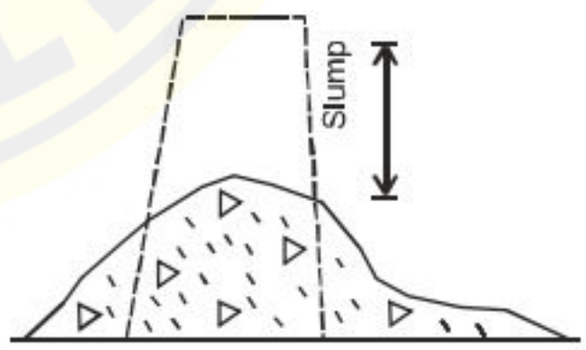
(b) **Shear Slump :** If one half of the concrete slides down as soon as the mould is removed as shown, it is known as shear slump. It is difficult to measure. as occurs in harsh-mixes.

(c) **Collapse Slump:** If the concrete slides down as soon as the mould is removed it is known as collapse slump. It is difficult to measure. as occurs in very wet mixes.



True Slump
(a)

Shear Slump
(b)



Collapse Slump
(c)

Table

Degree of workability with respect to slump value

S.No.	Slump value in mm	Degree of workability
1.	Compacting factor is suitable	Very low
2.	25 – 75	Low
3.	50 – 100	Medium
4.	100 – 150	High

Suitability : The method is widely adopted for determining the workability of concrete mix in the field (site of work). It is suitable only for the concrete of high or medium workability.

Recommended Slumps for placement in various conditions as per IS : 456-2000

Table

Recommended Slumps for placement in various conditions
(As per IS : 456-2000)

S.No.	Slump in mm	Degree of workability	Placing Conditions
1.	Compacting factor is suitable	Very low	(i) Blinding concrete (ii) Shallow section (iii) Pavements using powers
2.	25 – 75	Low	(i) Mass concrete (ii) Lightly reinforced section in slabs, beams, walls, columns. (iii) Floors (iv) Hand placed pavement (v) Canal linings (vi) Strip footings
3.	50 – 100	Medium	(i) Heavily reinforced section in slabs, beam, wall, columns (ii) Pumped concrete (iii) Slip form work
4.	100 – 150	High	(i) Trench fill (ii) In-situ pilling

Compacting Factor Test Table

Degree of workability with respect to compacting factor		
S.No.	**Compacting factor**	**Degree of workability**
1.	0.75 to 0.80	Very low
2.	0.87	Low
3.	0.935	Medium
4.	0.90	High

Suitability : This method is adopted for determining the workability of concrete mix in laborites. It gives fairly good results for concrete of low workability.

Vee-Bee Consistometer Test Table

Degree of workability with respect to Vee Bee Seconds		
S.No.	**Time in Seconds (Vee-Bee Seconds)**	**Degree of workability**
1.	20 – 40	Very low
2.	10 – 20	Low
3.	7 – 10	Medium
4.	3 – 7	High
5.	1 – 3	Very High

Suitability : This method is suitable for dry concrete having very low workability.

Mix Design : Normal mix may be used for grades M20 lower. There is no guarantee that a nominal mix will give a desired strength. For example, it is not necessary that a M20 nominal mix with adopted proportion (say 1:15:3) will have 28 days cube strength of 20 N/mm^2.

IS : 456-2000 suggests the proportions of materials required for nominal mix concrete as given in table.

Table

Proportion for Nominal Mix concrete (As per IS : 456-2000)			
Grade of concrete	**Total quantity of dry aggregate Per 50 kg of cement (kg)**	**Proportion of fine aggregate to coarse aggregate (by weight)**	**Maximum quantity of water per 50 kg of cement (litres)**
M 10	480	Generally 1 : 2	34
M 15	330	but upper limit is 1 : 1.5 and lower	32
M 20	250	limit is 1 : 2.5	30

Controlled concrete (Design Mix Concrete)

The concrete in which the proportion of cement aggregates and water are determined by conducting preliminary test for the design of mix is called controlled concrete. A design mix concrete is preferreds to a nominal mix concrete for durability, strength and economy.

Concreting Operations

The operations (Process) which are followed in actual practice in the making of concrete and in improving and maintaining the quality of concrete are known as concreting operations.

