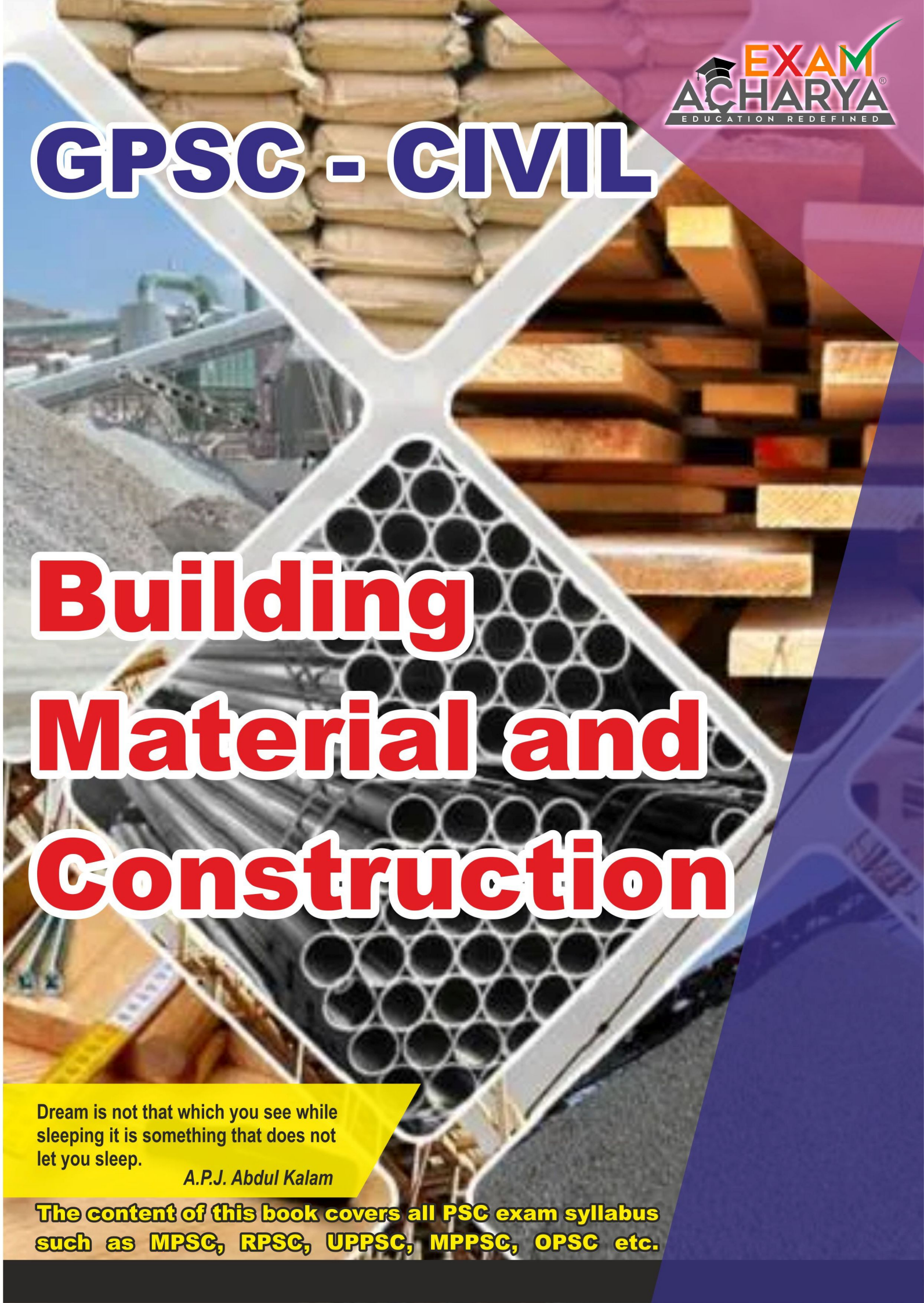
EXAM ACHARYA
EDUCATION REDEFINED

GPSC - CIVIL

Building Material and Construction



Dream is not that which you see while sleeping it is something that does not let you sleep.

A.P.J. Abdul Kalam

The content of this book covers all PSC exam syllabus such as MPSC, RPSC, UPPSC, MPPSC, OPSC etc.

INDEX

New Batches are going to start.....

Contact:

7622050066

Test Series Available..

Total weekly test : 35

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CHAPTER – 1

STONE

STONE

- Stones are derived from rock's earth crust.
- It does not have any shape and structure.
- In actual these are the fragmented parts of the rock.

These are mainly formed by weathering of the sedimentary rocks by sunray, wind and water.

COMPOSITION OF STONE

S.NO.	COMPOSITION OF STONE	SPECIFIC GRAVITY	REMARK
1.	QUARTZ (Silicon dioxide)	2.5 – 2.7	Transparent and Indestructible
2.	FELDSPAR	2.5 – 2.8	Silicate of Aluminium with Sodium or Potassium Silicates
3.	MICA (Silicate of Aluminium with Potassium)	2.8 – 3.2	Glistering appearance to stone
4.	AUGITE (Silicate of Calcium & Magnesium)	3.3 – 3.6	Found in Deccan trap of India
5.	HORNBLENDE	2.7 – 3.2	Strong, Durable, Brittle & Glossy Nature
6.	CALCIUM CARBONATE	2.7 – 2.9	Prime constituent of Chalk, Limestone & Calcarious Stones
7.	GYPSUM (Hydrate calcium sulphate)	2.31 – 2.33	Vitreous to silky, pearly, or waxy

CLASSIFICATION OF STONE

Geological Classification

Igneous Rocks

Rocks that are formed by cooling of magma or lava (molten or pasty rock material) are known as igneous rocks. Eg: Granite, Basalt, Dolerite etc.

Sedimentary Rocks

These rocks are formed by the consolidation of the products of weathering obtained from the pre-existing rocks. Eg: Gravel, Sandstone, Limestone, Gypsum, Lignite etc.

Metamorphic Rocks

These rocks are formed by the change in character of the pre-existing rocks when subjected to great heat and pressure. The process of their transformation is called metamorphism. Eg: Quartzite, Schist, Slate, Marble and Gneiss.

Physical Classification

Stratified Rocks

These rocks possess planes of cleavage or stratification along which they can be split. Sedimentary rocks usually possess this property.

Un-stratified Rocks

The structure may be crystalline granular or compact granular: Igneous rocks.

Foliated Rocks

These rocks have a tendency to split up in a definite direction only. Eg: Metamorphic rocks.

Chemical Classification

Siliceous Rocks

In these rocks, silica is predominating. These rocks are hard, durable and not easily affected by weathering agencies. Eg: Granite, Quartzite, etc.

Argillaceous Rocks

In these rocks, clay is predominating. These rocks may be dense and compact or may be soft. Eg: Slates, Laterites etc.

Calcareous Rocks

Calcium carbonate is the main constituent in these rocks. The durability to these rocks will depend upon the constituents presenting in surrounding atmosphere. Eg: Limestone, Marble etc.

CHARACTERISTIC OF STONE

Following are the qualities or characteristics or requirements properties of a good building stone:

1. Crushing Strength

For a good structural stone, the crushing strength should be greater than 100 N/mm^2.

2. Appearance

The stones which are to be used for face work should be decent in appearance and they should be capable of preserving their colour uniformly for a long time. The colour of the stones for face work should be chosen by keeping in mind the general get up of the surrounding area.

The same is then transferred into the cup and again tamped 25 times. The hammer is then allowed to fall freely onto the specimen 15 times.

The specimen is then sieved through a 2.36 mm sieve.

Then, Impact value = **W2 / W1**

Where,

W2= Weight of Fines.

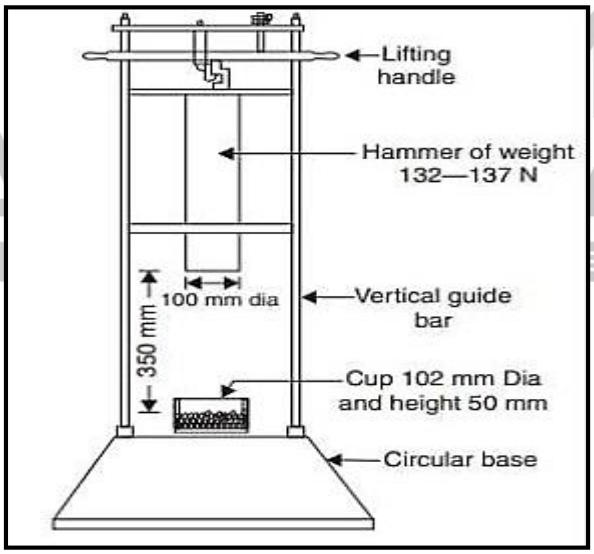
W1= Original Weight.

The recommended impact values for various works are:

(i) For wearing course 30%

(ii) For bituminous macadam 35%

(iii) For water-bound macadam 40%



5. Acid Test of Stone

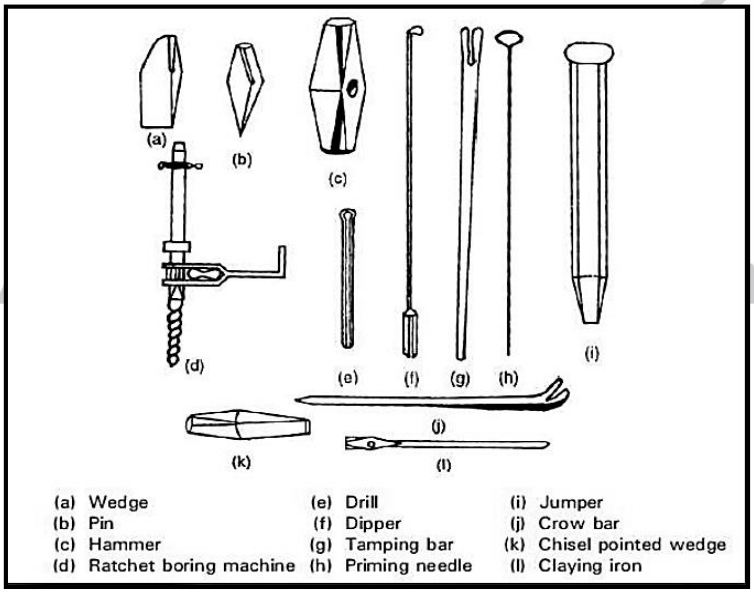
This test is normally carried out on sandstones to check the presence of calcium carbonate, which weakens the weather resisting quality.

In this test, a sample of **stone weighing about 50 to 100 gm** is taken and kept in a solution of one percent hydrochloric acid for seven days.

Quarrying Tools

Quarrying tools are

- Wedge
- Pin
- Hammer
- Dipper or Scraping Spoon
- Tamping Bar
- Priming Needle
- Jumper, Borer
- Claying Iron
- Crow Bar



Method of Stone Quarrying

1. ***Digging***

   In this method stones are excavated with the help of suitable instruments. This method is useful when soft stones occur at the low levels in ground.

are broken into pieces of desired size and are removed with the help of pick-axes and crowbars.

4. *Quarrying with Channeling Machine*

In this method, the channeling machines driven by steam, compressed air or electricity are used to make vertical or oblique grooves or channels on the rock mass. These machines make rapidly the grooves having length of about 24 m, width of about 50 mm to 75 mm and depth of about 2.40 cm to 3.70 cm. The process consists of the following steps:

- The channels are cut around the stone block which is to be removed from the rock mass.
- The horizontal holes are drilled beneath the block,
- The wedges are driven into holes and the block is then broken loose from its bed.
- This process of separation of stone from the rock mass is almost invariably employed in case of limestones, marbles and other soft sandstones. It is possible to separate very large blocks of stones from the rocks by the application of this method.

5. *Blasting*

In this method, the explosives are used to convert rocks into small pieces of stones. This method is used when stone to be excavated is of very hard variety and it has no cracks or fissures. Moreover, if stone is to be excavated on very large scale, blasting method will have to be adopted. No definite size blocks can be excavated by this method.

