LECTURE NOTE

on

CIVIL ENGINEERING MATERIALS & CONSTRUCTION

COURSE CODE: BCE 203

SYLLABUS

Module Number	Chapter Number	Title	Lecture hours (3-1-0)
1	1	Brick	3
	2	Cement	4
	3	Concrete	3
		Total	**10**
2	4	Arches	3
	5	Cavity Wall	2
	6	Stairs	3
		Total	**8**
3	7	Fire Resistive Construction	2
	8	Plastering	2
	9	Damp prevention	2
		Total	**6**
4	10	Types of doors and windows	3
	11	Painting and decoration	2
	12	Glazing	2
	13	Repair of Building	2
	14	Stone	1
	15	Timber	4
	16	Foundation	2
		Total	**16**
		Total lecture hours	**40**

Text books

1. A Text book of Building Construction, S.P. Arora and S.P. Bindra, Dhanpat Rai & Sons.

Reference books

1 A Text Book of Building Materials, C.J. Kulkarrni
2 Building Materials, P. C. Varghese, PHI, Pvt. Ltd.
3 Building Construction, P. C. Varghese, PHI, Pvt. Ltd.

1. BRICK

Constituents of good brick earth:

Bricks are the most commonly used construction material. Bricks are prepared by moulding clay in rectangular blocks of uniform size and then drying and burning these blocks. In order to get a good quality brick, the brick earth should contain the following constituents.

- Silica
- Alumina
- Lime
- Iron oxide
- Magnesia

Silica

- Brick earth should contain about 50 to % of silica.
- It is responsible for preventing cracking, shrinking and warping of raw bricks.
- It also affects the durability of bricks.
- If present in excess, then it destroys the cohesion between particles and the brick becomes brittle.

Alumina

- Good brick earth should contain about 20% to 30% of alumina.
- It is responsible for plasticity characteristic of earth, which is important in moulding operation.
- If present in excess, then the raw brick shrink and warp during drying.

Lime

- The percentage of lime should be in the range of 5% to 10% in a good brick earth.
- It prevents shrinkage of bricks on drying.
- It causes silica in clay to melt on burning and thus helps to bind it.
- Excess of lime causes the brick to melt and brick looses its shape.

Iron oxide

- A good brick earth should contain about 5% to 7% of iron oxide.
- It gives red colour to the bricks.
- It improves impermeability and durability.
- It gives strength and hardness.
- If present in excess, then the colour of brick becomes dark blue or blakish.
- If the quantity of iron oxide is comparatively less, the brick becomes yellowish in colour.

Magnesia

- Good brick earth should contain less a small quantity of magnesia about1%)
- Magnesium in brick earth imparts yellow tint to the brick.
- It is responsible for reducing shrinkage
- Excess of magnesia leads to the decay of bricks.

Harmful Ingredients in Brick:

Below mentioned are some of the ingredients which are undesired in brick earth.

Lime

- A small quantity of lime is required in brick earth. But if present in excess, it causes the brick to melt and hence brick looses its shape.
- If lime is present in the form of lumps, then it is converted into quick lime after burning. This quick lime slakes and expands in presence of moisture, causing splitting of bricks into pieces.

Iron pyrites

- The presence of iron pyrites in brick earth causes the brick to get crystallized and disintegrated during burning, because of the oxidation of the iron pyrits.

- Pyrites discolourise the bricks.

Alkalis

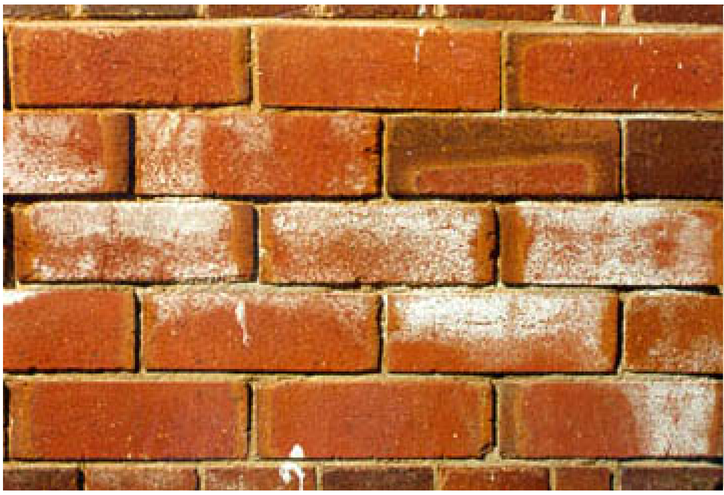
- These are exist in the brick earth in the form of soda and potash. It acts as a flux in the kiln during burning and it causes bricks to fuse, twist and warp. Because of this, bricks are melted and they loose their shape.
- The alkalis remaining in bricks will absorb moisture from the atmosphere, when bricks are used in masonry. With the passage of time, the moisture gets evaporated leaving grey or white deposits on the wall surface (known as**efflorescence**). This white patch affects the appearance of the building structure.

Pebbles

- Pebbles in brick earth create problem during mixing operation of earth. It prevents uniform and through mixing of clay, which results in weak and porous bricks
- Bricks containing pebbles will not break into shapes as per requirements.

Vegetation and Organic Matter

- The presence of vegetation and organic matter in brick earth assists in burning. But if such matter is not completely burnt, the bricks become porous. This is due to the fact that the gasses will be evolved during the burning of the carbonaceous matter and it will result in the formation of small pores.

Efflorescence in BrickStone in Brick

Manufacturing of bricks

In the process of manufacturing bricks, the following distinct operations are involved.

- Preparation of clay
- Moulding
- Drying
- Burning

Each of the above operation of the manufacturing bricks will now be studied at length.

Preparation of clay

The clay for brick is prepared in the following order.

- Unsoiling
- Digging
- Cleaning
- Weathering
- Blending
- Tempering

Unsoiling: The top layer of the soil, about 200mm in depth, is taken out and thrown away. The clay in top soil is full of impurities and hence it is to be rejected for the purpose of preparing bricks.

Digging: The clay is then dug out from the ground. It is spread on the levelled ground, just a little deeper than the general level. The height of heaps of clay is about 600mm to 1200mm.

Cleaning: The clay as obtained in the process of digging should be cleaned of stones, pebbles, vegetable matters. If these particles are in excess, the clay is to be washed and screened. Such a process naturally will prove to be troublesome and expensive.

Weathering: The clay is then exposed to atmosphere for softening and mellowing. The period varies from few weeks to full season.

Blending: The clay is made loose and any ingredient to be added to it , is spread out at its top. The blending indicates intimate or harmonious mixing. It is carried out by taking a small amount of clay every time and turning it up and down in vertical direction. The blending makes clay fit for the next stage of tempering.

Tempering: In the process of tempering, the clay is brought to a proper degree of hardness and it is made fit for the next operation of moulding .Kneaded or pressed under the feet of man or cattle .The tempering should be done exhaustively to obtain homogeneous mass of clay of uniform character.For manufacturing good bricks on a large scale, tempering is done in pug mill.A typical pug mill capable of tempering sufficient earth for a daily output of about 15000 to20000 bricks.

A pug mill consists of a conical iron tub with cover at its top .It is fixed on a timber base which is made by fixing two wooden planks at right angle to each other. The bottom of tub is covered except for the hole to take out pugged earth. The diameter of pug mill at bottom is about 800mm and that at top is about 1 m.The provision is made in top cover to place clay inside pug mill .A vertical shaft with horizontal arms is provided at center of iron tub.The small wedge-shaped knives of steel are fixed at arms.The long arms are fixed at vertical shaft to attach a pair of bullocks .The ramp is provided to collect the pugged clay .The height of pug mill is about 2m. Its depth below ground is 600m to800mm lessen the rise of the barrow run and to throw out the tempered clay conveniently.In the beginning, the hole for pugged clay is closed and clay with water is placed in pug mill from the top. When vertical shaft is rotated by a pair of bullock, the clay is thoroughly mixed up by the action of horizontal arms and knives and homogeneous mass is formed.