The following operations are involved in concrete making :

1. Storing of materials
2. Batching of materials
3. Mixing of various ingredients
4. Transportation of concrete mix
5. Placing of concrete
6. Compaction of concrete
7. Finishing of concrete surface
8. Curing of concrete
9. Joints in concrete

Stroage of Concrete Materials

The process of keeping the ingredients of concrete in their proper place to protect them from the effect of weathering is called storing.

Objectives of storing : Maintaning the quality and grading of materials is the main objective of storage of materials.

Storage of Cement

During the storage and transporting of cement, care is always taken to keep it away from moisture.

Storing of cement in a warehouse : Warehouse is a weather proof building for storage of cement.

Requirement (Details) of warehouse : The warehouse most fulfill the following requirements :

(i) Wall should be constructed of water-proof material brick masonry in cement mortar with plaster on both sides.

(ii) The roof should be made of R.C.C. and waterproofed properly by damp-proof course.

(iii) The windows should be a few and small. Windows and constructed as near to the celling as possible.

(iv) The floor should be of at least of 150 mm thick concrete.

(v) Doors are so arranged that the loading and unloading can be done conveniently.

Method of storing cement in a warehouse (Precaution in storing cement) :

(i) The cement bags should be placed directly over the floor if it is dry and if not then the bags should be placed on a raised platform made of wooden planks.

(ii) The space between the exterior wall and plies should be 0.30 m (A group of number of bags arranged together closely is called a pile).

(iii) The height of pile should not be more than 15 bags placed on each other. The width of pile should not be more than 3 m.

(iv) The cement bags should be placed in header course and stretcher course alternatively if height of pile exceeds 1.44 m (8 Bags).

(v) Cement bags should be removed on the particles of first in and first out. For this purpose each consignment should be piled separately and date plates should be kept,showing date of arrival.

Storing of Aggregates

Storing of aggreates should be done in such a way as to :

(i) Maintain the uniformity of grading

(ii) Prevent segregation

(iii) Maintain uniform surface water condition

(iv) Avoid mixing of harmful material in the aggregates.

Storing of Water

Water is stored at site in a masonry tank for the purposeful use or in other clean containers. The walls of the tank should be somewhat higher than the surrounding ground. Sufficient quantity of water should be stored in advance to ensure the continuity of concreting operations. If the water obtained from a source contain dust etc. It should be collected a day in advanace to allow such suspended impurities to settle down before use.

Batching

The process of measurement of ingredients (cement, fine aggregate, coarse aggregate and water) for making concrete is called batching.

Batching is done in two ways :

1. Volume batching 2. Weight batching

The water is usually measured by volume since this can be done quite accurately.

2. Weight Batching

(a) Batching of cement : Cement is always batched by weight. Mostly it is batched in term of 50kg bags. Cement should never be batched by volume because its weight per unit volume varies according to compacting effort used in filling the container (forma).

(b) Batching of aggregates : Batching of aggregate by weight is preferable. In weight batching no correction needs to be made for bulking of sand but the only correction made is for weight of water contained by wet aggregates.

Mixing of Concrete

The process of mixing of various ingredients of concrete in specified proportions is termed as mixing of concrete.

Objective of Mixing : The quality and strength of concrete depends upon proper mixing. The object of mixing is to coat the surface of all aggregate particle with cement paste and to obtain concrete of uniform colour and desired consistency.

1. Volume Batching

(a) Batching of Cement : Cement is always batched by weight. Cement should never be batched by volume, because it's weight per unit volume according to which container (forma) is filled.

(b) Batching of aggregates : Wooden batch boxes known as formas are used for batching a fine and coarse aggregates by volume. The formas should be made of 30 mm thick timber. While filling the forma, the material should be filled loosely and no compacting should be allowed. After filling aggregate in forma, the top of the forma should be levelled straight. Inside dimension of the formas depend upon their capacity in litres. Forma larger than 50 litres are difficult to handle. The moisture present in aggregates and bulking of sand must be considered when batching is done volume wise. Volume batching is normally adopted in ordinary concrete, even though measurment by weight is preferable whenever possible.

(e) Batching of water : It is practice in the field to add water by tin cans or buckets. It is not an accurate method. It results in variable strength of concrete.