After blasting, the excavated stone is sorted out in different sizes and categories. Explosives such as blasting powder, blasting cotton, dynamite and cordite are used. The operations involved are boring, charging, tamping and fining.

GPSC - CIVIL

Construction, Planning and Management

"All Birds find shelter during a rain.
But Eagle avoids rain by flying above
the Clouds."

A.P.J. Abdul Kalam

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Methods of Dressing of Stones

Dressing of stone can be done both manually as well as mechanically.

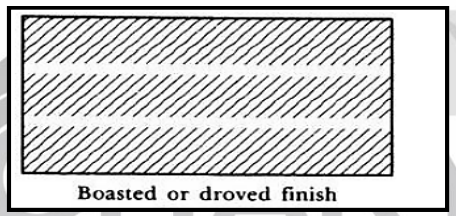
- Manually, skilled stone-smiths can work wonders on the suitable type of stones with chisels and hammers and abrasives.
- Mechanically, machines can cut the stone to any desired size and shape.

Their surfaces can be made extra smooth by polishing through machines.

Types of Dressing

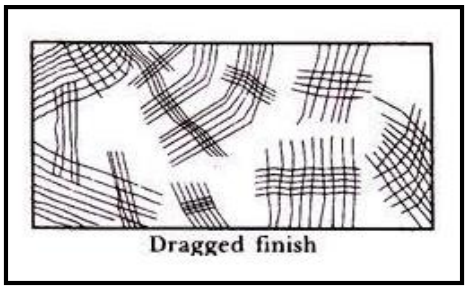
1) *Boasted or Droved Finish*

In this, the dressing is done with the help of a boaster and hammer, forming a series of 38 to 50 mm wide bands of more or less parallel tool marks, which cover the whole surface.



2) *Dragged or Combed Finish*

This finish is used only in soft stones, This type of finish, a drag or a comb, which is a piece of steel with a number of teeth, is rubbed on the surface in all directions and surface.



CLEAR YOUR CONCEPT

Qu1. An explosive which contain 65% saltpeter, 20% Sulphur and 15% charcoal, is

a) Dynamite

b) Nitrocellulose

c) Blasting powder

d) Cordite

Qu2. Out of the following, which may be termed as Unstratified rock?

a) Sandstone

b) Limestone

c) Marble

d) Slate

Qu3. Chemically, marble is known as

a) Metamorphic rock

b) Argillaceous rock

c) Calcareous rock

d) Siliceous rock

Qu4. Which of the following is a rock?

a) Quartzite

b) Mica

c) Gypsum

d) None of the above

Qu5. A stone is rejected if it absorbs water more than

a) 5%

b) 10%

c) 20%

d) 25%

Qu6. The tendency of a stone is to split along

a) Texture

b) Fracture

c) Cleavage

d) Structure

Qu7. Hardness of rock can be tested in situ using

a) Smith's test

b) Schmidt Hammer test

c) Acid test

d) Crystallization test

TEST YOUR SELF

Qu8. Following stone is suitable for damp proofing

a) Slate

b) Marble

c) Laterite

d) Granite

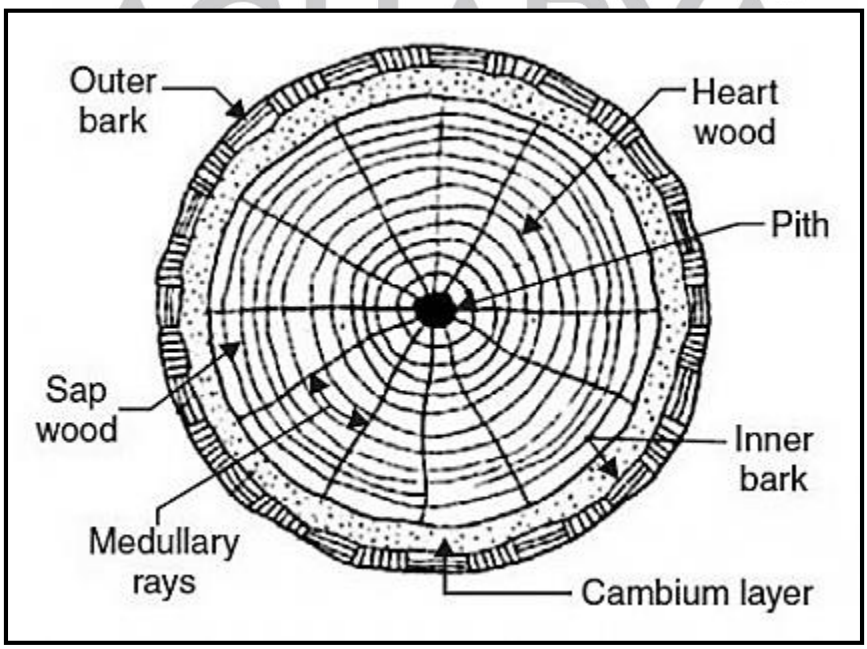
Exogenous Trees

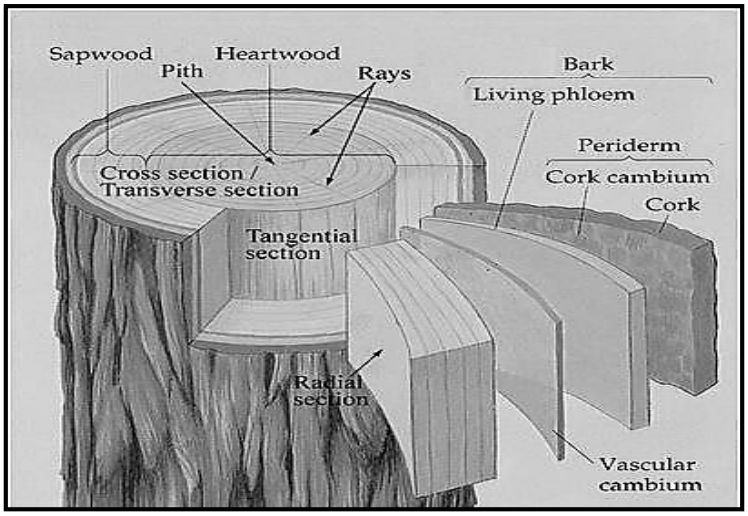
- Conifers are also known as evergreen trees and leaf of these do not fall till new ones are grown. As these bear cone-shaped fruits, they are given the name conifers. These trees yield soft woods.
- Deciduous trees are also known as broadleaf trees and leaf of these trees fall in autumn and new ones appear in spring season. Timber for engineering purposes is mostly derived from deciduous trees. These trees yield hard woods.

Endogenous Trees

- These trees grow inwards and fibrous mass is seen in their longitudinal sections.
- Timber from these trees has very limited engineering application Examples of endogenous trees are bamboo, cane, palm, etc.

STRUCTURE OF TIMBER





1. Macrostructure

- ***Pith:*** The innermost central portion or core of the tree is called the pith of medulla.
- ***Heart Wood:*** The inner annual rings surrounding the pith is known as heart wood. It is usually dark in colour.
- ***Sap Wood:*** The outer annual rings between heart wood and cambium layer is known as sap wood.
- ***Cambium Layer:*** The thin layer of sap between sap wood and inner bark is known as cambium layer.
- ***Inner Bark:*** It gives protection of cambium layer from any injury.
- ***Outer Bark:*** It consists of cells of wood fibre and is also known as cortex.
- ***Medullary Rays:*** The thin radial fibres extending from pith to cambium layer are known as medullary rays.

2. Microstructure

- Wood consists of living and dead cells of various sizes and shapes.
- A living cell consists of four parts, namely (i) membrane, (ii) protoplasm

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Defectless

This property isgained if the timber is from a sound tree. A defectless tree is free from sap, shakes, and dead knots.

Workability

A good timber is always easy to work on it. Easy to drag using saw on good timber. The finishing can be done well.

Soundness

A good quality timber gives good sound.

Texture

The texture of good timber is fine and even.

Free of Abrasion

Timber should not be damaged by the external environment. It has to gain the ability to protect its skin.

USES OF WOOD IN DIFFERENT SECTORS

Wood is a plant part having multipurpose uses those are impossible to deny and difficult to note all in our daily life. From the ancient time wood is used by human and this continuation still remains in the modern civilization. A few of many uses of wood are mentioned below:

1. Construction and Fencing
2. Household Uses
3. Art Industry
4. Sports Equipment
5. Commercial Uses

Commercial Uses

- ***Furniture***

  At present, the market for wooden furniture is very profitable. No one can deny the demand for wooden furniture as it is a sign of aristocracy since ancient time. e.g. Teak (Tectona grandis) wood is the best for making furniture. Some other woods from Mahogany (Swietenia macrophylla), Shimla (Bombax ceiba), Sundari, Jackfruit (Artocarpus heterophyllus), Mango trees are used in south Asia from making different types of furniture.

- ***Shipbuilding***

  Ships and rural fishing boats were made from wood. For constructing boats and ships wood is one of the most important construction material. Hardwood and softwood were used in the past for ship industry.

  e.g. Teak, shal (Shorea robusta), mango, Arjun (Terminalia arjuna) were frequently used in the past. Now Cypress (Cupressaceae sp), redwood (Sequoioideae sp), white Oak (Quercus alba) are water resistant and used for shipbuilding and boat building. Woods like Kauri (Agathis australis) is used for making the frames of ships.

- ***Fuel***

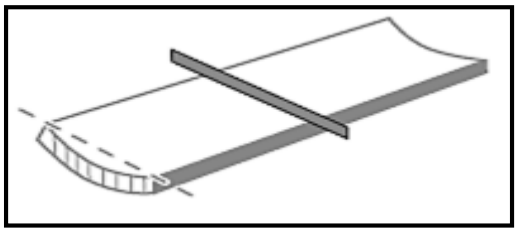
  Wood is an age-old source of energy all over the world. Before the exploration of gas, fuel was the main source we can also define as only one source of energy that people used by burning as woods were available in the forest easily. Generally, sticks, pellets, sawdust, and charcoal are used as an energy source from wood. Usually, woods from Cheap plants are used in the sector.

- ***Stationary***

  Some stationaries like paper pencil are made of wood. Wood pulp is used for making paper. Wood is used for making pencils too.

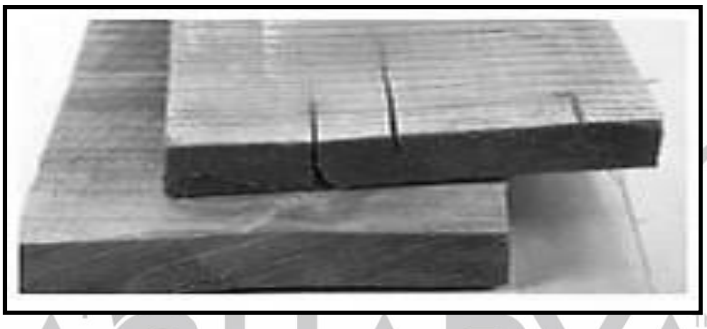
2. *Cup*

If the timber planks curve along its width, then it is called Cupping of timber.



3. *Check*

Check is the formation of a crack in the wood, which will separate the wood fibers. They form due to over seasoning of timber.

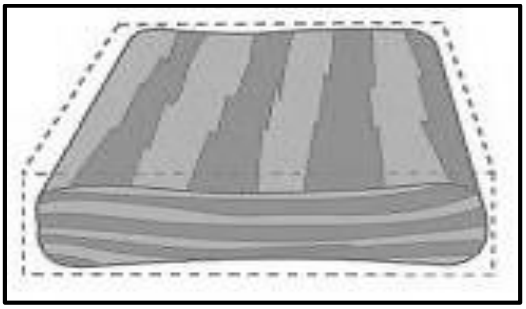


4. *Split*

Split forms when a check extends from one end to the other end, which will split the wood into a number of pieces.