The rotation of vertical shaft can also be achieved by using steam, diesel or electrical power.When clay has been sufficiently pugged, the hole at the bottom of the tub, is opened out and pugged earth is taken out from the ramp by barrow i.e. a small cart with wheels for next operation of moulding.The pug mill is then kept moving and feeding of clay from top and taking out of pugged clay from bottom are done simultaneously.If tempering is properly carried out, the good brick earth can then be rolled without breaking in small threads of 3mm diameter.

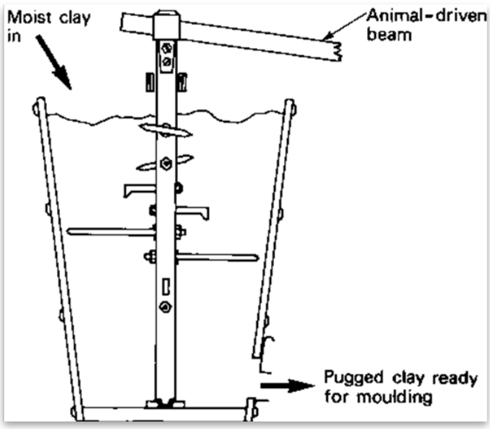


Fig of a Pug mill

Moulding:

The clay which is prepared as above is then sent for the text operation of moulding.Following are two types of moulding:

i. Hand Moulding

ii. Machine Moulding

<u>Hand moulding:</u>

In hand moulding , the bricks are moulded by hand *i.e.;* manually. It is adopted where manpower is cheap and is readily available for the manufacturing process of bricks ona small scale.The moulds are rectangular boxes which are open at top and bottom.They may be of wood or steel.It should be beprepared from well-seasonedwood. The longer sides are kept slightly projecting to serve as handles. The strips of brass or steel are sometimes fixed on the edges of wooden moulds to make them more durable.It is prepared from the combination of steel plate and channel. It may even be prepared from steel angles and plates. Thethickness of steel mould is 6mm.They is used for manufacturing bricks on alarge scale. The steel moulds are more durable than wooden one and turn out bricks of uniform size.The bricks shrink during drying and burning .Hence the mouldsare therefore made larger than burnt bricks (8-12%).

The bricks prepared by hand moulding are of two types: Ground mouldedand Tablemoulded

<u>Ground mouldedbricks:</u> The ground is first made level and fine sand is sprinkled over it.The mould is dipped in water and placed over the ground. The lump of tempered clay is taken and is dashed is the mould.The clay is pressed in the mould in such a way that it fills all the corners of mould.The surplus clay is removed by wooden strike or framed with wire. A strike is a piece of wood or metal with a sharp edge.It is to be dipped in water every time.The mould is then lifted up and raw brick ids left on the ground.The mould is dipped in water and it is placed just near the previous brick to prepare another brick.The process is repeated till the ground is covered with raw bricks.The lower faces of ground moulded bricks are rough

and it is not possible to place frog on such bricks.A frog is mark of depth about 10mm to 20mm which is placed on raw brick during moulding.It serves two purposes.

1.It indicates the trade name of the manufacturer

2.In brick work, the bricks are laid with frog uppermost. It thus affords a key for mortar when the next brick is placed over it.

The ground moulded bricks of better quality and with frogs on their surface are made by using a pair of pallet boards and a wooden block. A pallet is a piece of thin wood.The block is bigger than the mould and it has projection of about 6mm height on its surface.The dimensions of projection correspond to internal dimensions of mould.The design of impression or frog is made on this block.The wooden block is also known as the moulding block or stock board.

The mould is placed to fit in the projection of wooden block and clay is then dashed inside the mould.A pallet is placed on the top and the whole thing is then turn upside down.The mould is taken out and placed over the raw brick and it is conveyed to the drying sheds.The bricks are placed to stand on their longer sides in drying sheds and pallet boards are brought back for using them again.As the bricks are laid on edge, they occupyless space and they dry quicker and better.

Table Moulded Bricks:

i) The process of moulding of bricks is just similar as above.But in this case, the mould stands near a table size 2m x 1m. The bricks are moulded on the table and send for further process of drying.
ii) However the efficiency of the moulder gradually decreases because of standing at some place for a longer duration.The cost of brick is also increases when table moulding is adopted.

Machine Moulding:

This type of moulding is carried out by two processes:

i) Plastic clay machine
ii) Dry clay machine

Plastic Clay Moulding

i) Such machine consists of a rectangular opening having length and width is equal to an ordinary bricks. The pugged clay is placed in the machine and it comes out through the rectangular opening.

ii) These are cut into strips by the wire fixed at the frame. The arrangement is made in such a way that the strips thickness is equal to that of the bricks are obtained. So it is also called as WIRE CUT BRICKS.

Dry Clay Machinemoulding:

In these machines, the strong clay is finally converted in to powered form.A small quantity of water is then added to form a stiff plastic paste.

ii) Such paste is placed in mould and pressed by machine to form dry and well-shaped bricks. They do not require the process of drying.

Drying

The damp bricks, if brunt,are likely to be cracked and distorted.Hence the moulded bricks are dried before they are taken for the next operation of burning. For the drying the bricks are laid longitudinally in the stacks of width equal to two bricks,A stack consists of ten or eight tiers.The bricks are laid along and across the stock in alternate layers. All the bricks are placed on edges. The bricks are allowed to dry until the bricks are become leather hard of moisture content about 2%.

Burning

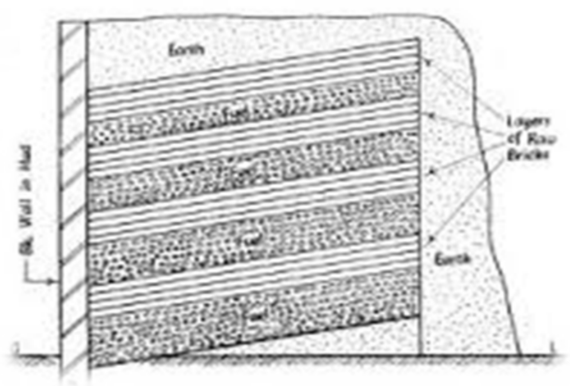
Bricks are burned at high temperature to gain the strength, durability, density and red color appearance.All the water is removed at the temperature of 650 degrees but they are burnt at an temperature of about 1100 degrees because the fusing of sand and lime takes place at this temperature and chemical bonding takes between these materials after the temperature is cooled down resulting in the hard and dense mass.

Bricks are not burnt above this temperature because it will result in the melting of the bricks and will result in a distorted shape and a very hard mass when cooled which will not be workable while brickwork. Bricks can be burnt using the following methods:

(a) Clamp Burning
(b) Kiln Burning

Clamp Burning:

Clamp is a temporary structure generally constructed over the ground with a height of about 4 to 6 m. It is employed when the demand of the bricks is lower scale and when it is not a monsoon season. This is generally trapezoidal in plan whose shorter edge among the parallel sides is below the ground and then the surface raising constantly at about 15 degrees to reach the other parallel edge over the ground.A vertical brick and mud wall is constructed at the lower edge to support the stack of the brick. First layer of fuel is laid as the bottom most layer with the coal, wood and other locally available material like cow dung and husk.Another layer of about 4 to 5 rows of bricks is laid and then again a fuel layer is laid over it. The thickness of the fuel layer goes on with the height of the clamp.



After these alternate layers of the bricks and fuel the top surface is covered with the mud so as to preserve the heat.Fire is ignited at the bottom, once fire is started it is kept under fire by itself for one or two months and same time period is needed for the cooling of the bricks.