Methods of mixing : There are two methods of mixing :

(1) Hand mixing

(2) Machine mixing

1. Hand Mixing : The Process of mixing the ingredients of concrete by manual labour is called hand mixing.

Hand mixing is adopted for small and unimportant works and where quantity of concrete used in small. Hand mixing method requires more cement (10% more) than machine mixing for obtaining the same strength of concrete.

2. Machine mixing : The process of mixing the ingredients of concrete by a machine is called machine mixing.

In case where a large quantity of concrete is to be produced, hand mixing becomes costly even if the labour is cheap. The machine mixing become essential. The concrete can thus be produced at a faster rate and at a cheaper cost. The quality of concrete by machine mixing is also better.

Mixers

The machine used for mixing of concrete material is known as a concrete mixer.

There are two types of mixtures:

1. Batch mixers
2. Continuous mixers

1. Batch Mixers : Batch mixer mix and discharge. Batch mixers can be of any one of the following types:

(a) Non-tilting type mixer or Rotary type mixer

(b) Tilting type mixer.

Transportation of Concrete

The process of carrying concrete mix from the place of its mixing to final position of deposition is called transportation of concrete.

Precautions in Transportation of Concrete :

(i) Concrete should be transported as quickly as possible to the formwork within the intial setting time of cement.

(ii) Efforts should be made to prevent segregation.

(iii) The concrete mix should be protected from drying in hot weather and from rain during transportation.

(iv) The concrete should be kept agitated in truck mixer so that it does not become stiff when transportation is likely to take more time.

(v) No water should allowed to be lost from the mix during transportation.

Formwork

The temporary construction used as a mould for the structure in which the concrete is placed and in which it hardens is called formwork or shuttering. The economical design and construction of formwork is of great importance sinch the cost of formwork may be upto 30 to 40% of the cost of concrete work.

The various materials used for formwork are:

1. Timber
2. Plywood
3. Hardboard
4. Steel
5. Formwork lining

(B) Form stripping and stripping time : The operation of removing the formwork is known as stripping. In no circumstance shall forms be removed until the concrete reaches a strength of at least twice the stress to which the concrete may be subjected to at the time of removal of formwork.

The period of time upto which the forms must be left in place before they are stripped is called stripping time. It depends upon.

(i) the loads coming on member immediately after stripping.

(ii) the position of the form work

(iii) temperature of the atmosphere

Table : Stripping Time For formwork (As per IS : 456-2000)

S.No.	Name of R.C.C Structure	Stripping Period
1.	Wall, columns and vertical sides of beam	16 to 24 hours
2.	Slabs (Props left under)	3 days
3.	Beam soffits (props left under)	7 days
4.	Removal of Props under slabs (a) Spanning upto 4.5 m	7 days
	(b) Spanning over 4.5 m	14 days
5.	Removal of props under beam and arches (a) Spanning upto 6 m	14 days
	(b) Spanning over 6 m	21 days

Cambler : It is generally desirable to give work forms an upward camber to ensure that the becomes compact and do not have a sag when they have taken up their deflection. But this should not be done unless allowed for in design calculations of the beams.

MORTAR

It is used to describe the paste obtained by the addition of water in the mixture of binding material like cement or lime and aggregates (like sand).

The binding material used for the preparation of mortar is also termed as matrix and aggregate used is called adulterant.

Qualities of sand to be used in mortar :

(i) It should be free of organic matter or vegetative material.

(ii) It should be chemically inert.

(iii) It should not contain chemical salts that absorbs the moisture from the atmosphere.

Eg. [Alkalies (NaOH, KOH) causes efflorescences]

(iv) The sand used for formation of mortar should be well graded.

Functions of Sand in Mortar :

1. **Bulk :** Sand in mortar does not imparts strength to it but helps in adding bulk or volume which in turn makes the mortar more economical.
2. **Strength :** Sand helps in adjustment of the strength of the mortar achieved by increasing or decreasing proportion in mortar.
3. **Surface Area :** Sand sub-divides the paste of the binding material into number of layers thereby increases the surface area over which mortar can be spread or adhered.
4. **Shrinkage :** Sand in mortar helps in reducing the shrinkage during the setting process thereby prevents its crashing hence, increasing the durability of structure.

[Fine sand used - Shrinkage is less]

[Coarse sand used - Shrinkage is more]

Quality of Good Mortar :

(1) The mortar should not affect the durability of the construction unit in which it comes in contact with.

(2) It should be capable of developing the design stresses.