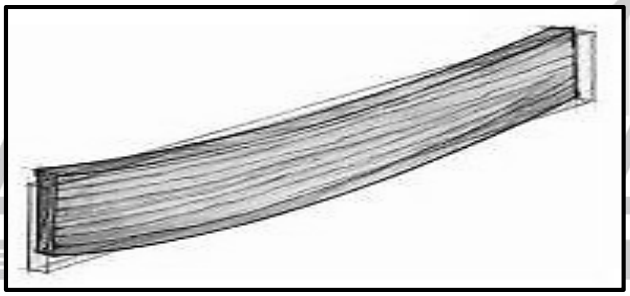
8. *Collapse*

During drying, some parts of the wood may dry rapidly while some may not. Because of this, improper drying shrinkage of wood occurs, that results in the defect called collapse.



9. *Warp*

Warping is the loss of shape of wood due to stresses developed during drying. Cupping, bowing, twisting of wood come under warping.



Defects Due to Fungi

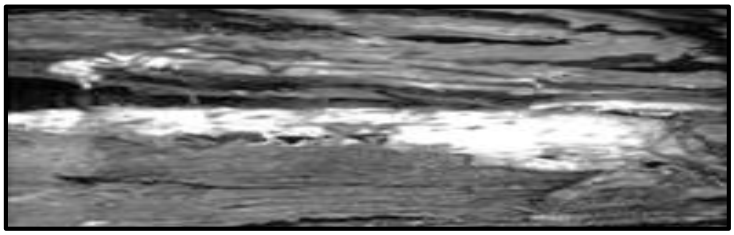
1. *Dry Rot in Timber*

- Dry rot is caused by a certain type of fungi that eats wood for their living. They make food by converting timber into dry powder form. This occurs mainly when there is no ventilation of air or if the wood is improperly seasoned.

- Absence of sunlight, dampness, presence of sap will increase the growth of dry rot, causing fungi. This can be prevented by using well-seasoned wood and also by painting the timber surface with copper sulfate.

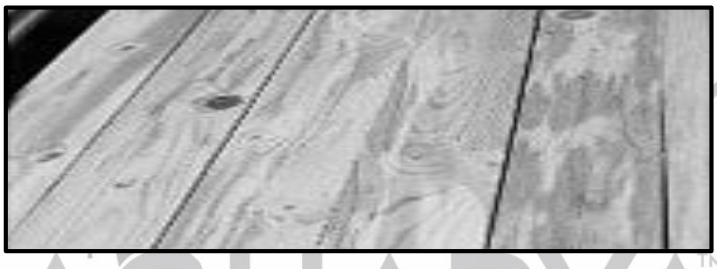
4. White Rot in Timber

Some types of fungi attack lignin of timber and leaves cellulose compounds hence the wood will turn into white color, which is called white rot.



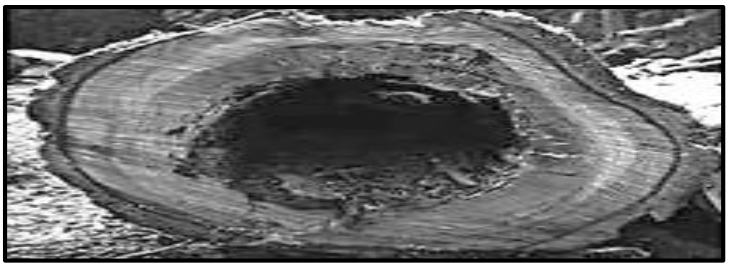
5. Blue Stain in Timber

Blue stain is a defect caused by some kind of fungi, which makes the timber bluish.



6. Heart Rot in Timber

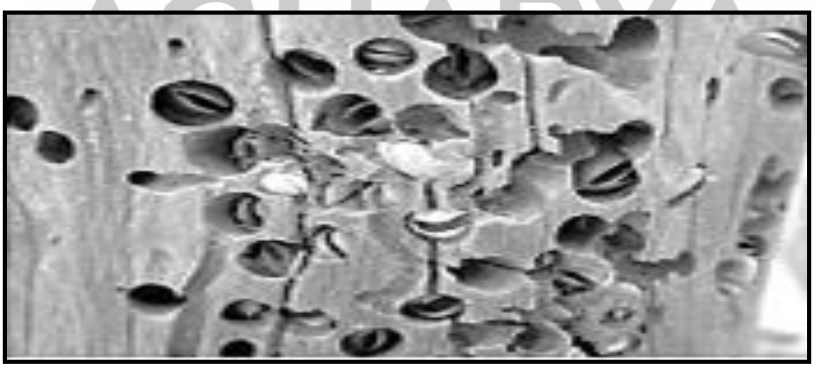
Heart rot is generated in the trees when fungi attack the heartwood through its newly formed branch. This type of fungi makes the tree hollow by consuming heartwood. This defect is known as heart rot.



2 mm. They convert sapwood into powder form, and larvae of these beetles use these holes. Almost all hardwood trees can be prone to damage by these beetles.

3. *Marine Borers in Timber*

Marine borers are found near coastal areas. They do not consume wood, but they make large holes of diameter up to 25mm in the timber to live inside it. They excavated up to 60mm deep in the wood. The wood attacked by marine borers is of less strength and discolored. They can attack all types of trees present in their region.

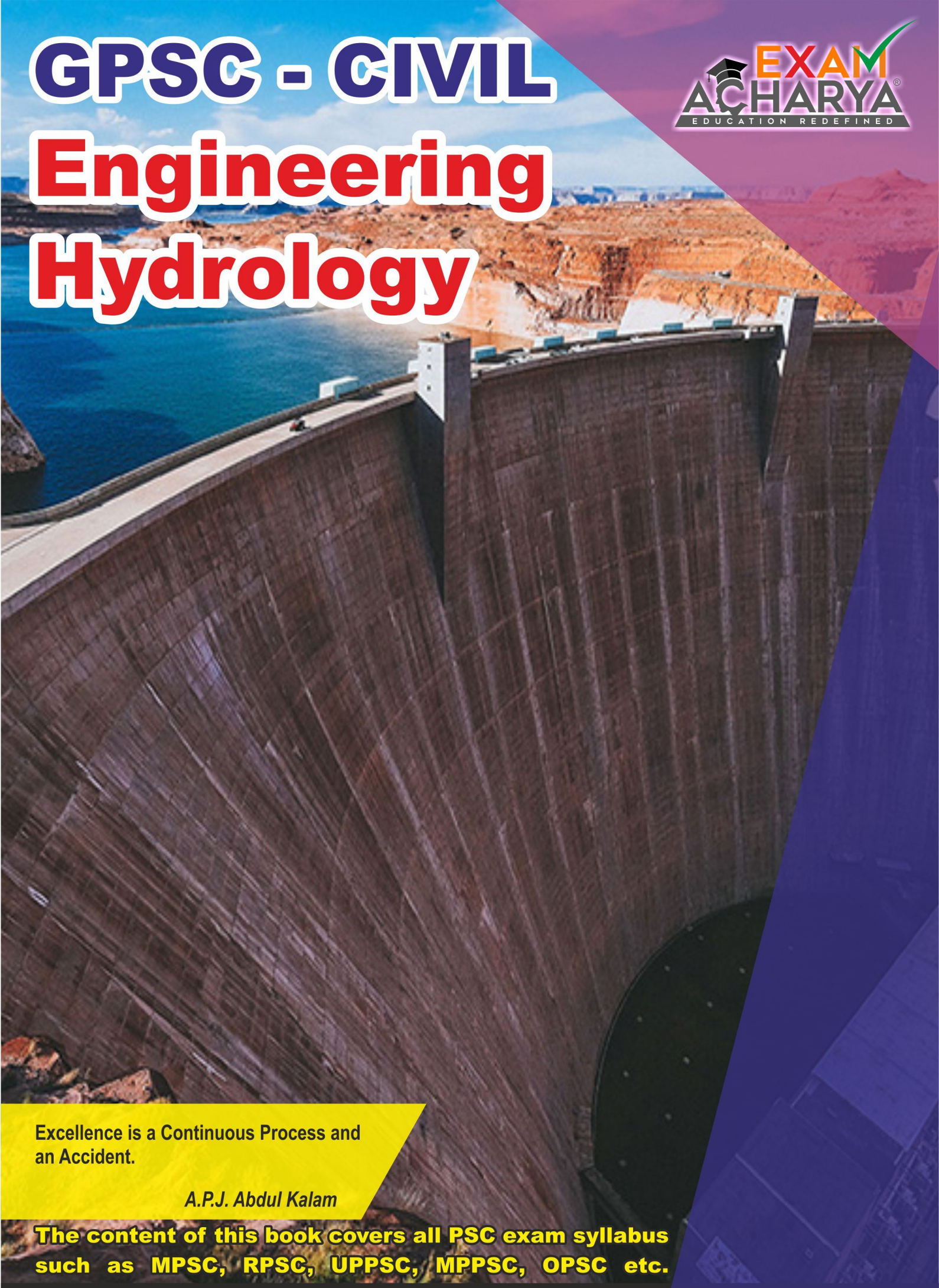


Defects Due to Natural Forces

1. *Wind Cracks in Timber*

If the wood is exposed continuously to the high-speed winds, the outer surface shrinks and forms crack externally, which are called wind cracks.

GPSC - CIVIL Engineering Hydrology



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Excellence is a Continuous Process and an Accident.

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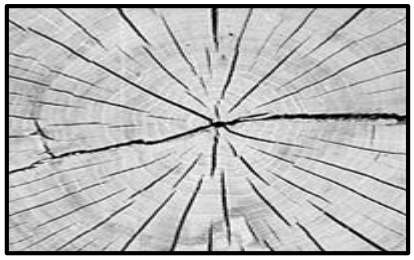
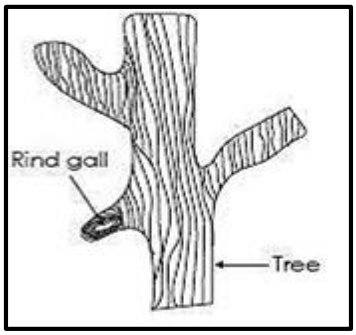


2. *Twisted Fibers in Timbers*

When the tree in its younger age is exposed to high-speed winds, the fibers of wood gets twisted. This type of wood is not suitable for sawing. So, this can be used for making poles, posts, etc.

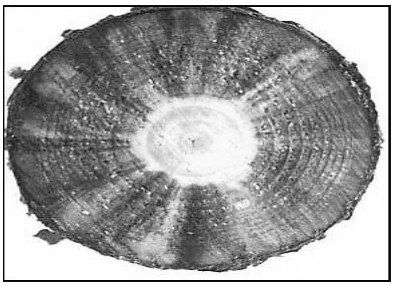
3. *Rind* Galls

The rind means bark and gall indicates abnormal growth. Hence peculiar curved swelling found on the body of tree are known as rind gall. They develop at points from where branches are improperly cut off or removed. They are rarely found in a tree and the timber in this part is very weak and not durable.



7. *Chemical Stain*

Chemical stain is formed on the wood by the action of any external chemical agents like reaction by the gases present in the atmosphere etc. The stain area gets discolored in this defect.