Disadvantages of Clamp burning:

1. Bricks at the bottom are over-burnt while at the top are under-burnt.
2. Bricks loose their shape, and reason may be their descending downward once the fuel layer is burnt.
3. This method cannotemploy for the manufacturing of large number of bricks and it is costly in terms of fuel because large amount of heat is wasted.
4. It cannot be employed in monsoon season.

Kiln Burning:

Kiln is a large oven used for the burning of bricks. Generally coal and other locally available materials like wood, cow dung etc can be used as fuel. They are of two types:

- Intermittent Kilns.
- Continuous Kilns.

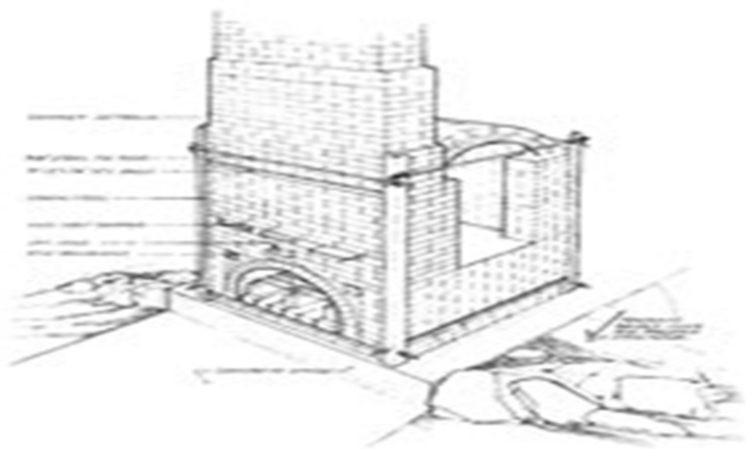


Fig of a typical kiln

Intermittent Kilns: these are also the periodic kind of kilns, because in such kilns only one process can take place at one time. Various major processes which takes place in the kilns are:*Loading, unloading, Cooling, and Burning of bricks.*

There are two kind of intermittent kilns:

(i) Up-draught Intermittent Kilns
(ii) Down draught Intermittent Kilns

Down draught kilns are more efficient because the heat is utilized more by moving the hot gases in the larger area of the kiln. In up draught kilns the hot gases are released after they rise up to chimney entrance.

Continuous Kilns:

These kilns are called continuous because all the processes of loading, unloading, cooling, heating, pre-heating take place simultaneously. They are used when the bricks are demanded in larger scale and in short time. Bricks burning are completed in one day, so it is a fast method of burning.There are two well-known continuous kilns:

*Bull's Trench Kiln:*Bull's trench kiln consists of a rectangular, circular or oval plan shape. They are constructed below the ground level by excavating a trench of the required width for the given capacity of brick manufacturing.This Trench is divided generally in 12 chambers so that 2 numbers of cycles of brick burning can take place at the same time for the larger production of the bricks. Or it may happen that one cycle is carried out at one time in all the 12 chambers by using a single process in the 2-3 chambers at the same time.The structure is under-ground so the heat is conserved to a large extent so it is more efficient. Once fire is started it constantly travels from one chamber to the other chamber, while other operations like loading, unloading, cooling, burning and preheating taking place simultaneously.

Such kilns are generally constructed to have a manufacturing capacity of about 20,000 bricks per day. The drawback of this kiln is that there is not a permanent roof, so it is not easy to manufacture the bricks in the monsoon seasons.

*Hoffman's Kiln:*The main difference between the Bull's trench kiln and the Hoffman kilns are:

1. Hoffman's kiln is an over the ground structure while Bull's Trench Kiln is an underground structure.
2. Hoffman's kiln have a permanent roof while Bull's trench Kiln do not have so it former can be used in 12 months a year to manufacture bricks but later is stopped in the monsoon season.

Hoffman's kiln is generally circular in plan, and is constructed over the ground. The whole structure is divided into the 12 chambers and the entire processes takes place simultaneously like in Bull's trench Kiln.

Classification of Bricks as per common practice:

Bricks, which are used in construction works, are burnt bricks. They are classified into four categories on the basis of its manufacturing and preparation, as given below.

1. First class bricks
2. Second class bricks
3. Third class bricks
4. Fourth class bricks

First Class Bricks:

These bricks are table moulded and of standard shape and they are burnt in kilns. The surface and edges of the bricks are sharp, square, smooth and straight. They comply with all the qualities of good bricks. These bricks are used for superior work of permanent nature.

Second Class Bricks:

These bricks are ground moulded and they are burnt in kilns. The surface of these bricks is somewhat rough and shape is also slightly irregular. These bricks may have hair cracks and their edges may not be sharp and uniform. These bricks are commonly used at places where brick work is to be provided with a coat of plaster.

Third Class Bricks:

These bricks are ground moulded and they are burnt in clamps. These bricks are not hard and they have rough surfaces with irregular and distorted edges. These bricks give dull sound when struck together. They are used for unimportant and temporary structures and at places where rainfall is not heavy.

Fourth Class Bricks:

These are over burnt bricks with irregular shape and dark colour. These bricks are used as aggregate for concrete in foundations, floors, roads etc, because of the fact that the over burnt bricks have a compact structure and hence they are sometimes found to be stronger than even the first class bricks.

Classification of Bricks as per constituent materials

There are various types of bricks used in masonry.

- Common Burnt Clay Bricks
- Sand Lime Bricks (Calcium Silicate Bricks)
- Engineering Bricks
- Concrete Bricks
- Fly ash Clay Bricks

Common Burnt Clay Bricks

Common burnt clay bricks are formed by pressing in moulds. Then these bricks are dried and fired in a kiln. Common burnt clay bricks are used in general work with no special attractive appearances. When these bricks are used in walls, they require plastering or rendering.

Sand Lime Bricks

Sand lime bricks are made by mixing sand, fly ash and lime followed by a chemical process during wet mixing. The mix is then moulded under pressure forming the brick. These bricks can offer advantages over clay bricks such as: their colour appearance is grey instead of the regular reddish colour.Their shape is uniform and presents a smoother finish that doesn't require plastering.These bricks offer excellent strength as a load-bearing member.

Engineering Bricks

Engineering bricks are bricks manufactured at extremely high temperatures, forming a dense and strong brick, allowing the brick to limit strength and water absorption.Engineering bricks offer excellent load bearing capacity damp-proof characteristics and chemical resisting properties.

Concrete Bricks

Concrete bricks are made from solid concrete. Concrete bricks are usually placed in facades, fences, and provide an excellent aesthetic presence. These bricks can be manufactured to provide different colours as pigmented during its production.

Fly Ash Clay Bricks

Fly ash clay bricks are manufactured with clay and fly ash, at about 1,000 degrees C. Some studies have shown that these bricks tend to fail poor produce pop-outs, when bricks come into contact with moisture and water, causing the bricks to expand.

Tests on Bricks

To know the quality of bricks following 7 tests can be performed. In these tests some are performed in laboratory and the rest are on field.

- Compressive strength test
- Water Absorption test
- Efflorescence test
- Hardness test
- Size, Shape and Colour test
- Soundness test
- Structure test

Compressive strength test: This test is done to know the compressive strength of brick. It is also called crushing strength of brick. Generally 5 specimens of bricks are taken to laboratory for testing and tested one by one. In this test a brick specimen is put on crushing machine and applied pressure till it breaks. The ultimate pressure at which brick is crushed is taken into account. All five brick specimens are tested one by one and average result is taken as brick's compressive/crushing strength.

Water Absorption test: In this test bricks are weighed in dry condition and let them immersed in fresh water for 24 hours. After 24 hours of immersion those are taken out from water and wipe out with cloth. Then brick is weighed in wet condition. The difference between weights is the water absorbed by brick. The percentage of water absorption is then calculated.The less water absorbed by brick the greater its quality. Good quality brickdoesn't absorb more than 20% water of its own weight.