(3) It should be capable of assisting the penetration of water than the structure and offer high water tightness over the limit.

(4) It should be cheap, durable and easily workable.

◆ **Types of Mortar Depending Upon Different Construction Activity :**

	Types of Construction	Types of Mortar
1.	Pointing works	Cement Mortar (1:1)
2.	Damp proof course (DPC)	Cement Mortar (1:2)
3.	Cement Pavement	Cement Mortar (1:2)
4.	Plastering	Cement Mortar (1:3) Or lime Mortar (1:2)
5.	Masonry Infra superstructure	Cement Mortar (1:3) Or lime Mortar (1:3)
6.	Masonry foundation	Cement Mortar (1:6) Or Lime Mortar (1:3)

Application of Mortar :

1. Preparation of surface
2. Dampening
3. Gauging
4. Pointing
5. Brushing

Ex : Take 150 g of mortar for plastering amount of

cement = $\frac{1}{4}$ × 150 (25% of 150) (1:3)

37.5 gs of cement

amount of lime = $\frac{1}{3}$ × 150 50g s of lime (1:2)

∴ 37 of cement strength = 50 gs of lime strength.

ADMIXTURES :

Admixtures are minerals (other than cement, water and aggregates) used in concrete mix to modify one or more of its properties in the plastic or hardened state.

FUNCTIONS OF ADMIXTURES :

(i) To accelerate or retard the rate of hydration of cement.

(ii) To increase the strength durability and workability of of concrete.

(iii) To retard the initial setting time.

(iv) To increase the resistance to chemical attack.

(v) To reduce bleeding and segregation of concrete mix.

(vi) To increase the resistance to freezing and thawing.

(vii) To improve the penetration and pump-ability of concrete.

CLASSIFICATION OF ADMIXTURES :

There are two types of admixtures:

(1) Chemical admixtures :

(a) Accelerators

(b) Retarders

(c) Water-reducing admixtures

(d) Air-entraining admixtures

(e) Plasticizers.

(2) Mineral admixtures :

(a) Fly ash (b) Silica fume

(c) Rice husk ash (d) Metakaolin

ACCELERATING ADMIXTURES (ACCELERATORS)

Accelerators are the chemicals used to accelerate the setting and hardening of concrete.

Accelerators are added to concrete to :

(i) increase the rate of hydration hence, to increase the rate of strength development.

(ii) reduce the setting time.

The accelerators many help in :

(i) early removal of formwork

(ii) reduce the required period of curing

(iii) emergency repair work.

Materials used as accelerators are :

(i) Calcium chloride

(ii) Some soluble carbonates, silicates and fluorosilicate.

(iii) Organic compounds such as triethanolamine. In the past one of the commonly used material as an accelerator was calcium chloride (5%). But now a days it is not used. The recent studies have shown that calcium is harmful for reinforced concrete and prestressed concrete.

RETARDING ADMIXTURES(RETARDERS)

Retarders are the chemicals used to delay the setting and hardening of concrete. Trader slow down the chemical process of hydration so that concrete remains plastic and durable than concrete without the retarder.

Retarders are used in hot weather concreting. These are also used in ready mixed concrete so that concrete when finally placed and compacted is in perfect plastic stage.

Material used as retarders are :

(v) Doors are so arranged that the loading and unloading can be done conveniently.

(i) Calcium sulphate

(ii) Sugar

(iii) Skimmed milk

(iv) Ammonium chloride

(v) Calcium borate

(vi) Calcium tartrate

(vii) Ferrous and ferric chlorides

(viii) Calcium acetate

(ix) Mucic acid

WATER REDUCING ADMIXTURES

These are used to :

(i) Increase the workability of freshly mixed mortar or concrete without increasing water-cement ratio.

(ii) Maintain workability with reduced water-cement ratio.

Sugar in addition to acting as a retarder, improves the workability of concrete also. Carbohydrates and organic acids are other example of water-reducing admixtures.

AIR–ENTRAINING ADMIXTURE

The main object of entraining air in concrete are :

(i) to increase the workability of concrete.

(ii) to decrease the bleeding and segregation

(iii) to improve the resistance of concrete to frost.