8. *Shakes in Timber*

Shakes are nothing but cracks which separate the wood fibers partly or completely. Different shakes are formed in different conditions as follows:

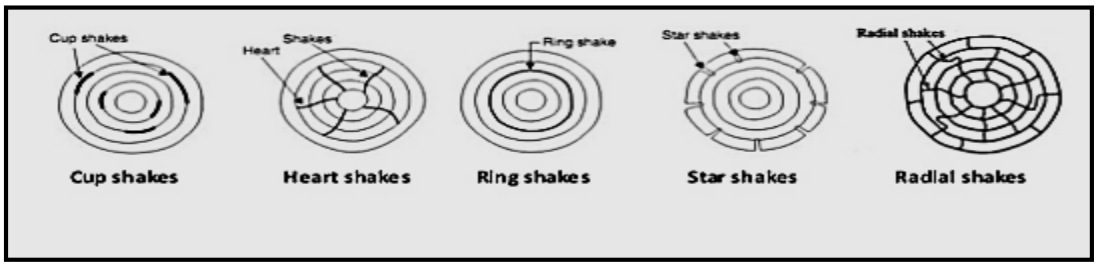
a) Cup shakes are formed due to the non-uniform growth of a tree or excessive bending by cyclones or winds. In this case, the shakes develop between annual rings and separate them partly.

b) Heart shakes, the other type of shakes which develop in maturity approaching trees whose inner part is under shrinkage. The shake spread from pith to sapwood following the directions of medullary rays.

c) Ring shakes are similar to cup shakes, but they completely separate the annual rings.

d) Star shakes are formed due to extreme heat or severe frost action. They develop wider cracks on the outside of timber from bark to the sapwood.

e) Radial shakes are developed radially from pith to the bark



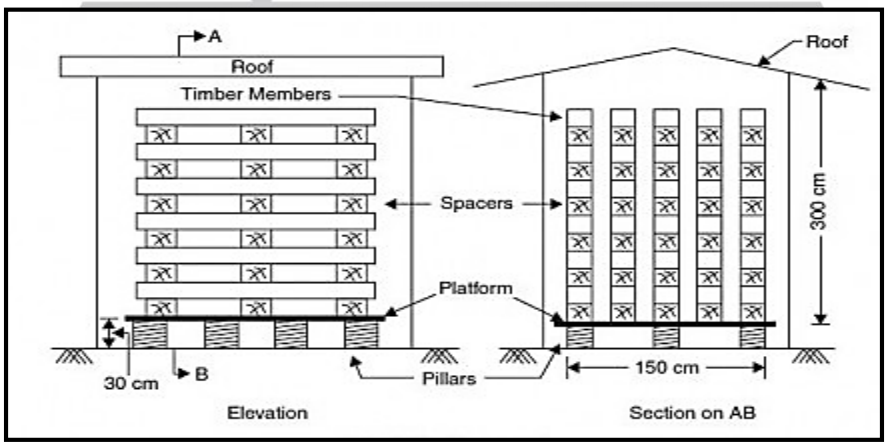
- To make timber safe from the attack of fungi and insects.
- To reduce the tendency of timber to crack, shrink and warp.
- To make timber fit for receiving treatment of paints, preservatives, varnishes.
- To import hardness, stiffness, strength and better electrical resistance to timber.

Natural Seasoning

Seasoning of woods or timbers using natural elements is called natural seasoning. eg. water and air seasoning.

a. Air Seasoning

Exposing the woods to air for seasoning. At first, a platform is required that is built on the ground at 300mm height above the ground. Secondly, the arrangement of woods in layers. Air circulation is maintained between logs because it helps to reduce the moisture which is important for seasoning. The environment for this need to maintain some conditions. A clean, shady, dry, cool place is preferred. Sometimes logs are coated by the impermeable substance to reduce extreme moisture. To improve the quality oil coating, thick paint coating is maintained. To prevent fungal infection logs are treated with petrol or gasoline.



b. Water Seasoning

Removal of wood sap immersing logs into water flow is called water seasoning. It is carried out on the banks of the river while thicker ends are kept towards upstream. After that, the logs are allowed to dry.

Disadvantage: It is time consuming such as 2 to 4 weeks generally.

Natural Seasoning

Advantage

- Depending upon the climatic conditions, the moisture content of wood can be brought down to about 10-20%
- It does not require skilled supervision
- This method of seasoning timber is cheap and simple.
- It is uneconomical to provide artificial seasoning to timber sections thicker than 100 mm, as such sections dry very slowly.

Disadvantage

- As the process depends on the natural air, it sometimes becomes difficult to control it.

b. *Chemical Seasoning*

Reduction of moisture using salt solution is called chemical seasoning. After the absorption of water by the solution logs are let to dry.

Advantage

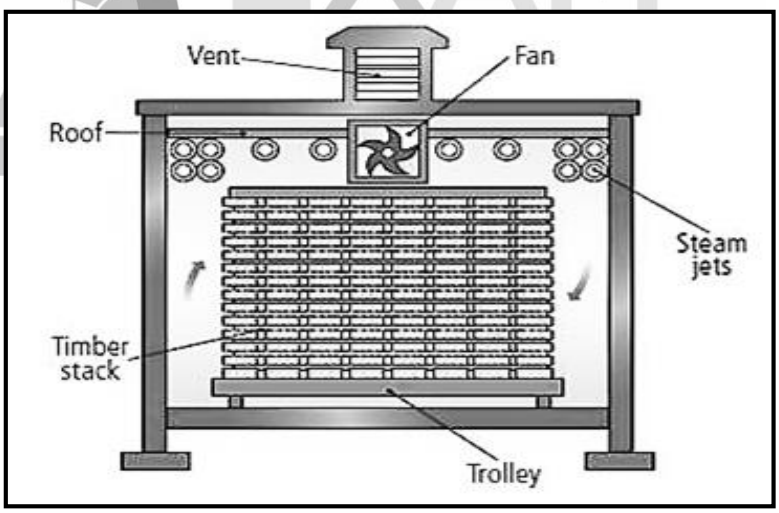
- It increases the strength of the timber.
- It is less time-consuming.

Disadvantage

- Chemical reagents can sometimes reduce strength.
- It can cause a problem in gluing or finishing or corrosion while using.

c. *Kiln Seasoning*

Seasoning of wood by using a large chamber or oven where there is a good process for the circulation of hot air. In this method, drying of timber is carried out inside an airtight chamber or oven.



d. *Electrical Seasoning*

Dry wood is non-conductor of electricity while green timber is a conductor, so, can pass alternating current. Thus in this method alternating current is used for

REQUIREMENTS OF A GOOD PRESERVATIVE

- It should allow decorative treatment on timber after being applied over timber surface.
- It should be capable of covering a large area with small quantity.
- It should be cheap and easily available.
- It should be free from unpleasant smell.
- Its penetrating power into wood fibres should be high. It is necessary for the preservative to be effective to penetrate at least for a depth of 6 mm to 25 mm.

Types of Preservatives

1. *ASCU Treatment*

ASCU is special preservative which is developed at the Forest Research Institute, Dehradun.

Its composition is as follows:

- X-Part by weight of hydrated arsenic pentoxide, ($As_2O_5.2H_2O$).
- Y-Part by weight of blue vitriol or copper sulphate, ($CuSO_4.5H_2O$).
- Z-Part by weight of potassium dichromate ($K_2Cr_2O_7$) or sodium dichromate ($Na_2Cr_2O_7.2H_2O$)
- This preservative gives timber protection against the attack of white ants. The surface treated with this preservative can be painted, polished, varnished or waxed.

2. *Chemical Salts*

- These are water-borne preservatives and they are mostly salts dissolved in water. The usual salts used are copper sulphate, mercury chloride, sodium fluoride and zinc chloride.
- These preservatives are odourless and non-inflammable.

Method for Preservation

There are six Methods Adopted for Preservation of Timber:

1. ***Brushing***

   - The solution prepared from preservative is applied on timber surface by good quality of brushes.
   - This is the simplest method and it is generally adopted for seasoned timber.
   - The cracks should be filled up before the application of preservative.

2. ***Charring***

   - The surface to be charred is kept wet for about half an hour and it is then burnt up to a depth of about 15 mm over a wood fire.
   - The charred portion is then cooled with water.
   - Due to burning, a layer of coal is formed on the surface.
   - This layer is not affected by moisture and it is not attacked by white ants, fungi.
   - The disadvantage of this method are:
     (i) The charred surface becomes black in appearance and hence it cannot be used for exterior work.
     (ii) There is some loss of strength of timber as the cross-section is reduced due to charring.

3. ***Dipping and Steeping***

   - In this method, the timber to be given preservative treatment is dipped or soaked for a short period in the solution of preservative.
   - This method gives slightly better penetration of preservative than in case of brushing or spraying.

CLEAR YOUR CONCEPT

Qu1. A well seasoned timber may contain moisture upto:

a) 4 to 6%

b) 6 to 8%

c) 8 to 10%

d) 10 to 12%

Qu2. The quality of timber does not depend upon:

a) Maturity of tree

b) Time of felling

c) Type of tree

d) Size of tree

Qu3. How should the smell of a freshly cut timber be?

a) Sweet

b) Pungent

c) Unpleasant

d) Odourless

Qu4. Timbers with _____ annular rings are generally the strongest.

a) Narrow

b) Wide

c) Distinct

d) Indistinct

- Minimum compressive strength 7.0 MPa
- Water absorpsion not more than 22.5%
- Used as Permanent Structure

c) Third Class Bricks

- These are ground moulded and they are burnt in clamps.
- Also called Aama Bricks or under burnt bricks.
- These bricks are not hard and they have rough surface with irregular and distorted edges.
- These bricks gives dull sound when struck together.
- They are used for unimportant and temporary structures.
- Minimum compressive strength 3.5 MPa
- Water absorpsion not more than 25%
- Used as Temporary structure

d) Forth Class Brick

- Forth class brick is called Jhama brick or over burnt bricks.
- These bricks have compressive strength more than 10.5 Mpa .
- Used as Road Metals, Ballast, Base of Foundation.

USES OF BRICKS

Brick plays very important role in the field of civil engineering construction. Bricks are used as an alternative of stones in construction purpose. Here some main uses of construction brick are given below.

- Construction of walls of any size
- Construction of floors
- Construction of arches and cornices

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Test Series Available..

Total weekly test : 35

Total mid subject test : 16

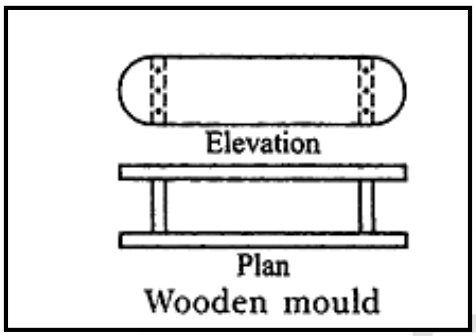
Total full length test : 13

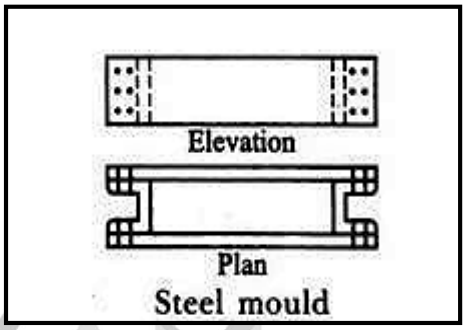
Mock test : 16

Total test : 80

seasoned wood. 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.

A typical steel mould is shown in fig. It is prepared from the combination of steel plates and channels. It may even be prepared from steel angles and plates. The thickness of steel mould is generally 6 mm. They are used for manufacturing bricks on a large scale. The steel moulds are more durable than wooden moulds and they turn out bricks of uniform size. The bricks shrink during drying and burning.





The bricks prepared by hand moulding are of two types:

(a) Ground-moulded bricks (b) Table-moulded bricks.

Ground-Moulded Bricks

- 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 it is dashed in the mould. The clay is pressed or forced in the mould in such a way that it fills all the corners of mould.
- The extra or surplus clay is removed either by wooden strike or metal strike or frame 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 is 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

Advantages of Clamp Burning

Following Are the Advantages of Clamp Burning

(i) The burning and cooling of bricks are gradual in clamps. Hence the bricks produced are tough and strong.

(ii) The burning of bricks by clamps proves to be cheap and economical.

(iii) No skilled labour and supervision are required for the construction and working of clamps.

(iv) The clamp is not liable to injury from high wind or rain.

(v) There is considerable saving of fuel.

Disadvantages of Clamp Burning

Following Are the Disadvantages of Clamp Burning

(i) The bricks are not of regular shape. This may be due to the settlement of bricks when fuel near bottom is burnt and turned to ashes.

(ii) It is a very slow process.

(iii) It is not possible to regulate fire in a clamp once it starts burning and the bricks are liable to uneven burning.

(iv) The quality of bricks is not uniform. The bricks near the bottom are over-burnt and those near sides and top are under-burnt.