Efflorescence test: The presence of alkalies in bricks is harmful and they form a grey or white layer on brick surface by absorbing moisture. To find out the presence of alkalis in bricks this test is performed. In this test a brick is immersed in fresh water for 24 hours and then it's taken out from water and allowed to dry in shade.If the whitish layer is not visible on surface it proofs that absence of alkalis in brick. If the whitish layer visible about 10% of brick surface then the presence of alkalis is in acceptable range. If that is about 50% of surface then it is moderate. If the alkalies' presence is over 50% then the brick is severely affected by alkalies.

Hardness test: In this test a scratch is made on brick surface with a hard thing. If that doesn't left any impression on brick then that is good quality brick.

Size, shape and colour test: In this test randomly collected 20 bricks are staked along lengthwise, width wise and height wise and then those are measured to know the variation of sizes as per standard. Bricks are closely viewed to check if its edges are sharp and straight and uniform in shape. A good quality brick should have bright and uniform colour throughout.

Soundness test: In this test two bricks are held by both hands and struck with one another. If the bricks give clear metallic ringing sound and don’t break then those are good quality bricks.

Structure test: In this test a brick is broken or a broken brick is collected and closely observed. If there are any flows, cracks or holes present on that broken face then that isn’t good quality brick.

2. CEMENT

Cement is a binder, a substance that sets and hardens and can bind other materials together. Cements used in construction can be characterized as being either hydraulic or non-hydraulic, depending upon the ability of the cement to be used in the presence of water.Non-hydraulic cement will not set in wet conditions or underwater, rather it sets as it dries and reacts with carbon dioxide in the air. It can be attacked by some aggressive chemicals after setting.Hydraulic cement is made by replacing some of the cement in a mix with activated aluminium silicates, pozzolanas, such as fly ash. The chemical reaction results in hydrates that are not very water-soluble and so are quite durable in water and safe from chemical attack. This allows setting in wet condition or underwater and further protects the hardened material from chemical attack (e.g., Portland cement).

Use

- Cement mortar for Masonry work, plaster and pointing etc.
- Concrete for laying floors, roofs and constructing lintels,beams,weather-shed,stairs,pillars etc.
- Construction for important engineering structures such asbridge,culverts,dams,tunnels,light house,clocks,etc.
- Construction of water,wells, tennis courts,septic tanks, lamp posts, telephone cabins etc.
- Making joint for joints,pipes,etc.
- Manufacturing of precast pipes,garden seats, artistically designed wens, flower posts, etc.
- Preparation of foundation, water tight floors, footpaths, etc.

Types of Cements

Many types of cements are available in markets with different compositions and for use in different environmental conditions and specialized applications. A list of some commonly used cement is described in this section:

Ordinary Portland cement

Ordinary Portland cement is the most common type of cement in general use around the world. This cement is made by heating limestone (calcium carbonate) with small quantities of other materials (such as clay) to 1450°C in a kiln, in a process known as calcination, whereby a molecule of carbon dioxide is liberated from the calcium carbonate to form calcium oxide, or quicklime, which is then blended with the other materials that have been included in the mix. The resulting hard substance, called 'clinker', is then ground with a small amount of gypsum into a powder to make 'Ordinary Portland Cement'(often referred to as OPC). Portland cement is a basic ingredient of concrete, mortar and most non-specialty grout. The most common use for Portland cement is in the production of concrete. Concrete is a composite material consisting of aggregate (gravel and sand), cement, and water. As a construction material, concrete can be cast in almost any shape desired, and once hardened, can become a structural (load bearing) element. Portland cement may be grey or white.

- This type of cement use in construction when there is no exposure to sulphates in the soil or ground water.
- Lime saturation Factor is limited between i.e. 0.66 to 1.02.
- Free lime-cause the Cement to be unsound.
- Percentage of (AL_2O_3/Fe_2O_3) is not less than 0.66.
- Insoluble residue not more than 1.5%.
- Percentage of SO_3 limited by 2.5% when $C_3A < 7\%$ and not more than 3% when $C_3A > 7\%$.
- Loss of ignition -4%(max)
- Percentage of Mg0-5% (max.)
- Fineness -not less than 2250 cm^2/g.

Rapid hardening Portland cement

- It is firmer than Ordinary Portland Cement
- It contains more C_3S are less C_2S than the ordinary Portland cement.
- Its 3 days strength is same as 7 days strength of ordinary Portland cement.

Low heat Portland cement

- Heat generated in ordinary Portland cement at the end of 3days 80 cal/gm. While in low heat cement it is about 50cal/gm of cement.
- It has low percentage of C3A and relatively more C_2S and less C_3S than O.P. Cement.
- Reduce and delay the heat of hydration. British standard (B S. 1370 : 1974) limit the heat of hydration of this cement.

Sulphate resisting Portland cement

- Maximum C3A content by 3.5% and minimum fineness by 2500 cm'/g.

- Firmer than ordinary pot land cement.
- Sulphate forms the sulpha-aluminates which have expensive properties and so causes disintegration of concrete.

Sulphate resisting Portland cement

- For this cement, the silage as obtained from blast furnace is used
- The clinkers of cement are ground with about 60 to 65 percent of slag.
- Its strength in early days is less and hence it required longer curing period. It proves to be economical as slag, which is a Waste product, is used in its manufactures.

Pozzolanic cement

- As per Indian standard, the proportions of Pozzolana may be 10 to 25 % by weight. e.2. Burnt clay, shale, Fly ash.
- This Cement has higher resistance to chemical agencies and to sea water because of absence of lime.
- It evolves less heat and initial strength is less but final strength is 28 days onward equal to ordinary Portland cement.
- It possesses less resistance to the erosion and weathering action.
- It imparts higher degree of water tightness and it is cheap.

White Portland cement

- Grey colour of O.P. cement is due to presence of Iron Oxide. Hence in White Cement Fe,,O, is limited to 1 %. Sodium Alumina Ferrite (Crinoline) NavAlF6 is added to act as flux in the absence of Iron-Oxide. •:
- It is quick drying, possesses high strength and has superior aesthetic values and it also cost lee than ordinary Cement because of specific requirements imposed upon the raw materials and the manufacturing process.
- White Cement are used in Swimming pools, for painting garden furniture, moulding sculptures and statues etc.

Coloured Portland

- The Cement of desired colour may be obtained by mixing mineral pigments with ordinary Cement.
- The amount of colouring material may vary from 5 to 10 percent. If this percentage exceeds 10percent, the strength of cements is affected.
- The iron Oxide in different proportions gives brown, red or yellow colour. The coloured Cement are widely used for finishing of floors, window sill slabs, stair treads etc.

Expansive cement

- This type of cement is produced by adding an expanding medium like sulphoaluminate and a stabilising agent to the ordinary cement.
- The expanding cement is used for the construction of water retaining structures and for repairing the damaged concrete surfaces.

High alumina cement

- This cement is produced by grilling clinkers formed by calcining bauxite and lime. It can stand high temper lures.
- If evolves great heat during setting. It is therefore not affected by frost.

Composition of Cement clinker

The various constituents combine in burning and form cement clinker. The compounds formedin the burning process have the properties of setting and hardening in the presence ofwater.They are known as Bogue compounds after the name of Bogue who identified them. These compounds are as follows: Alite (Tricalcium silicate or C_3S), Belite (Dicalcium silicate or C_2S), Celite (Tricalciumalluminate or C_3A) andFelite (Tetracalciumalumino ferrite or C_4AF).

Tricalcium silicate

It is supposed to be the best cementing material and is well burnt cement.It is about 25-50% (normally about 40 per cent) of cement. It renders the clinker easier to grind,increases resistance to freezing and thawing, hydrates rapidly generating high heat and developsan early hardness and strength. However, raising of C_3S content beyond the specified limitsincreases the heat of hydration and solubility of cement in water. The hydrolysis of C_3S is mainly responsible for 7 day strength and hardness. The rate of hydrolysis of C_3S and the character of gel developed are the main causes of the hardness and early strength of cement paste. The heat of hydration is 500 J/g.