Uses :

Plasticizers can be easily used where a high degree of workability is required in situation such as in:

(i) Deep beams

(ii) Thin walls of water retaining structure with high percentage of steel reinforcement

(iii) Column and beam junctions

(iv) Tremie concrete

(v) Pumping of concrete

FLY ASH :

The use of fly ash as an admixture reduces segregation and bleeding. At early ages there is a decrease in the compressive strength which disappears at age of 3 months and more. It also reduces the permeability of the concrete.

Uses :

Concrete with fly ash as admixture is used for mass concrete (e.g. dams, retaining, wall etc.).

The uses of fly ash as a replacement of sand in a lean mix increases the workability and it has appreciable effect on the drying shrinkage of concrete. It reduction the permeability of concrete improves the resistance to sulphate water action under cold climatic conditions.

Materials used as air-entraining admixtures are:

(i) Natural wood resins e.g. vinsol resin.

(ii) Animals and vegetables fats and oils like olive oil, stearic acid and oleic acids.

(iii) Alkali salts of sulfonated or sulfated organic compound e.g darex.

(iv) Miscellaneous materials such as the sodium salts of petroleum sulphonic acids, aluminium powder etc. Vinsol resin is used in mass concrete and concrete used in highway pavements.

PLASTICIZERS (PLASTICIZING ADMIXTURE)

Plasticizing admixture is a substance which imparts very high workability with a large decrease in water content (at least 20%) for a given workability. It also permits the use of lower water cement ratio for the same workability.

Material used as plasticizers are :

(i) lignosulphonates

(ii) hydroxylated carboxylic acids.

(iii) carbohydrates. However Calcium,sodium and ammonium lignosulphonates are mostly used as plasticizers.

SILICA FUMES

The use of silica fumes as admixture in concrete has the following effects.

(i) Modulus of elasticity increases

(ii) Low creep

(iii) Low drying shrinkage

(iv) Excellent freeze thawing resistance

(v) Low permeability

(vi) Chemical resistance increases

(vii) Reduced bleeding

RICE HUSK ASH

Rice husk ash shows high pozzolance characteristics. It contributes to high strength and high impermeability of concrete. along with resistance to acid environments.

METAKAOLIN

High reactive metakaolin as admixture increases the strength and decreases the permeability of concrete.

PLACEMENT OF CONCRETE

The process of depositing the concrete in its required position is known as placement of concrete. The quality of concrete also depends on the method of placing it. If not placed properly, segregation will take place.

Preparation of Surface Before placing Concrete:

It is very essential to prepare base before placing the concrete mix in order to develop proper bond between the base and fresh concrete. Before placing concrete, different types of base should be prepared as discussed below.

1. **Base on natural soil :** In natural soil the base should be properly trimmed to required shape and compacted. It should be kept moist so that the soil does not absorb moisture from the concrete.
2. **Rocky Base :** All loose material should be removed before concrete is placed. Whenever possible, the rock should be cut vertically and horizontally(known as benching) instead of sloping. This provide good key with the new concrete.
3. **Specially prepared base (Brick soling and water bound macadam base) :** When the concrete is to be placed on specially prepare base brick soling and water bound macadam surface, the surface should be brushed and cleaned of dust and all loose particles. It should be kept moist before. the beginning of concreting .
4. **Hardened concrete bases :** When fresh concrete is to be placed on hardened concrete, it should be exposed by making the base rough.

Precautions During Placing of Concrete:

(i) The concrete should not be dropped from a height of more than 1m to prevent segregation.
(ii) Construction should be stopped in heavy rains unless suitably.
(iii) The laitance should be removed before placing new concrete.
(iv) Oiling should be done on the internal surface of steel formwork so that concrete, may not stick to it.

COMPACTION OF CONCRETE:

Compaction of concrete is a process of eliminating the entrapped air in concrete and achieving maximum density. The strength of concrete is reduced by about 30% with presence of only 5% voids. The compaction reduces voids to a minimum.

Method of Compaction:

1. Hand (Manual) compaction
2. Machine compaction

1. Hand compaction: In certain concreting works like beams, columns etc, compaction is done by inserting a rod vertically into plastic concrete and moved up and down. It sets the concrete in motion and air bubbles present in the concrete flow to the surface. This type of hand compaction is called 'tamping'. In mass concrete, the thickness of layer iron compaction should not be more than 0.30m and 0.15m for R.C.C.