Kiln Burning

The 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.

VC: The Pathshala

They are of two types:

a. Intermittent Kilns.

b. Continuous Kilns.

Qu6. What is the loading rate used in compressive strength test?

a) 14 N/mm^2 per hour

b) 14 N/mm^2 per minute

c) 20 N/mm^2 per minute

d) 40 N/mm^2 per hour

Qu7. What should be observed ideally when two bricks are struck together?

a) Dull sound

b) Sides shatter

c) Clear ringing sound

d) Brick breaks

Qu8. Creep test is carried out in accordance with

a) IS 1528

b) IS 5688

c) IS 3495

d) IS 4568

Qu9. When observed efflorescence is more than 10% but less than 50% of the exposed area, it is

a) Moderate efflorescence

b) Serious efflorescence

c) Heavy efflorescence

d) Light efflorescence.

CHAPTER – 4

AGGREGATES

- Aggregates are the materials basically used as filler with binding material in the production of mortar and concrete.
- They give body to the concrete and occupy 70 to 80 percent of volume of concrete. Therefore, they exert considerable impact on the characteristics and properties of concrete.
- They are derived from igneous, sedimentary and metamorphic rocks or manufactured from blast furnace slag, etc.
- They should be clean, hard, strong, durable and graded in size to achieve utmost economy from the paste.
- Earlier aggregates were considered to be chemically inert but the latest research has revealed that some of them are chemically active and also that certain types exhibit chemical bond at the interface of aggregates and Cement paste.
- To increase the bulk density of concrete aggregates are used in two different sizes—the bigger ones known to be coarse aggregate (grit) and the smaller ones fine aggregate (sand).
- Coarse aggregate form the main matrix of concrete and fine aggregate from the filler matrix between the coarse aggregate.

CLASSIFICATION OF AGGREGATE

On the Basic of Geological Origin

Natural Aggregates

- Natural aggregates are obtained by crushing from quarries of igneous, sedimentary or metamorphic rocks.
- Most widely used aggregate are from igneous origin.

Fine Aggregate

- Aggregate passing through 4.75 mm sieve are defined as fine.
- They may be natural sand—deposited by rivers, crushed stone sand—obtained by crushing stones and crushed gravel sand.
- Smallest size of fine aggregate (sand) is 0.06 mm
- Depending upon the particle size, fine aggregates are described as fine medium and coarse sand.

On the Basis of Shape

Rounded aggregates

- These are usually obtained from river or sea shore.
- These have minimum ratio of surface area to the volume.
- Cement paste required is minimum and produce minimum voids (about 32%) in concrete.

Irregular aggregates

- These have voids about 36 per cent and require more cement paste as compared to rounded aggregate.
- Due to irregularity in shape they develop good bond and are suitable for making ordinary concrete.

Angular Aggregate

- These have sharp, angular and rough particles having maximum voids (about 40 per cent).
- Angular aggregate provide very good bond than the earlier two, are most suitable for high strength concrete and pavements; the requirement of cement paste is relatively more.

CHARACTERISTICS OF AGGREGATES

- If either the strength of the paste or bond between the paste and aggregate is low, than irrespective of the strength of aggregate, a concrete of poor quality will be obtained.
- However strength of aggregate will influence strength of concrete when the paste and bond strength are good.
- Therefore strong aggregates are an essential requirement for a strong concrete.
- Through naturally available aggregates are quite strong still they are required to be tested in certain situations like for production of high strength and ultra high strength concrete.
- Assessment of strength of aggregate is made by carrying out several tests to determine values like:
  - (a) Aggregate crushing value
  - (b) 10 percent fineness value
  - (c) Aggregate impact value
  - (d) Aggregate abrasion value

Stiffness

- Modulus of elasticity of concrete is approximately equal to the weighted average of the moduli of the cement paste and the aggregate, as such the modulus of the coarse aggregate has an important influence on the stiffness of concrete.
- A high value reduces the dimensional changes due to creep and shrinkage of cement paste, but at the cost of higher internal stresses.
- Concrete that is to be subjected to wide variations of temperature and humidity, internal cracking is reduced by the use of a more compressible aggregate, but in practice this effect is rarely of sufficient importance to determine the choice of aggregate.

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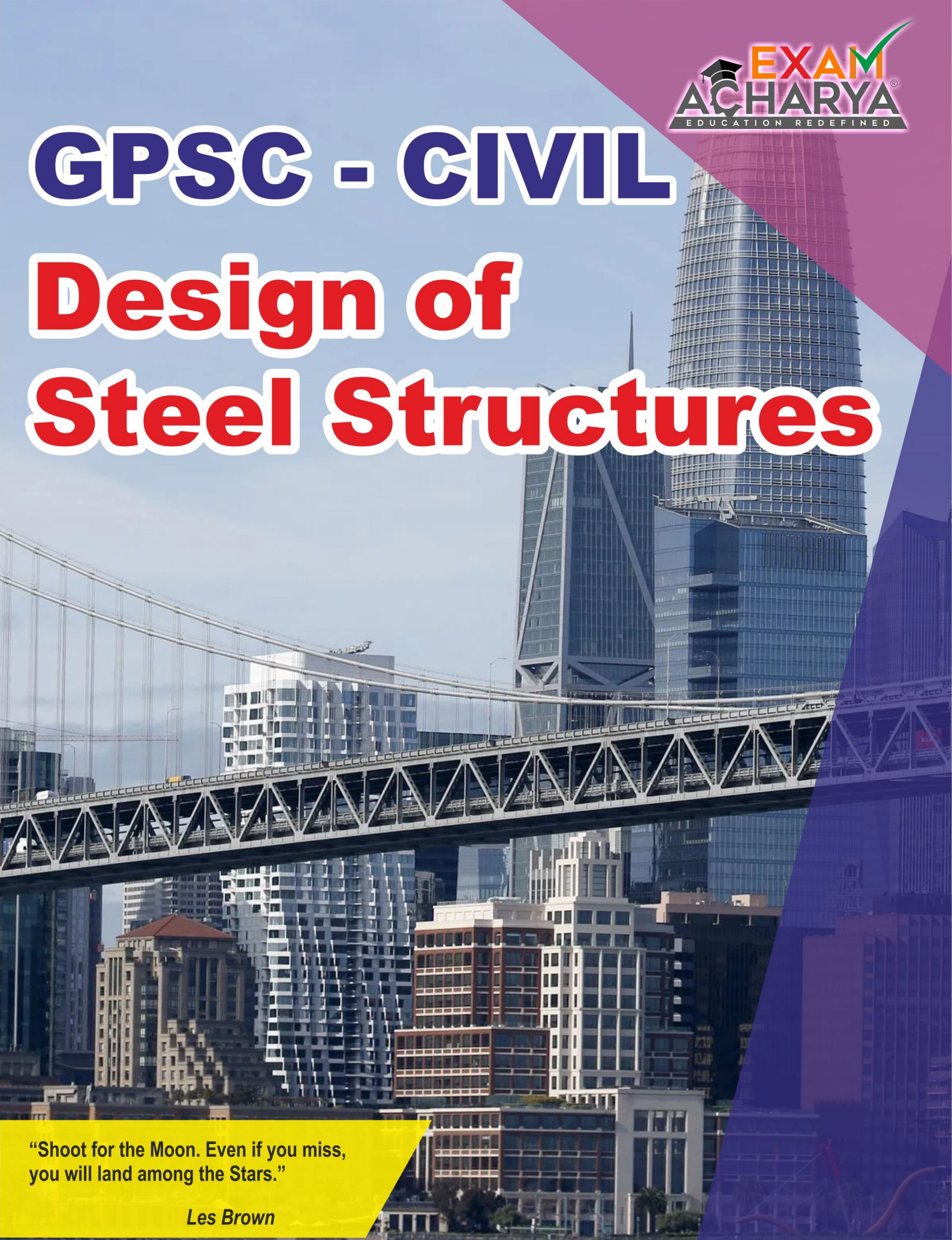
Design of Steel Structures



"Shoot for the Moon. Even if you miss, you will land among the Stars."

Les Brown

The content of this book covers all PSC exam syllabus such as MPSC, RPSC, UPPSC, MPPSC, OPSC etc.

Specific Gravity

- Specific gravity of aggregates is an important factor in design of concrete mixes as it greatly influences the strength and absorption of concrete.
- Specific gravity of aggregates generally is indirective of its quality, for most of natural aggregates it lies between 2.6 - 2.7.
- Low specific gravity indicate high porosity and therefore poor durability and low strength.
- Concrete density will greatly depend on specific gravity.

Bulk Density

- Bulk density or unit weight gives useful information regarding the shape and grading of aggregates.
- It shows how densely the aggregate is packed when filled in a standard manner.
- Higher the bulk density, the lower is the void content to be filled by the sand and cement.
- For coarse aggregate a higher bulk density is an indication of fewer voids to be filled by sand and cement.

Voids

- The void is calculated as,

$$\textbf{Void ratio} = 1 - \frac{\textbf{Bulk density}}{\textbf{Apparent specific gravity}}$$

- If the voids in the concrete are more the strength will be low.

Moisture Content

- Surface moisture expressed as a percentage of the weight of the saturated surface dry aggregate is known as moisture content.
- It should be noted that adsorption represents water contained in aggregate in a saturated and surface dry condition, and moisture content is the water in excess

- In ordinary sand bulking various from 15 to 30% for increase in moisture content 5 to 8%. For fine sand this might increase to 40% also.
- In production of concrete if sand is measured by volume and no allowance is made for bulking then moist sand will occupy considerably large volume incomparision to dry volume.
- Therefore concrete produced will be rich in cement as less quantity of concrete per bag is produced.
- For example, if bulking of sand is 20% and if mix ratio is 1:2:4, and if bulking correction is not applied to sand then dry sand in the concrete will be $\frac{1}{1.2} \times 2 = 1.667$ instead of 2 per unit volume of cement.
- Mix proportion will be 1:1.667:4 in place of 1:2:4, which indicates less production of concrete.
- To counter effect the, effect of bulking volume of sand used in the mix should be equal to 1.2 X 2 = 2.5 instead of 2 per unit volume of cement.
- Bulking in field is determined by simple field test sample of moist sand is filled in a measuring cylinder and its volume in measured as (A)
- Now pore water and completely submerge the sand and shake and note down the volume (B).
- In above method we should have dried the sand but volume of saturated and dried sand are approximately same.

$$\textbf{Percentage bulking} = \frac{A-B}{B} \times 100$$

Fineness Modulus

- Fineness modulus is defined as sum of cumulative percentage retained, on the seives of the standard seives: 150µm. 300µm, 600µm, 1.18mm, 2.36mm, 4.75mm. 10mm, 12.5mm, 20mm. 63mm and 80 mm.

Impurities

Which interfere with the processes of hydration of cement like humus or organic loam found mostly in sands.

Coating

Which prevent the development of good bond between aggregate and the matrix like clay, silt and other fine material.

Unsound particles

Like iron pyrites, soft shale, clay nodules, mica, wood coal.

SOUNDNESS

- Soundness is defined as the ability of aggregate to resist changes in volume as a result of changes in physical conditions.
- The physical conditions responsible for the unsoundness are:
  (a) Freezing and Thawing
  (b) Thermal Changes at Temperature above freezing
  (c) Alternating wetting and Drying
- Porous and weak aggregates containing undesirable extraneous matter undergo excessive volume changes under favorable conditions.
- Freeze thaw resistance of aggregate is related to its porosity, absorption, and pore structure. This may cause local scaling to surface cracking consequently leading to impaired appearance and sometimes structural failure.

Alkali-Aggregate Reaction

- Previously aggregate were considered. to be inert but later it was realized that aggregates are not fully inert.
- Infact some of the aggregates contains reactive silica, which reacts with alkalies (Na_2O) and K_2O) present in the cement.