Dicalcium silicate

It constitutes about 25-40% (normally about 32 per cent) of cement. It hydrates andhardens slowly and takes long time to add to the strength (after a year or more). It impartsresistance to chemical attack. Rising of C_2S content renders clinker harder to grind, reducesearly strength, decreases resistance to freezing and thawing at early ages and decreases heat ofhydration. The hydrolysis of C_2S proceeds slowly. At early ages, less than a month, C_2S has little influence on strength and hardness. While after one year, its contribution to the strength and hardness is proportionately almost equal to C_3S. The heat of hydration is 260 J/g.

Tricalciumalluminate

It is about 5-11% (normally about 10.5 per cent) of cement. It rapidlyreacts with water and is responsible for flash set of finely grounded clinker. The rapidity ofaction is regulated by the addition of 2-3% of gypsum at the time of grinding cement. Tricalciumaluminate is responsible for the initial set, high heat of hydration and has greater tendency tovolume changes causing cracking. Raising the C3A content reduces the setting time, weakens resistance to sulphate attack and lowers the ultimate strength, heat of hydration and contractionduring air hardening. The heat of hydration of 865 J/g.

Tetracalciumalumino ferrite

It constitutes about 8–14% (normally about 9 per cent) of cement. It isresponsible for flash set but generates less heat. It has poorest cementing value. Raising theC4AF content reduces the strength slightly. The heat of hydration is 420 J/g.

Hydration of Cement

In the anhydrous state, four main types of minerals are normally present: alite, belite, celiteand felite. Also present are small amounts of clinker sulfate (sulfates of sodium, potassium and calcium) and gypsum, which was added when the clinker was ground up to produce the familiar grey powder.

When water is added, the reactions which occur are mostly exothermic, that is, the reactions generate heat. We can get an indication of the rate at which the minerals are reacting by monitoring the rate at which heat is evolved using a technique called conduction calorimetry.Almost immediately on adding water some of the clinker sulphates and gypsum dissolve producing an alkaline, sulfate-rich, solution.Soon after mixing, the (C_3A) phase (the most reactive of the four main clinker minerals) reacts with the water to form an aluminate-rich gel (Stage I on the heat evolution curve above). The gel reacts with sulfate in solution to form small rod-like crystals of ettringite. (C_3A) reaction is with water is strongly exothermic but does not last long, typically only a few minutes, and is followed by a period of a few hours of relatively low heat evolution. This is called the dormant, or induction period (Stage II).The first part of the dormant period, up to perhaps half-way through, corresponds to when concrete can be placed. As the dormant period progresses, the paste becomes too stiff to be workable.At the end of the dormant period, the alite and belite in the cement start to react, with the formation of calcium silicate hydrate and calcium hydroxide. This corresponds to the main period of hydration (Stage III), during which time concrete strengths increase. The individual grains react from the surface inwards, and the anhydrous particles become smaller. (C_3A) hydration also continues, as fresh crystals become accessible to water.The period of maximum heat evolution occurs typically between about 10 and 20 hours after mixing and then gradually tails off. In a mix containing OPC only, most of the strength gain has occurred within about a month. Where OPC has been partly-replaced by other materials, such as fly ash, strength growth may occur more slowly and continue for several months or even a year.Ferrite reaction also starts quickly as water is added, but then slows down, probably because a layer of iron hydroxide gel forms, coating the ferrite and acting as a barrier, preventing further reaction.

Products of Hydration

During Hydration process several hydrated compounds are formed most important of which are, Calcium silicate hydrate, calcium hydroxide and calcium aluminium hydrates which is important for strength gain.

Calcium silicate hydrate:

This is not only the most abundant reaction product, occupying about 50% of the paste volume, but it is also responsible for most of the engineering properties of cement paste. It is often abbreviated, using cement chemists' notation, to "C-S-H," the dashes indicating that no strict ratio of SiO_2 to CaO is inferred. C-S-H forms a continuous layer that binds together the original cement particles into a cohesive whole which results in its strong bonding capacity. The Si/Ca ratio is somewhat variable but typically approximately 0.45-0.50 in hydrated Portland cement but up to perhaps about 0.6 if slag or fly ash or microsilica is present, depending on the proportions.

Calcium hydroxide:

The other products of hydration of C3S and C2S are calcium hydroxide. In contrast to theC-S-H, the calcium hydroxide is a compound with distinctive hexagonal prism morphology. It constitutes 20 to 25 per cent of the volume of solids in the hydrated paste. The lack ofdurability of concrete is on account of the presence of calcium hydroxide. The calcium hydroxide also reacts with sulphates present in soils or water to form calcium sulphate which further reacts with C3A and cause deterioration of concrete. This is known as sulphate attack. To reduce the quantity of $Ca(OH)_2$ in concrete and to overcome its bad effects by converting it into cementitious product is an advancement in concrete technology.The use of blendingmaterials such as fly ash, silica fume and such other pozzolanic materials are the steps toovercome bad effect of Ca(OH)2 in concrete. However, $Ca(OH)_2$ is alkaline in nature due to which it resists corrosion in steel.

Calcium aluminium hydrates:

These are formed due to hydration of C_3A compounds. The hydrated aluminates do notcontribute anything to the strengthof concrete. On the other hand, theirpresence is harmful to the durabilityof concrete particularly where theconcrete is likely to be attacked bysulphates. As it hydrates very fast itmay contribute a little to the earlystrength.

Various tests on cement:

Basically two types of tests are under taken for assessing the quality of cement. These are either field test or lab tests. The current section describes these tests in details.

Field test:

There are four field tests may be carried out to as certain roughly the quality of cement.There are four types of field tests to access the colour, physical property, and strength of the cement as described below.

Colour

- The colour of cement should be uniform.
- It should be typical cement colour i.e. grey colour with a light greenish shade.

Physical properties

- Cement should feel smooth when touched between fingers.
- If hand is inserted in a bag or heap of cement,it should feel cool.

Presence of lumps

- Cement should be free from lumps.
- For a moisture content of about 5 to 8%,this increase of volume may be much as 20 to 40 %,depending upon the grading of sand.

Strength

- A thick paste of cement with water is made on a piece of thick glass and it is kept under water for 24 hours.It should set and not crack.

Laboratory tests:

Six laboratory tests are conducted mainly for assessing the quality of cement. These are: fineness, compressive strength, consistency, setting time, soundness and tensile strength.

Fineness

- This test is carried out to check proper grinding of cement.
- The fineness of cement particles may be determined either by sieve test or permeability apparatus test.
- In sieve test ,the cement weighing 100 gm is taken and it is continuously passed for 15 minutes through standard BIS sieve no. 9.The residue is then weighed and this weight should not be more than 10% of original weight.
- In permeability apparatus test,specific area of cement particles is calculated.This test is better than sieve test.The specific surface acts as a measure of the frequency of particles of average size.

Compressive strength

- This test is carried out to determine the compressive strength of cement.
- The mortar of cement and sand is prepared in ratio 1:3.
- Water is added to mortar in water cement ratio 0.4.
- The mortar is placed in moulds.The test specimens are in the form of cubes and the moulds are of metals.For 70.6 mm and 76 mm cubes ,the cement required is 185gm and 235 gm respectively.
- Then the mortar is compacted in vibrating machine for 2 minutes and the moulds are placed in a damp cabin for 24 hours.
- The specimens are removed from the moulds and they are submerged in clean water for curing.
- The cubes are then tested in compression testing machine at the end of 3days and 7 days. Thus compressive strength was found out.