2. Machine compaction : The equipment used for compaction of concrete by mechanical method is called a vibrator. The following three types of vibratorp are commonly used.

(a) Internal vibrator
(b) Form vibrator
(c) Screed vibrators.

Selection of Vibrators

S.No.	Type of Vibrator	Places where used
1.	Internal	For general concrete work sufficient thickness and width mass concrete in structure, concrete of column, beam etc.
2.	Form	For thin arches, tunnel lining and per cast units.
3.	Screed	For thin horizontal surface such as roads, floors etc.

Precautions for compaction of concrete with vibrator:

(i) The formwork should be strong and water tight to avoid leakage of mortar.
(ii) Vibrator should be inserted vertically.
(iii) Vibrator stay should not be prolonged at any one position.
(iv) Over use vibrators should be avoided as it will lead to segregation.
(v) Vibrators should be withdrawn slowly so that the hole resulting from the insertion of vibrators closes automatically.

FINISHING OF CONCRETE SURFACE :

Finishing may be defined as the process adopted for obtaining a true, uniform concrete surface.

Importance of finishing : The importance of finishing is to keep the concrete surfaces free from undulations. The vibrating or hand tamping of concrete leaves a slightly rough surface. Finishing of concrete surface is therefore important. The choice of concrete finish depends upon, the ultimate use of the component and desired, aesthetic effect.

Finishing Operations : The following operations are carried out for finishing the slabs and floors.

1. **Screeding (Striking off) :** Screeding is the process of striking off the excess concrete to bring the top surface to proper grade. This is done by a tempiate (screed).

2. **Floating :** The process of removing irregularities from the surface of concrete after screeding is called floating. It helps in levelling the surface and compacting the concrete. The floating is done using a wooden float.

   Bull Float : It is used if the area of concrete surface is large.

3. **Trowelling :** The final operation of finishing is called trowelling. The purpose of trowelling is to give smooth and dense surface. It should be done after excess water has evaporated and when considerable pressure frequired to make any impression on the concrete surface has aheady been applied. The trowelling is done by steel trowels.

Broom finish : For roadways, perestrian paths etc. a rough surface is required. A rough surface can be made with a stiff broom crosswise to the direction of trowelling.

CURING OF CONCRETE : The process of keeping the concrete moist to enable to gain strength is called curing. Curing is the name given to procedure used for promoting the hydration of cement. The concrete hardness because of hydration, a chemical reaction between water and cement. The reaction depends on the presence of water. Although there is sufficient water at the time of mixing yet it is necessary to ensure that the water is retained to enable the chemical reaction to continue.

Objects of curing :

(i) It prevents loss of moisture from concrete due to evaporation thus maintaining the process of hydration.

(ii) It reduces shrinkage of concrete.

(iii) It improves wear resisting and weather resisting properties of concrete.

(iv) It maintains the uniform temperature throughout the whole of concrete.

(v) It increase impermeability and durability of concrete.

Method of curing :

1. Shading of concrete work.
2. Covering concrete surface with gunny bags.
3. Sprinkling of water
4. Ponding method
5. Membrane curing
6. Steam curing

Duration of curing : Strength of concrete increases with the duration of curing. It also increases other concrete properties. Therefore curing should be continued for longer periods. As per IS 456 : 2000 the curing for ordinary Portland cement must be carried at least for 7 days from the date of placing concrete. In 7 days concrete attains about 67% of designed strength.

Strength of ordinary Portland cement with different periods of curing

S.No.	Period of curing	Strength in Percentage
1.	1 days	16
2.	3 days	40
3.	7 days	67
4.	28 days	100
5.	3 months	122
6.	6 months	146
7.	1 year	155

DEFECTS IN CONCRETE : Though concrete is a relatively durable building material, it may suffer damage/defect during its life period due to a number of reasons. Even if good materials, strict quality control and excellent workmanship is employed in the making of concrete, there is every possibility of development of defect such as cracks, formation of holes, bulges and projection honeycombing stain etc. The various causes for these defects can be :

(i) Externally applied and environmental loads exceeding the design load.

(ii) Accidents and subsidences.

(iii) Poor construction practices.

(iv) Adverse weather conditions.

(v) Plastic shrinkage.

(vi) Corrosion or reinforcement.

REPAIR AND MAINTENANCE OF CONCRETE

Repair of Concrete :

The method and the process adopted to remove the defects in concrete is call repairs of concrete.