- Unfortunately, such a concrete mix is prone to be 'harsh' and unworkable. Moreover, it is very likely to segregate, with the coarser particles separating out or settling more than the finer particles.
- The cement paste must be in sufficient. quantity to be able to coat properly all the aggregate surfaces, to achieve the required workability, and to ensure that the particle and sizes are distributed as homogeneously as possible without segregation.
- Pressure of more 'fines (sand and cement) in a mix is found to improve both workability and resistance to segregation, because the fines tend to lubricate' the larger particles, and also fill into their voids as mortar.
- But too much of fine aggregate in a mix is considered to be undesirable because the durability and impermeability of the hardened concrete may be adversely affected.

Qu6. An aggregate is said to be flaky if its least dimension is less than _____

a) 1/5th of mean dimension

b) 2/5th of mean dimension

c) 3/5th of mean dimension

d) 4/5th of mean dimension

Qu7. The light weight aggregates are obtained from

a) Sedimentary rocks

b) Metamorphic rocks

c) Igneous rocks

d) Volcanic source

Qu8. For the construction of cement concrete floor, the maximum permissible size of aggregate is _____

a) 4.75mm

b) 8mm

c) 10mm

d) 15mm

Qu9. The 28 days cube strength of mass concrete using aggregates of maximum size 5 cm for gravity dams should be _____

a) Between 150 to 300 kg/cm^2

b) Between 350 to 600 kg/cm^2

c) Between 150 to 400 kg/cm^2

d) Less than 200 kg/cm^2

CHAPTER – 5

ADMIXTURES

ADMIXTURES

- Admixtures are chemicals which are added to concrete at the mixing stage to modify some of the properties of the mix.
- Admixtures should never be regarded as a substitute for good mix design, good workmanship, or use of good materials.

USES OF ADMIXTURES

Most common reasons for using admixtures in concrete are:

(a) To increase workability without changing water content.

(b) To reduce water content without changing workability.

(c) To effect a Combination of the above.

(d) To adjust setting time.

(e) To reduce -Segregation and/or bleeding.

(f) To improve pumpability.

(g) To accelerate the rate of strength development at early ages.

(h) To increase strength.

(i) To improve potential durability and reduce permeability.

(j) To reduce the total cost of the materials used in the concrete.

(k) To compensate for poor aggregate properties.

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Test Series Available..

Total weekly test : 35

Total mid subject test : 16

Total full length test : 13

Mock test : 16

Total test : 80

- The addition of a plasticizer makes it possible to achieve a given strength with a lower cement content.
- Plasticizers may improve pump ability.

Practical Considerations

- A number of plasticizers contain a retarder and can cause problems if overdosed.
- While some plasticizers entrain varying amounts of air, others are reasonably consistent in the amount of air they entrain.
- Where plasticizers are used to increase workability, the shrinkage and creep will invariably increased.

Superplasticizers

- These admixtures are chemically distinct from normal plasticizers and although their action is basically the same, it is more marked.
- When they are used to produce-flowing concrete a rapid loss of workability can be expected and therefore they should be added just prior to placing.
- Some of the examples of Superplasticizers are sulphonated melamine formaldehyde condensates naphthalene sulphonate formaldehyde condensates, modified lignosulphonate, and mixture of saccharates and acid amines.

Uses

Superplasticizers are used to best advantage:

- In areas of congested reinforcement.
- Where a self-levelling consistence facilitates placing.
- For high-strength concretes, by decreasing the water cement ratio as a result of reducing the water content by 15-25%.

designed for air entrainment and that the percentage of air entrained during construction be monitored.

- Because the doses are so small, special dispensers and accurate monitoring are required.
- Different types and sources of cement/cement extenders may result in the entrainment of different amounts of air for the same dose and mix proportions.
- A change in cementitious content, in the grading or proportions of the fine fractions of sand will normally alter the volume of air entrained.
- The amount of air entrained may depend on the source and grading of sand in concrete.
- Forced-action mixers entrain larger volumes of air than other types.
- Increasing ambient temperature tend to reduce. The volume of air entrained.
- The use of ground granulated blastfurnace slag (GGBS) and fly ash (FA) tends to reduce the amount of air entrained.
- Duration of mixing can also affect air content.

Accelerators

- These admixtures speed up the chemical reaction of the cement and water and so accelerate the rate of setting and/or early gain in strength of concrete.
- Among the main types of accelerators are chloride, based, non chloride bases and shotcrete accelerators:
- The example of accelerators are sulphates with an exception of calcium sulphate alkali carbonates aluminates and silicates, alluminium chloride, calcium chloride, sodium chloride, sodium and potassium hydroxides, calcium formate, formaldehyde, para formaldehyde etc.

Practical Considerations

- If a mix is overdosed beyond the limit recommended by the supplier, retardation can last for days.
- Retarders often increase plastic shrinkage. arid plastic settlement cracking.
- Delayed addition of retarders can result in extended retardation.

Note
- Some substances may act as accelerators or as retarders according to the proportion added. For example, $CaCl_2$ when added upto 2 percent by weight of cement acts as accelerator, but on increasing the proportion, it acts as retarder and leads to flash set.

Water Proofer

- Cement mortar or concrete should be impervious to water under pressure and also should have sufficient resistance to absorption of water.
- Concrete can-be made water resistant with the additives which may be water repellent type or pore filling type.
- Examples of water repellent materials such as soda and potash soaps are chemically active, whereas calcium soaps, resin, vegetable oil, fats, waxes and coal tar residue are the examples of chemically inactive materials.

Bleeding Agents

- To stop bleeding, paraffin wax at about.0.2-0.75 percent by mass of cement or air entrainment is used.
- Air entrainment fatter is more effective but requires high degree of control.

Pozzolanas

- These are siliceous materials which are themselves inactive but react in the presence of water, with time to form compounds having cementitious properties.
- Pozzolanas react with free lime in cement and improve the durability of concrete, and reduce the rate of hardening of concrete, which is the principal objection to its use.

CLEAR YOUR CONCEPT

Qu1. Consider the following statements:

The effect of air entrainment in concrete is to

1. **Increase resistance to freezing and thawing**
2. **Improve workability**
3. **Decrease strength**

Which of these statements are correct?

a) 1 and 2

b) 1 and 3

c) 1 alone

d) 1, 2 and 3

Qu2. Consider the following statements:

The addition of surfactants in the concrete mix results in

1. **Increase in the water cement ratio**
2. **Decrease in the water cement ratio**
3. **Increase in the strength of concrete**
4. **Decrease in the curing duration**
5. **Increase in the density of concrete**

Which of these statements are correct?

a) 1,3 and 4

b) 2, 3 and 5

c) 3, 4 and 5

d) 1, 4 and 5

TEST YOUR SELF

Qu5. Consider the following statements:

Superplasticizers when added

1. **Increase compressive strength of concrete**
2. **Permit to use lower water cement ratio thereby increasing compressive strength of concrete**
3. **Reduce setting time of concrete**
4. **Permit to use lower cement content, thereby increasing compressive strength of concrete**

Which of these statements is/ are correct?

a) 1 and 3

b) 3 and 4

c) 2 only

d) 1, 3 and 4

Qu6. The role of superplasticizer in a cement paste is to

a) Disperse the particles

b) Disperse the particles and to remove air bubbles

c) Disperse the particles, remove air bubbles and to retard setting

d) Retard setting

Answer

1-(d), 2-(b), 3-(d), 4-(c), 5-(d), 6-(c)

2. Workability

It was the ability of a mortar or a plaster to remain smooth and mouldable even against the suction it may experience from other porous building materials. These aspects depend on the plasticity and water retention of the mortar. The mix can penetrate and fills voids in a background to give a good key. Less workable mixes would become stiff and awkward as the water was sucked away from them. Good workability greatly assists good workmanship, helping to achieve full joints with good bonding to the other materials.

3. Soft Texture

This contributes to the comfortable feel and charming appearance of lime surfaces. It also helps lime to cushion the joints between stones or bricks and prolong their life

4. Durability

Lime was exceptionally durable material. An outstanding example was the Pantheon Temple in Rome which has a lime concrete dome spanning over 43m. This has survived for nearly nineteen hundred years.

5. Breathability (High Porosity and High Permeability)

This group of characteristics allows lime mortars to protect the other materials in a building by handling moisture movements through the building, protecting masonry materials from harmful salts. Breathability greatly assists the drying out of buildings and the avoidance of condensation problems, which contributes to the comfort of people using the buildings. This property depends on the high porosity and permeability characteristics of lime mortars

6. Low Thermal Conductivity

This property affects the surface temperatures of buildings, making lime plasters in cool climates feel warmer to the touch than cement plasters. The higher surface temperatures contribute to a feeling of comfort.

EXAM ACHARYA
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Fluid Mechanics and Hydraulic Machines

"Success Consists of going from Failure without Loss of Enthusiasm."

Winston Churchill

The content of this book covers all PSC exam syllabus such as MPSC, RPSC, UPPSC, MPPSC, OPSC etc.

c) ***Eminently hydraulic lime:*** Normally contains 18% to 25% reactive clay. The putty will set hard in less than a week.

2. Non-Hydraulic Lime

Non-hydraulic limes are derived from limestone which does not contain clay or other reactive silicates. The best and purest forms of non-hydraulic limes are made from limestone containing very high proportions of calcium carbonate. These limes are also known as "high-calcium" limes and used in the traditional basis of fat lime putty for plastering of buildings under favourable conditions and for working with soft sandstone or brick. Non-hydraulic limes rely for their hardening on drying and on absorption of carbon dioxide. The resultant gradual conversion of calcium hydroxide to calcium carbonate requires an optimum balance of moisture and temperature, and may take many years to complete and the right conditions non-hydraulic mortars may continue to develop strength over a period of many years.

3. Magnesian Lime

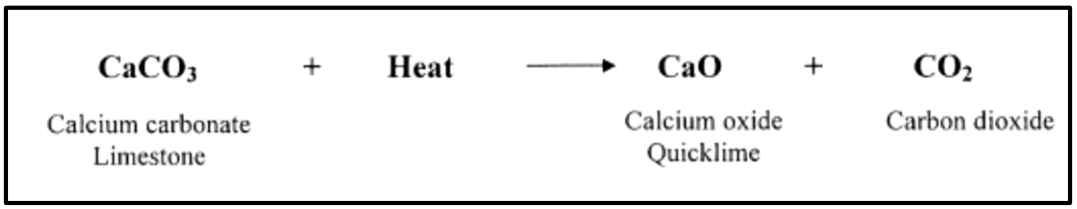
Magnesian lime was derived from limestone containing a combination of calcium carbonate and magnesian carbonate where the raw material consists of double carbonate of calcium and magnesium the material was known as dolomite and the resulting lime was dolomitic lime. Magnesian limestone and dolomite occur in some areas of Scotland.