Consistency

- The purpose of this test is to determine the percentage of water required for preparing cement pastes for other tests.
- Take 300 gm of cement and add 30 percent by weight or 90 gm of water to it.
- Mix water and cement thoroughly.
- Fill the mould of Vicat apparatus and the gauging time should be 3.75 to 4.25 minutes.
- Vicat apparatus consists of aneedle is attached a movable rod with an indicator attached to it.
- There are three attachments: square needle,plungerand needle with annular collar.
- The plunger is attached to the movable rod.the plunger is gently lowered on the paste in the mould.
- The settlement of plunger is noted.If the penetration is between 5 mm to 7 mm from the bottom of mould,the water added is correct.If not process is repeated with different percentages of water till the desired penetration is obtained.

Setting time

- This test is used to detect the deterioration of cement due to storage.The test is performed to find out initial setting time and final setting time.
- Cement mixed with water and cement paste is filled in the Vicat mould.
- Square needle is attached to moving rod of vicat apparatus.
- The needle is quickly released and it is allowed to penetrate the cement paste.In the beginningthe needle penetrates completely.The procedure is repeated at regular intervals till the needle does not penetrate completely.(upto 5mm from bottom)
- Initial setting time =<30min for ordinary Portland cement and 60 min for low heat cement.
- The cement paste is prepared as above and it is filled in the Vicat mould.
- The needle with annular collar is attached to the moving rod of the Vicat apparatus.
- The needle is gently released. The time at which the needle makes an impression on test block and the collar fails to do so is noted.
- Final setting time is the difference between the time at which water was added to cement and time as recorded in previous step,and it is =<10hours.

Soundness

- The purpose of this test is to detect the presence of uncombined lime in the cement.
- The cement paste is prepared.
- The mould is placed and it is filled by cement paste.
- It is covered at top by another glass plate.A small weight is placed at top and the whole assembly is submerged in water for 24 hours.
- The distance between the points of indicator is noted.The mould is again placed in water and heat is applied in such a way that boiling point of water is reached in about 30 minutes. The boiling of water is continued for one hour.
- The mould is removed from water and it is allowed to cool down.

- The distance between the points of indicator is again measured.The difference between the two readings indicates the expansion of cement and it should not exceed 10 mm.

Tensile strength

- This test was formerly used to have an indirect indication of compressive strength of cement.
- The mortar of sand and cement is prepared.
- The water is added to the mortar.
- The mortar is placed in briquette moulds.The mould is filled with mortar and then a small heap of mortar is formed at its top.It is beaten down by a standard spatula till water appears on the surface.Same procedure is repeated for the other face of briquette.
- The briquettes are kept in a damp for 24 hours and carefully removed from the moulds.
- The briquettes are tested in a testing machine at the end of 3 and 7 days and average is found out.

3. CONCRETE

Concrete is a composite material composed mainly of water, aggregate, and cement. Often, additives and reinforcements are included in the mixture to achieve the desired physical properties of the finished material. When these ingredients are mixed together, they form a fluid mass that is easily molded into shape. Over time, the cement forms a hard matrix which binds the rest of the ingredients together into a durable stone-like material with many uses.

The aim is to mix these materials in measured amounts to make concrete that is easy to: Transport, place, compact, finish and which will set, and harden, to give a strong and durable product. The amount of each material (ie cement, water and aggregates) affects the properties of hardened concrete.

Production of concrete

A good quality concrete is essentially a homogeneous mixture of cement, coarse and fineaggregates and water which consolidates into a hard mass due to chemical action between the cement and water. Each of the four constituents has a specific function. The coarser aggregate acts as a filler. The fine aggregate fills up the voids between the paste and the coarse aggregate. The cement in conjunction with water acts as a binder. The mobility of the mixture is aided by the cement paste, fines and nowadays, increasingly by the use of admixtures.The stages of concrete productionare:Batching or measurement of materials, Mixing, Transporting, Placing, Compacting, Curing andFinishing.

Batching

It i s the process of measuring concrete mix ingredients either by volume or by mass and introducing them into the mixture. Traditionally batching is done by volume but most specifications require that batching be done by mass rather than volume.The proportions of various ingredients are determined by proper mix design.

A concrete mix is designed to produce concrete that can be easily placed at the lowest cost. The concrete must be workable and cohesive when plastic, then set and harden to give strong and durable concrete. The mix design must consider the environment that the concrete will be in; ie exposure to sea water, trucks, cars, forklifts, foot traffic or extremes of hot and cold. Proportioning concrete is a mixture of cement, water, coarse and fine aggregates and admixtures. The proportions of each material in the mixture affects the properties of the final hardened concrete. These proportions are best measured by weight. Measurement by volume is not as accurate, but is suitable for minor projects.

Cement content as the cement content increases, so does strength and durability. Therefore to increase the strength, increase the cement content of a mix. WaterContent adding more water to a mix gives a weaker hardened concrete. Always use as little water as possible, only enough to make the mix workable.Water to cement ratio as the water to cement ratio increases, the strength and durability of hardened concrete decreases. To increase the strength and durability of concrete, decrease the water-cement ratio.Aggregates too much fine aggregate gives a sticky mix. Too much coarse aggregate gives a harsh or boney mix.Mixing concrete must be mixed so the cement, water, aggregates and admixtures blend into an even mix. Concrete is normally mixed by machine. Machine mixing can be done on-site or be a pre-mixed concrete company. Pre-mixed concrete is batched (proportioned) at the plant to the job requirements. Truck mixing the materials are normally added to the trucks at batching plants and mixed for required time and speed at the plant. The trucks drum continues to rotate to agitate the concrete as it is delivered to the site. Site mixing when site mixing begin by loading a measured amount of coarse aggregate into the mixer drum. Add the sand before the cement, both in measured amounts.

Mixing

The mixing operation consists of rotation or stirring, the objective being to coat the surface the all aggregate particles with cement paste, and to blind all the ingredients of the concrete into a uniform mass; this uniformity must not be disturbed by the process of discharging from the mixer. The mixing may done by manually or by mechanical means like, Batch mixer, Tilting drum mixer, Non tilting drum mixer, Pan type mixer, Dual drum mixer or Continuous mixers.

There are no general rules on the order of feeding the ingredients into the mixer as this depend on the properties of the mixer and mix. Usually a small quantity of water is fed first, followed by all the solids materials. If possible greater part of the water should also be fed during the same time, the remainder being added after the solids. However, when using very dry mixes in drum mixers it is necessary to feed the coarse aggregate just after the small initial water feed in order to ensure that the aggregate surface is sufficiently wetted.

Compaction

The operation of placing and compaction are interdependent and are carried out simultaneously. They are most important for the purpose of ensuring the requirements of strength, impermeability and durability of hardened concrete in the actual structure. As for as placing is concerned, the main objective is to deposit the concrete as close as possible to its final position so that segregation is avoided and the concrete can be fully compacted. The aim of good concrete placing can be stated quite simply.

It is to get the concrete into position at a speed, and in a condition, that allow it to be compacted properly. To achieve proper placing following rules should be kept in mind:The concrete should be placed in uniform layers, not in large heaps or sloping layers.The thickness of the layer should be compatible with the method of vibration so that entrapped air can be removed from the bottom of each layer.The rate of placing and of compaction should be equal. If you proceed too slowly, the mix could stiffen so that it is no longer sufficiently workable. On no account should water ever be added to concrete that is setting. On the other hand, if you go too quickly, you might race ahead of the compacting gang, making it impossible for them to do their job properly. Each layer should be fully compacted before placing the next one, and each subsequent layer should be placed whilst the underlying layer is still plastic so that monolithic construction is achieved. Collision between concrete and formwork or reinforcement should be avoided.For deep sections, a long down pipe ensures accuracy of location of concrete and minimum segregation.You must be able to see that the placing is proceeding correctly, so lighting should be available for large, deep sections, and thin walls and columns.Once the concrete has been placed, it is ready to be compacted. The purpose of compaction is to get rid of the air voids that are trapped in loose concrete.