Maintenance of concrete : The art of preserving and keeping the concrete surface in order, to prolong its useful life is called maintenance of concrete. Generally the maintenance is done periodically normally annually.

METHOD OF REPAIRING CRACKS AND HOLES

1. Dry Pack Method : This method is mainly adopted for small holes of depth not exceeding 25mm. The holes should be sharp and square at the surface. The inside corner of the holes should be rounded. The interior surface should be roughened enough to develop an effective bond.

2. Concrete Replacement Method : This method is used in following cases.

(i) When holes extend entirely through the concrete section.

(ii) When surface area of holes in plain concrete is more than 900 cm^2 width depth of 100 mm or more in new concrete and 150 mm or more in old concrete.

(iii) When surface area of holes in reinforced concrete is more than 450 cm^2 and the area of hole is more than the depth at which reinforcement is provided.

3. Mortar Replacement method : This method is adopted for repairing holes of intermediate size depth varying from 25 mm to 100 mm.

CONCRETING UNDER SPECIAL CONDITIONS

There are three special conditions which concreting has to be done with specific car.

COLD WEATHER CONCRETING : Any concreting operation done at a temperature below 5°C is known as cold weather concreting. Concreting is not recommended to be practiced at a temperature below 5°C without proper precautions.

Effects of Low Temperature on Concrete :

1. Delay in setting and hardening
2. Freezing of concrete at early age.

Precaution Cold Weather Concreting :

1. Precautions before concreting :

(i) Aggregates and cement should be stored on wooden platforms. wele covered with tarpaulins gunny bags etc.

(ii) Wind breakers(tarpaulin,plastic sheet etc.) should to be erected to shield the mixing and batching plants.

(iii) The water should be heated(below 60°C). The aggregates should be heated if temperature is below freezing temperature.

(iv) Concrete should never be placed on frozen ground.

(v) Use accelerators carefully.

2. Precautions after placing concrete :

(i) The formwork and exposed faces of concrete should be insulated to preserve the heat of hydration.

(ii) The concrete surface should be covered by tarpaulins or water proof paper till it hardens.

(iii) Curing should be continued for a longer period than in normal conditions. Concrete should be cured in cold weather for a period atleast 15 days.

HOT WEATHER CONCRETING : Any operation of concreting done at temperature above 40°C is called hot weather concreting. Concreting is not recommended to be placed at a temperature above 40°C without proper precautions.

Effect of Hot weather on Concrete :

1. High temperature causes rapid evaporation of water that causes plastic shrinkage. This plastic shrinkage increases when high temperature are accompanied with high velocity winds and lower reduction in strength.
2. The rate of hydration decreases with the increase in temperature. Faster the reaction, poorer is the quality of gel formation and lesser is the strength of concrete.
3. High temperatures also reduce the setting time and the concrete may harden even before compacting operation. In such a case, flat surface such as road, pavements, floors, etc. cannot be finished easily.

Precautions in hot weather concreting

1. Precaution before placing concrete :

(i) The water should be available in plenty for sprinkling aggregates, wood forms, sub-grades and curing.

(ii) The tarpaulin should be ready for sun shades and wind-breaks.

(iii) Restrict the concreting operation to evening or night hours.

(iv) The materials used should be cool.

(v) The water should be sprinkled over forms, reinforcement, steel and subgrade before the concreteing.

2. Precautions during and after concerting

(i) There should be no delay in transporting and placing of concrete.

(ii) The concrete should be protected in hot, dry and windy days by erecting temporary sun-shades or wind breakers.

(iii) The concrete should be covered in case of slabs or road pavements with wet hessian cloth. Only that part of the concrete surface should be uncovered which requires finishing.

(iv) The curing should be carried out without any delay.

(v) The curing time should not be less than 7 days.

(vi) Retarders need to be used with almost possible care.

Under-water concerting : It is concreting done in the submerged conditions.

Precautions during under-water concreting

1. The temperature of the concrete when placed should in range of 16°C - 38°C.
2. Atleast 10% more cement should be used than that required for same mix placed in the dry.
3. The water-cement ratio should not exceed 0.6.
4. The quantity of coarse aggregate should be about 1.5 to 2 times that of the fine aggregate.
5. Slump of concrete should not be less than 100 mm and not more than 180 mm.
6. The concrete should be placed continuously until it is brought to required height.