4. Selenitic Lime

Another variety of lime used historically was known as selenitic lime. This was made by incorporating calcium sulphate into the material, either by introducing sulphur dioxide into the kiln during lime burning or by adding sulphuric acid to the slaking water or by the addition of gypsum to a feebly hydraulic lime and grinding the mixture. The calcium sulphate promoted a rapid set and increased the strength of the mortar. Unfortunately it can result in stone decay in situations where any remaining free calcium sulphate, which was more readily soluble

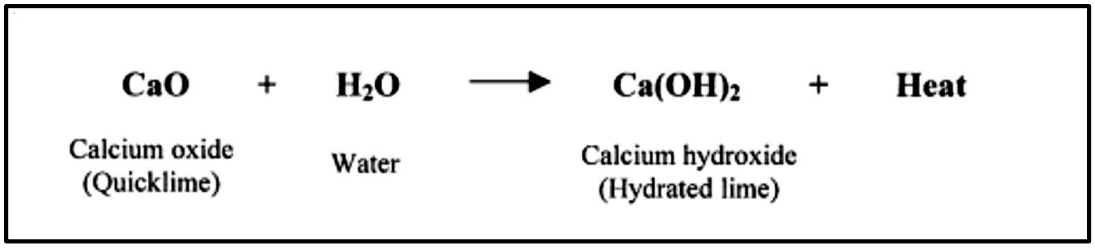
1. Limestone Burning

The first step in the preparations of lime was the burning of limestone in a kiln. The temperature required to start the decomposition of the carbonate was 700°C. To achieve the process in a reasonable time the temperature normally used is higher than 700°C and would be nearer to 900°C. The "burning" has the effect of displacing a molecule of carbon dioxide from calcium carbonate, this leaves calcium oxide (quicklime). The burning reaction was as follows:



2. Slaking

The controlled process of combining quicklime with water was known as slaking. Quicklime was so called because of its fast reaction with water. In the slaking process a large amount of heat was developed. The slaking of quicklime was a dangerous operation as the reaction of the calcium oxide with water was violent. If there was little amount of water in the presence of a large amount of lime, the heat evolved may bring the mixture rapidly above the boiling point and cause eruptions of caustic sprays of lime and limewater. The slaking reaction was as follows:



USES OF LIME

1. Lime Used in Mortar

Lime in one form or another has been a binder in mortars for centuries, well before cement was invented. Lime today is still used as the primary binder in many mixes, usually in the form of lime putty or Hydraulic lime. Hydrated lime is used in modern cement based mortars mainly for its properties as a plasticizer

2. Lime Use in Making Aerated Blocks

Quicklime is mixed with cement, sand, water and aluminium powder to give slurry which rises and sets to form honeycomb structured blocks which have excellent thermal and sound insulation properties. The heat generated when quicklime reacts with water and the alkaline content combined with aluminium powder generates hydrogen bubbles which cause the blocks to rise.

The heat generated subsequently causes the slurry to set. The blocks are then heated in an autoclave, which promotes reactions between calcium and silicates in the sand and gives extra strength. Dolomite lime and/or modified quicklime can be added to reduce excessive shrinkage or cracking.

3. Lime Wash

Lime wash is a traditional method of painting walls with a colour base that allows the masonry to breathe, providing both protection and aesthetic appeal. It involves the routine, annual brushing on of slaked lime, watered down to a creamy consistency and sometimes, waterproof with additives such as a tallow. As a result, buildings frequently build up a thick, weathering skin due to successive applications. Lime wash is also widely used in agricultural buildings due to its germicidal qualities coupled with its extreme ease of application and low cost.

technique used was the same. Rendering was applied to the outside of buildings for protection and appearance. A lime render layer with fine stones was applied to the face of the wall.

8. Plastering

Lime plaster was used to improve living conditions in solid masonry houses. The lime plaster smoothed over the rough interior of the stone buildings, giving an even appearance

Uses of Lime

- It is used as matrix for concrete.
- It is used as a binding material in mortars for stoneware.
- It is used for plastering walls, ceilings, etc.
- It is employed for white washing and as a base coat for distempers.
- It is used for knotting of timber work before paining.
- It is used in the manufacture of paints.
- It is used for stabilizing the soils.
- It is used for production of artificial stone.

Qu6. Lime is widely used for

a) Waste water treatment

b) Manufacturing tiles

c) Jewellery making

d) As an aggregate

Qu7. Which of the following methods yields quick, small supplies of Quick Lime?

a) Intermittent kiln

b) Continuous kiln

c) Clamp burning

d) Kankar burning

Qu8. How can one understand the completion of the burning of lime?

a) Blue flame at the top disappears

b) Blue flame appears at the top

c) Smoke is released in huge quantity

d) Red flame appears at the top

Qu9. The temperature at which standard Gibbs free energy is zero for calcination reaction is called

a) Absolute temperature

b) Negative temperature

c) Transition temperature

d) Thermal decomposition temperature

Qu10. In which feed type kiln, limestone does not come in contact with fuel?

a) Single feed

b) Isolated feed

c) Separate feed

d) Mixed feed

CHAPTER – 7

CEMENT

CEMENT

- Cement is a material which has cohesive and adhesive properties in the presence of water.
- For civil engineering works i.e. construction industry, its primary function is to bind the fine aggregates (sand) and coarse aggregates particles together into a hard compact durable mass.
- Cement is a product obtained by pulverizing clinker formed by calcinating raw-materials primarily consisting of Lime (CaO), Silicate (SiO_2), Alumina (Al_2O_3) and Iron oxide (Fe_2O_3).
- When cement is mixed with water it forms a paste which hardens and binds aggregates (fine and coarse) together to form a hard durable mass called concrete.
- Cements used in construction industry can be classified as hydraulic and non-hydraulic.
- Hydraulic cement set and harden in water and give a product which is stable. e.g. Portland cement.
- Non hydraulic cement does not set and harden in water such as non-hydraulic lime or which are unstable in water e.g. plaster of Paris.
- Cement can be manufactured either from natural cement stones or artificially by using calcareous and argillaceous materials. Examples of natural cements are Roman cement, Pozzolana cement and Medina cement and of artificial cement are Portland cement and special cements.

Note

Argillaceous	Calcareous
➢ Shale and clay ➢ Cement rock ➢ Blast furnace slag ➢ Marl	➢ Limestone ➢ Chalk ➢ Marine shells

Constituents of Portland Cement (Raw Material)			
Oxide	**Function**	**Composition (%)**	**Average**
Lime, CaO	Controls strength and soundness. Its deficiency reduces strength and setting time. Excess of it cause unsoundness.	60-65	63
Silica, SiO_2	Gives strength. Excess of it cause slow setting.	17-25	20
Alumina, Al_2O_3	Responsible for quick setting, if in excess, it lowers the strength.	3-8	6
Iron oxide, Fe_2O_3	Gives colour and helps in fusion of different ingredients. i.e., it acts as a flux	0.5-6	3
Magnesia, MgO	Imparts colour and hardness. If in excess, it causes cracks in mortar and concrete and unsoundness.	0.5-4	2
Soda and/or potash $Na_2O+ K_2O$	These are residues, and if in excess cause elforescence and cracking.	0.5-1	1
Sulphur trioxide, SO_3	Excess of it makes cement unsound.	1-2	1.5

COMPOSITION OF CEMENT CLINKER

- When these raw materials are put in kiln then it fuses and following compounds are formed and they are known as Bogue compound.

Bogue compound	Formula	Name	Symbol	Composition
1. Tricalcium silicate	$3CaO.SiO_2$	Alite	C_3S	40%
2. Dicalcium silicate	$2CaO.SiO_2$	Belite	C_2S	32%
3. Tricalcium aluminate	$3CaO.Al_2O_3$	Celite	C_3A	10.5%
4. Tetra calcium alumino ferrite	$3CaO.Al_2Fe_2O_3$	Felite	C_4AF	9%

Tricalcium Silicate (C_3S) (25 - 50%) (Normally 40%)

- It is considered as best cementing material and is well burnt cement.
- It enables clinker easy to grind, increases resistance to freezing and thawing.

- Raising the C_3A content reduces the setting time, weakens resistance to sulphate attack and lowers the ultimate strength, heat of hydration and contraction during air hardening.
- Heat of hydration of 865 J/g.

Tetracalcium Alumino Ferrite (C_4AF) (8 – 14%) (Normally 9%)

- It is responsible for flash set but generates less heat.
- It has poorest cementing value.
- Raising the C_4AF content reduces the strength slightly.
- Heat d hydration 420 J/g

HYDRATION OF CEMENT

- When water is added to cement, a chemical reaction between water and cement takes place which is known as hydration of cement.
- Heat liberated during this chemical reactions is known as Heat of hydration.
- It has been observed that the significant product of hydration is ($CaO\ SiO_2\ H_20$) which is called as Tobermorite Gel because of its structural similarity to a naturally occurring mineral Tobermorite and commonly it is reffered C-S-H Gel.

Hydration of Cement Depends on Following Factors

1. ***Temperature at which hydration takes place***

   Higher the temperature rapid is the hydration.

2. ***Fineness of cement***

   Finer the cement rapid is the hydration. But the total heat involved its same.

is not valid. This is because even if excess water is present, complete hydration of cement never takes place due to deposition of hydration products.

- As a matter of fact water/cement ratio less than 0.38 is very common for high strength concretes.
- If excess water is present, it will lead to capillary cavities.

MANUFACTURE OF CEMENT

Raw materials

- Raw materials used in the manufacture of cement are classified into two broad categories

Argillaceous	Calcareous
Shale and clay	Limestone
Cement rock	Chalk
Blast furnace slag	Marine shells
Marl	

- From the above materials, other like lime, silica, alumina, iron oxide and small quantities of other chemicals are obtained.
- Cement can be manufactured either by dry processor wet process.
- In these process oxides combine to form tricalcium silicate (C_3S), dicalcium silicate (C_2S), tricalcium aluminate (C_3A) and tetra calcium aluminoferrite (C_4AF).

New Batches are going to start.....

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Test Series Available..

Total weekly test : 35

Total mid subject test : 16

Total full length test : 13

Mock test : 16

Total test : 80

- Dry process is adopted when the raw materials are quite hard.
- This process is slow and the product is costly.
- Limestone and clay are ground to fine powder separately and are mixed.
- Water is added to make a thick paste. Cakes of this paste containing about 14 percent of moisture are dried and are charged into rotary kiln and the product obtained after calcination in rotary kiln is called as clinker.
- Clinker is obtained as a result of incipient fusion and sintering at a temperature of about 1400°- 1500°C. Because ferric oxide has lower melting point than the other oxides, it acts as a flux.
- Aeration of cement clinker, which is commonly practised to slake free lime, also causes an absorption of moisture and carbon dioxide.
- Absorption of moisture tends to decrease the setting whereas that of carbon dioxide accelerates setting.
- Clinker is cooled rapidly to preserve the metastable compounds and their solid solutions — dispersion of one solid in another — which are made as the clinker is heated.
- Clinker (3 to 20mm size) is then cooled and ground in tube mills, where 2-3% of gypsum is added.
- Purpose of adding gypsum is to coat the cement particles by interfering with the process of hydration of the cement particles.

- In wet process Crushed raw materials are fed into ball mill and a little water is added.
- During operation of ball mill, the steel balls in it pulverize the raw materials which form a slurry with water.

VC: The Pathshala

- This slurry is passed to silos (storage tanks), where the proportioning of the compounds is adjusted to ensure desired chemical composition.
- Corrected slurry having about 40 per cent moisture content, is then fed into rotary kiln where it uses moisture and forms into lumps or nodules.
- Then it is finally burned at 1500-1600°C and nodules change to clinker at this temperature.
- Clinker is cooled and then ground in tube mills.
- While grinding the clinker, about 3 per cent gypsum is added.
- The cement is then stored in silos from where it is supplied.

COMPARISON OF WET AND DRY PROCESS

- Dry process is considered to be economical as compared to wet process because of less consumption of fuel in the kiln.
- Longer kilns are required in wet process which are more costly and less responsive to a variable clinker demand than the short kilns which can be used in dry process.
- Advantages of the wet process are the low cost of excavating and grinding raw materials, the accurate control of composition and homogeneity of the slurry.

TYPES OF CEMENT

1. Portland Cement

- It is obtained by finely pulverizing clinker produced by calcining to incipient fusion, an intimate and properly proportioned mixture of argillaceous and calcarecous materials.

Physical Requirement	Method of Testing	Grade		
		33	43	53
1. Fineness (Sq. Surface in m^2/kg	Blaine's air permissibility	225	225	225
2. Soundness	Le-Chatelier apparatus	10 mm	10 mm	10 mm
	Autoclave	0.8%	0.8%	0.8%
3. Setting time Initial (min) Final (max) (in min)	Vicat apparatus	30 600	30 600	30 600
4. Compressive strength (Mpa) not less than				
3 days ± 1hr		16	23	27
7 days ± 2 hr		22	33	37
28 days ± 4hr		33	43	53

2. Rapid Hardening Cement (IS: 8041)

- Also known as high early strength Portland cement.
- This cement is similar to OPC, except that it has more C_3S (unto 50%) and less C_2S, and it is ground more finely.
- It is used in situations where a rapid development of strength is desired (e.g., when form work is to be removed early for reuse).
- This cement must not be used for mass concrete because due to large quantity of heat of hydration, the temperature inside the concrete increases, leading to formation of undesirable crack on cooling.
- RHC attains same strength in 1 day which a ordinary cement attains it 3 days with the same water cement ratio.
- It is subjected to large shrinkage and water requirement for workability is more.
- Cost of rapid hardening cement is about 10 per cent more than the ordinary cement.