It is important to compact the concrete fully because:Air voids reduce the strength of the concrete. For every 1% of entrapped air, the strength falls by somewhere between 5 and 7%. This means that concrete containing a mere 5% air voids due to incomplete compaction can lose as much as one third of its strength.Air voids increase concrete's permeability. That in turn reduces its durability. If the concrete is not dense and impermeable, it will not be watertight. It will be less able to withstand aggressive iquids and its exposed surfaces will weather badly.Moisture and air are more likely to penetrate to the reinforcement causing it to rust. Air voids impair contact between the mix and reinforcement (and, indeed, any other embedded metals). The required bond will not be achieved and the reinforced member will not be as strong as it should be.Air voids produce blemishes on struck surfaces. For instance, blowholes and honeycombing might occur. There are two methods for compaction which includes: vibration by vibrators or by tamping using tamping rods.

Curing

Curing is the process of making the concrete surfaces wet for a certain time period after placing the concrete so as to promote the hardening of cement. This process consists of controlling the temperature and the movement of moisture from and into the concrete.

Curing of concrete is done for the following purposes. Curing is the process of controlling the rate of moisture loss from concrete to ensure an uninterrupted hydration of Portland cement after concrete has been placed and finished in its final position.Curing also helps maintain an adequate temperature of concrete in its early stages, as this directly affects the rate of hydration of cement and eventually the strength gain of concrete or mortars.

Curing of concrete must be done as soon as possible after placement and finishing and must continue for a reasonable period of time, for the concrete to achieve its desired strength and durability.Uniform temperature should be maintained throughout the concrete depth to avoid thermal shrinkage cracks.

Material properties are directly related to micro-structure. Curing assists the cement hydration reaction to progress steadily and develops calcium silicate hydrate gel, which binds aggregates leading to a rock solid mass,makes concrete denser, decreases the porosity and enhances the physical and mechanical properties of concrete.

Some other purposes of curing can be summed up as: curing protects the concrete surfaces from sun and wind, the process of curing increase the strength of the structure, the presence of water is essential to cause the chemical action which accompanies the setting of concrete. Generally there is adequate quantity of water at the time of mixing to cause the hardening of concrete,but it is necessary to retain water until the concrete is fully hardened.

If curing is efficient, the strength of concrete gradually increases with age. This increase in strength is sudden and rapid in early stages and it continues slowly for an indefinite period.By proper curing, the durability and impermeability of concrete are increased and shrinkage is reduced.The resistance of concrete to abrasion is considerably increased by proper curing.

Curing period:

For ordinary Portland cement, the curing period is about 7 days to 14 days.If rapid hardening cement is used the curing period can be considerably reduced.

Disadvantages of improper curing:

Following are the disadvantages of improper curing of concrete:

The chances of ingress of chlorides and atmospheric chemicals are very high.The compressive and flexural strengths are lowered.The cracks are developed due to plastic shrinkage, drying shrinkage and thermal effects.The durability decreases due to higher permeability.The frost and weathering resistances are decreased.The rate of carbonation increases.The surfaces are coated with sand and dust and it leads to lower the abrasion resistance.The disadvantages are more prominent in those parts of surfaces which are directly exposed or which have large surfaces compared to depth such as roads, canal, bridges, cooling towers, chimneys etc.

Factors affecting evaporation of water from concrete:

The evaporation of water depends upon the following 4 factors: Air temperature, Fresh concrete temperature, Relative humidity and Wind velocity.

From the above mentioned factors it can be concluded environment directly influences the process of evaporation, hence only the fresh concrete temperature can be monitored or supervised by the concrete technologists.The evaporation of water in the first few hours can leave very low amount of water in the concrete hydration, this leads to various shrinkage cracks.Under normal condition the average loss of water varies from 2.5 to 10 N per m2 per hour.The major loss occurs in the top 50 mm layer over a period of 3 hours, the loss could be about 5% of the total volume of that layer.

Methods of curing:

While selecting any mode of curing the following two factors are considered:

- The loss of water should be prevented.
- The temperature should be kept minimum for dissipation of heat of hydration.

Methods of curing can be categorised into the following categories:

Water curing-preventing the moisture loss from the concrete surface by continuously wetting the exposed surface of concrete.

Membrane curing-minimizing moisture loss from concrete surface by covering it with an impermeable membrane.

Steam curing-keeping the surface moist and raising the temperature of concrete to accelerate the rate of strength gain.

Water curing is of the following types:

Ponding: most inexpensive and common method of curing flat slabs, roofs, pavements etc. A dike around the edge of the slab, is erected and water is filled to create a shallow pond. Care must be taken to ensure that the water in the pond does not dry up, as it may lead to an alternate drying and wetting condition.

Sprinkling: fogging and mist curing- using a fine spray or fog or moist of water to the concrete can be efficient method of supplying water to concrete during hot weather, which helps to reduce the temperature of concrete.

Wet coverings: water absorbent fabrics may be used to maintain water on concrete surfaces. They must be continuously kept moist so as to prevent the fabrics from absorbing water from the body of concrete,due to capillary action.

Impermeable membrane curing is of following types:-

Formwork: leaving the form work in place during the early age of concrete is an efficient method of curing.

Plastic sheeting: plastic sheets form an effective barrier to control the moisture losses from the surface of concrete, provided they are secured properly and protected from damage. The efficiency of this system can be enhanced by flooding the concrete surface with water, under the plastic sheet.

Membrane curing compounds: Curing compounds are wax, acrylic and water based liquids are spread over the freshly finished concrete to form an impermeable membrane that minimises the loss of moisture from the concrete surfaces.These are cost effective methods of curing where standard curing procedures are difficult to adopt.When applied to cure concrete the time of the application is critical for maximum effectiveness.Too early application dilutes the membrane, whereas too late application results in being absorbed into the concrete.They must be applied when the free water on the surface has evaporated.For concrete with low w/c ratio, this is not a suitable process.

Steam curing: Steam curing is the process of accelerating the early hardening of concrete and mortars by exposing it to steam and humidity. These types of curing systems are adopted for railway sleepers, concrete blocks, pipes, manhole covers, poles etc.Precast iron is cured by this method under pressure.Curing in hot and cold weather requires additional attention.

Hot weather: During hot weather, concrete must be protected from excessive drying and from direct wind and sun. Curing materials which reflect sunlight to reduce concrete temperature must be used.

Cold weather: Some problems associated with temperature below 40^0C are:

- Freezing of concrete before strength is developed.
- Slow development of concrete strength.
- Thermal stresses induced by the cooling of warm concrete to cooler ambient temperatures

Chemical curing: In this method water is sprinkled over the surface, after adding certain amount of some hygroscopic material (e.g. sodium chloride or calcium chloride). The hygroscopic materials absorb moisture from the atmosphere and thus keep the surface damp.

Alternating current curing: Concrete can be cured by passing alternating current through freshly laid concrete.

Water cement ratio and compressive strength

A cement of average composition requires about 25% of water by mass for chemical reaction. In addition, an amount of water is needed to fill the gel pores. Nearly 100 years ago, Duff Abrams discovered the direct relationship between water-to-cement ratio and strength, i.e.,lesser the water used higher the strength of the concrete,since too much water leaves lots of poresin the cement past. According toAbram’s law, *the strength of fully compacted concrete at a given age and normal temperature is inversely proportional to the water – cement ratio.* Here the water-cement ratio is the relative weight of water to the cement in the mixture. For most applications, water-to-cement ratio should be between 0.4 and 0.5 lower for lower permeability and higher strength. In concrete, the trade off, of course,is with workability, since very low water content result in very stiff mixtures that are difficult to place. The water-to-cement ratio is a factor selected by the civil engineer.

Workability

Workability is one of the physical parameters of concrete which affects the strength and durability as well as the cost of labor and appearance of the finished product. Concrete is said to be workable when it is easily placed and compacted homogeneously i.e without bleeding or Segregation. Unworkable concrete needs more work or effort to be compacted in place, also honeycombs &/or pockets may also be visible in finished concrete.Definition of Workability "The property of fresh concrete which is indicated by the amount of useful internal work required to fully compact the concrete without bleeding or segregation in the finished product."