Method for placing concrete under-water

1. Tremie
2. Drop bottom bucket
3. Placing in bags
4. Grouting

Concreting in sea-water : Concrete in sea-water or exposed directly along the sea cost shall be at least of M20 grade in the case of plain concrete and of M30 in the case of reinforced concrete. The use of blast furnance slag cement or pozzolana cement is advantageous under such conditions.

Concreting in Alkali soils and Alkaline water : Where concrete structures are directly to sea water such

as exposed to water of moderate alkali concentrations a high alkali resisting cement like high alumina cement shall be used. The concrete shall be designed for a minimum compressive strength of 24.5 N/mm^2 and shall contain not be less than 370kg of cement per cubic metre of concrete in place.

Reinforced cement concrete: Basically plain cement concrete is strong in compression but weak in tension. In order to increase the tensile strength of concrete steel bars known as reinforcement are embedded in concrete. It is known as reinforced cement concrete (R.C.C.)

Pre-stressed concrete: Here in this type of concrete, high tensile steel wires are used as reinforcement instead of mild steel bars. Basically there are two types of prestressing namely Pre-tensioningand post tensioning.In case of pre-tensioning method, the wires are initially stressed and the concrete is cast in the moulds builts around the wires. The wires released after the concrete attain its strength. The tendency of the wires to return to their original length sets up a compression in concrete, which helps the concrete to resist more tensile stress.

In case of post tensioning method, the wires are placed inside the concrete and then stressed. The use of prestressed concrete results in saving of concrete and steel to the extent of 50% and 80% respectively compared to R.C.C.

Light weight concrete: Production of this type of concrete is achieved from a wide variety of both natural earth substance and fly ash. It mainly consists of cement, aggregates of loose porosity, steel and water. The bulk density of this concrete varies from 500 to 1800 kg/m^3 whereas the bulk density of ordinary concrete is about 2300 kg/m^3.

The advantage of light weight concrete are,

(1) Local industrial waste can be economically utilised to prepare this type of concrete.
(2) It has a high water absorption property.
(3) The use of light weight concrete results in the reduction of cost to the extend of about 30 to 40% or so.
(4) It has better insulating and fire resisting properties.
(5) Its weight is less.
(6) It saves the cost of material handling because of its lightness.

No fines concrete: This type of concrete consists of cement, coarse aggregate and water. Thus fine aggregate or sand is eliminated. This concrete has been adopted for cast-in-situ external load bearing walls of single and multi story houses, small retaining walls etc. The advantages are:

(1) On drying, shrinkage is low.
(2) There is direct saving in material requirements as the concrete does not require sand.
(3) The unit weight of no-fines concrete is about 2/3 of the unit weight of conventional concrete.
(4) It possesses better insulating properties.
(5) As there is absence of capillary passages, there is no transmission of water by capillary action.

Pre-cast Concrete: This type of concrete is manufactured in a factory and the transmitted to the site. The advantages are:

(i) When holes extend entirely through the concrete section.
(1) Concrete of superior quality is produced.
(2) The work can be completed in short time.
(3) The pre-cast articles may be given the desired shape and finish with accuracy.
(4) The pre-cast structures can be dismantled when required and they are then be suitably used elsewhere.
(5) The labour required in the manufacturing process of pre-cast units can be easily trained.

Fibre Reinforced Concrete (FRC): This type of concrete mainly consists of cement, fibre, sand and water. Asbestos, glass, nylon or coconut have been tried as alternative to steel. The advantages are:

(1) Production rate is less.
(2) It has thin sections.
(3) Less maintenance cost.
(4) More durable.

USES OF CONCRETE

(1) Lean Concrete is used to get a level surface below foundation and road pavements.
(2) Concrete is also used in the construction of nuclear reactor because of its high shielding capacity from radio activity.
(3) Prestressed concrete is used in the construction of bridges and flyovers.
(4) Coloured concrete is used for ornamental finishes in buildings.
(5) Concrete is used in the construction of road pavements, runways and sleepers in railways.
(6) Concrete is mainly used in the construction of foundations, columns, floors, roof slabs, beams, lintels, water tanks, sumps etc.
(7) Concrete is used in construction of bunkers, silos etc.
(8) Concrete is used in massive structures such as dams and bridges.

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