Factors affecting workability:

- Water content in the concrete mix
- Amount of cement & its Properties
- Aggregate Grading (Size Distribution)
- Nature of Aggregate Particles (Shape, Surface Texture, Porosity etc.)
- Temperature of the concrete mix
- Humidity of the environment
- Mode of compaction
- Method of placement of concrete
- Method of transmission of concrete

How to improve the workability of concrete

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

Workability tests:

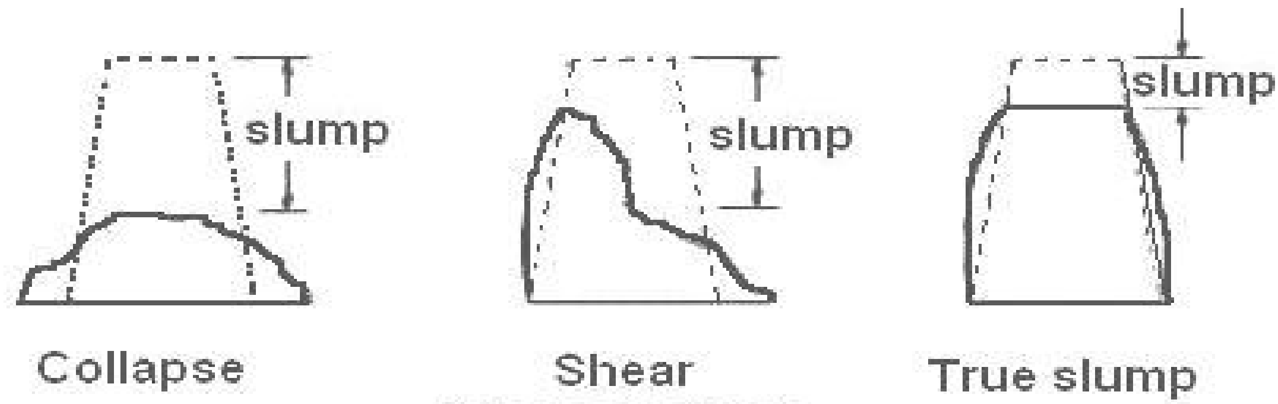
There are 4 types of tests for workability.They are slump test, compacting factor test, flow test, and vee bee test

Slump test

The slump test result is a slump of the behavior of a compacted inverted cone of concrete under the action of gravity. It measures the consistency or the wetness of concrete.Metal mould, in the shape of the frustum of a cone, open at both ends, and provided with the handle, top internal diameter 4 in (102 mm), and bottom internal diameter 8 in (203 mm) with a height of 1 ft (305 mm). A 2 ft (610 mm) long bullet nosed metal rod, (16 mm) in diameter.Apparatus Required: Compacting Factor apparatus, Trowels, Graduated cylinder, Balance and Tamping rod and iron bucket

The test is carried out using a mould known as a slump cone or Abrams **cone**. The cone is placed on a hard non-absorbent surface. This cone is filled with fresh concrete in three stages, each time it is tamped using a rod of standard dimensions. At the end of the third stage, concrete is struck off flush to the top of the mould. The mouldis carefully lifted vertically upwards, so as not to disturb the concrete cone. Concrete subsides. This subsidence is termed as slump, and is measured in to the nearest 5 mm if the slump is <100 mm and measured to the nearest 10 mm if the slump is >100 mm.

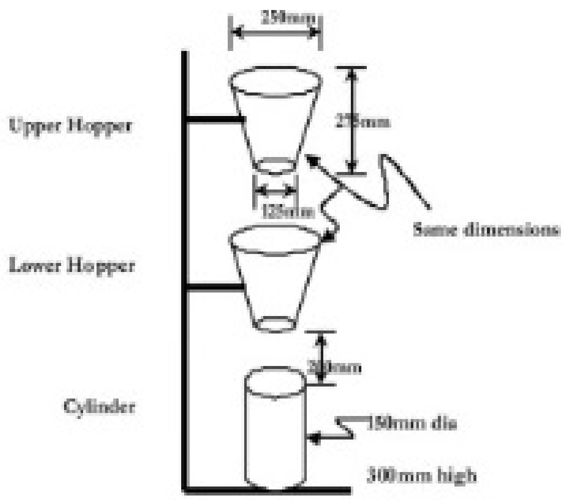
The slumped concrete takes various shapes, and according to the profile of slumped concrete, the slump is termed as true slump, shear slump or collapse slump. If a shear or collapse slump is achieved, a fresh sample should be taken and the test repeated. A collapse slump is an indication of too wet a mix. Only a true slump is of any use in the test. A collapse slump will generally mean that the mix is too wet or that it is a high workability mix, for which slump test is not appropriate. Very dry mixes; having slump 0 – 25 mm are used in road making, low workability mixes; having slump 10 – 40 mm are used for foundations with light reinforcement, medium workability mixes; 50 - 90 for normal reinforced concrete placed with vibration, high workability concrete; > 100 mm.



Types of slump

This test is usually used in laboratory and determines the workability of fresh concrete when size is about 40 mm maximum. The test is carried out as per specification of IS: 1199-1959.

Compacting factor test:



Steps for performing the experiment:

- keep the apparatus on the ground and apply grease on the inner surface of the cylinders.
- Measure the mass as w1 kg by weighing the cylinder accurately and fix the cylinder on the base in such a way that the central points of hoppers and cylinder lie on one vertical line and cover the cylinder with a plate.
- For each 5 kg of aggregate mixes are to be prepared with water-cement ratio by weight with 2.5 kg sand and 1.25 kg of cement and then add required amount of water thoroughly until and unless concrete appears to be homogeneous.

- With the help of hand scoop without compacting fill the freshly mixed concrete in upper hopper part gently and carefully and within two minutes release the trap door so that the concrete may fall into the lower hopper such that it bring the concrete into standard compaction.
- Fall the concrete to into the cylinder by bringing the concrete into standard Compaction immediately after the concrete has come to rest and open the trap door of lower hopper and then remove the excess concrete above the top of the cylinder by a pair of trowels, one in each hand will blades horizontal slide them from the opposite edges of the mould inward to the center with a sawing motion.
- Clean the cylinder from all sides properly. Find the mass of partially compacted concrete thus filled in the cylinder and say it W2 kg. After this refill the cylinder with the same sample of concrete in approximately 50 mm layers, by vibrating each layer heavily so as to expel all the air and obtain full compaction of the Concrete.
- Struck off level the concrete and weigh and cylinder filled with fully compacted concrete. Let the mass be W3 kg.
- Calculate compaction factor by using the formula: C.F = W2 – W1 / W3 – W1

Flow Table Test:

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

Flow table with a grip and a hinge, 70 centimetres (28 in) square.Abrams cone, open at the top and at the bottom - 30 centimetres (12 in) high, 17 centimetres (6.7 in) top diameter, 25 centimetres (9.8 in) base diameter.Water bucket and broom for wetting the flow table.Tamping rod, 60 centimetres (24 in) longConducting the testTheflowtable is wetted.The cone is placed in the center of the flowtable and filled with fresh concrete in two equal layers layers. Each layer is tamped 10 times with tamping rod.Wait 30 seconds before lifting the coneThe cone is lifted, allowing the concrete to flow.The flowtable is then lifted up 40mm and then dropped 15 times, causing the concrete to flowAfter this the diameter of the concrete is measured.

Vee-Bee Test:

This test is useful for concrete having low and very low workability. In this test the concrete is moulded into a cone in a cylinder container and the entire set up is mounted on a vibrating table. When vibrator starts, concrete placed on the cone starts to occupy the cylindrical container by the way of getting remoulded. Remoulding is complete when the concrete surface becomes horizontal. The time required for completion of remoulding since start of vibrator is measured and denoted as vee-bee seconds. This provides a measure for workability. Lesser is the vee-bee seconds more is the workability