- As rate of strength development is accelerated a higher percentage of $CaCl_2$ causes excessive shrinkage.
- Strength gained after 1 day is 25% more and 7 days is ≈ 20% more than OPC.
- It is also known as calcium chloride cement.
- Calcium chloride acts as an accelerator which increases the rate of hydration reaction in cement that is why its use in slow hardening cement proves more effective than in rapid hardening cement which already have high rate of reaction.

4. High Alumina Cement (IS: 6452)

- The raw material used for its manufacture consists of 40% bauxite 40% lime and 15% iron oxide with a little % of ferric oxide and silica, magnesia, etc. ground finely at a very high temperature.
- As Since C_3A is not present, the cement has good resistance against attack by sulphate and some dilute acids, and is particularly suitable to sea and under-water work.
- It's rapid hardening properties arises due to $Al_2O_3.CaO$ (calcium aluminate) as the predominant compound as shown in above table in place of calcium silicate of OPC and for setting and hardening there is no free hydrated lime as in the case of OPC.
- High Alumina cement has very high early compressive strength and has high heat of hydration in comparison to OPC - 43 grade.
- High alumina cement has initial setting time of about 3.5-4 hrs and final setting time of 5-5.5 hrs.
- It hardens and develops strength very rapidly. One day strength is $30N/mm^2$ (which is equal to 28 days strength of OPC) and 3 day is $35\ N/mm^2$, giving out a great amount of heat.
- It should not be used in places where temperature exceeds 18°C and it is extremely resistant to action of fire, chemical attack. sea water. acidic water and sulphates.

3 days ± 1 hour	10N / mm^2
7 days ± 2 hour	16N / mm^2
28 days ± 4 hour	33N / mm^2

- It should have a fineness not less than 225 m^2/Kg.
- Initial setting time ≥ 30 minutes and final setting time ≤ 600 minutes.
- It can be used as an alternative of OPC, PPC or Portland slag cement under normal conditions.
- But its use is restricted where the prevailing temperature is below 40°C and environment where chloride are present.
- It is strongly recommended for structures in sea water, coastal area and marshy lands.

Note
- Sulphate resisting cement is used for sewage and canal linings.

6. Portland Slag Cement (IS: 455:1989)

- It is made by intergrinding portland cement clinker (≮35%) and granulated blast furnace slag (which is a waste product in the manufacture of pig iron) and gypsum.
- Slag contains oxide of lime, silica and alumina.
- Properties of these slag cements are similar to those of OPC, but they have a lower lime and higher silica and alumina content.
- Blast furnace slag cement is less reactive than OPC and gain strength a little more slowly during the first 28 days. It has high percentage of C_2S.
- With higher slag content, it has fairly high sulphate resistance, rendering it suitable for use in environments exposed to sulphate (in the soil or in ground water) and is specified for marine work or pipe carrying water containing chemicals or sewage.
- Slag content in the cement varies between 25 to 65 per cent of the total mass of mixture.

3 day ± 1 hour	15N / mm^2
7 day ± 2 hour	22N / mm^2
28 days ± 4 hour	30N / mm^2

- It is highly resistant to sea-water, and can withstand high concentration of sulphate found in soil or ground water.
- It is also resistant to peaty acids and oils.
- It should have fineness of 400 m^2/kg (minimum).
- Expansion ≤ 5 mm.
- Initial setting time ≥ 30 minutes, and final setting time ≤ 600 minutes.
- Super sulphated cement should not be used with any admixture.

8. Low Heat Portland Cement (IS:12600)

- It is a portland cement with relatively lower contents of the more hydrating compounds, C_3S and C_3A and more contents of C_2S.
- This is desirable in mass concreting of gravity dam as otherwise, the excessive heat of hydration can result in serious cracking. Low heat is evolved, helpful in preventing shrinkage at high temperature.
- This cement possesses less compressive strength having initial setting time not less than 1 hour and final setting time not more than 10 hours.
- Heat of hydration should not be more than 272 and 314 KJ/Kg at the end of 7 and 28 days respectively.
- Rate of development of strength is slow but the ultimate strength is same as that of OPC. To fullfill this requirement, specific surface of cement is increased to about 3200 cm^2/g.
- Expansion should not be more than 10 mm and 0.8%, by Le Chatelier method and autoclave test respectively.
- Compressive strength should be as follows.

- Should not have expansion of more than 10 mm and 0.8% by Le-Chatelier and autoclave method respectively.
- Drying shrinkage should not be more than 0.15%
- Fineness should not be less than 300 m^2/kg, when tested by air permeability method.
- It has low heat evolution and is used in the places of mass concrete such as dams and in places of high temperature.

10. Quik Setting Portland Cement

- In the manufacture of this cement, gypsum content is reduced to get the Quick setting property. Also small amount of aluminium sulphate is added.
- It is ground much finer than OPC.
- It sets quickly but does not harden quickly

Initial setting time = 5 minutes

Final setting time = 30 minutes

- It is used when concrete is to be laid under water or in running water.

11. White and Coloured Portland Cement (IS: 8042)

- Manufactured from pure white chalk and clay free from iron oxide.
- Greyish colour of cement is due to iron oxide, so the iron oxide is reduced and limited below 1 per cent.
- Coloured cements are made by adding 5 to 10 per cent colouring pigments before grinding.
- Such cements have same properties as that of OPC and are non-staining because of low amount of soluble alkalis.
- Sodium alumino ferrite (cryolite) Na_3AlF_6 is added during burning which acts as a catalyst in place of iron oxide.
- Hunter scale or ISI scale is used to measured the whiteness of white cement.

- Air entrainment improves workability and w/c ratio can be reduced which in turn reduces shrinkage, etc.
- Minute voids are formed while setting of cement which increases resistance against freezing and scaling action of salts.
- It has higher initial setting time and longer final setting time than OPC.

13. Acid-Resistant Cement

- An acid-resistant cement is composed of the following:
  (a) Acid-resistant aggregates such as quartz, quartizites.
  (b) Aqueous solution of sodium silicate or soluble glass.
  (c) Additive such as sodium flurosilicate Na_2SiF_6.
- Addition of additive sodium flurosilicate (Na_2SiF_6) accelerates the hardening process of soluble glass and it also increases the resistance of cement to acid and water.
- The binding material of this cement is soluble glass which is a water solution of sodium silicate, $Na_2O.nSiO_2$ or potassium silicate, $K_2O.nSiO_2$ where n is the glass modulus varies from 2.5 to 3.5.
- Glass modulus indicates the ratio of the number of silica molecules to that of alkali oxide molecules.
- Addition of 0.5% of linseed oil or 2% of ceresit, its resistance to the water is increased and it is then known as the acid and water resistant cement.

- A thin paste of cement with water should feel sticky between the fingers.
- If the cement contains too much of pounded clay and silt as an adulterant, the paste will give an earthy smell.

(iii) Presence of lumps:

Cement should be free from any hard lumps. Such lumps are formed by the absorption of moisture from the atmosphere. Any bag of cement containing such lumps should be rejected.

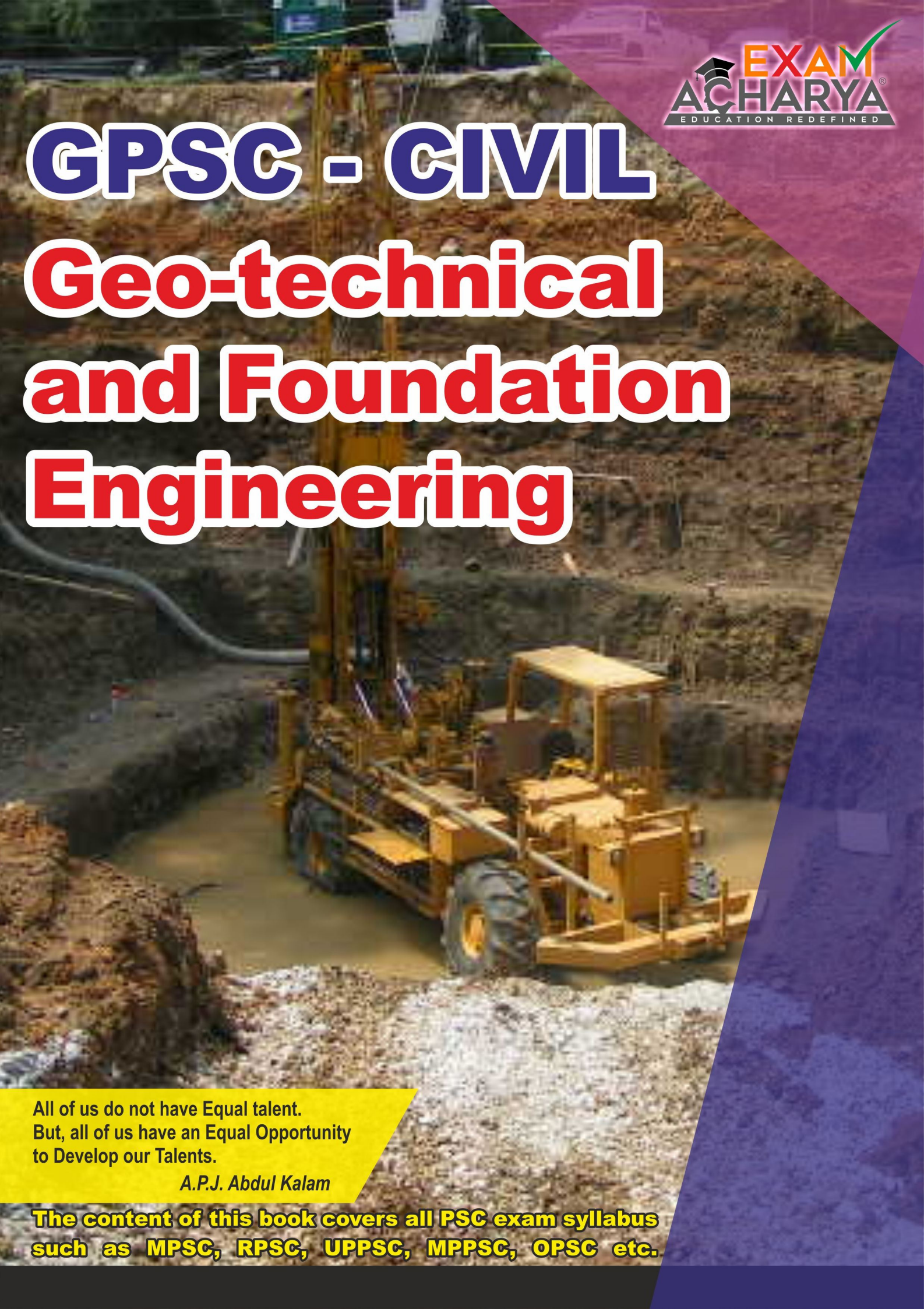
Physical Lab Test

1. Fineness Test

- Degree of fineness of cement is the measure of the mean size of the grains in it.
- There are three methods of testing of fineness of cement.
  (a) Sieve method - using 90 micron (9.No.) Sieve
  (b) Air permeability method - Nurse and Blaine's method
  (c) Sedimentation method - Wagner turbidimeter method
- Sieve method measures grain size where as air permeability method and sedimentation method measures surface area.
- Since cement grains are finer than 90 micron, the sieve analysis method does not represent true mean size of cement grains. Also, the tiny cement grains tend to conglomerate into lumps resulting in distortion in the final grain size distribution curves.
- Due to these demerits, fineness is generally expressed in terms of specific area, which is the total surface area of the particles in unit weight of material.

EXAM ACHARYA
EDUCATION REDEFINED

GPSC - CIVIL
Geo-technical and Foundation Engineering



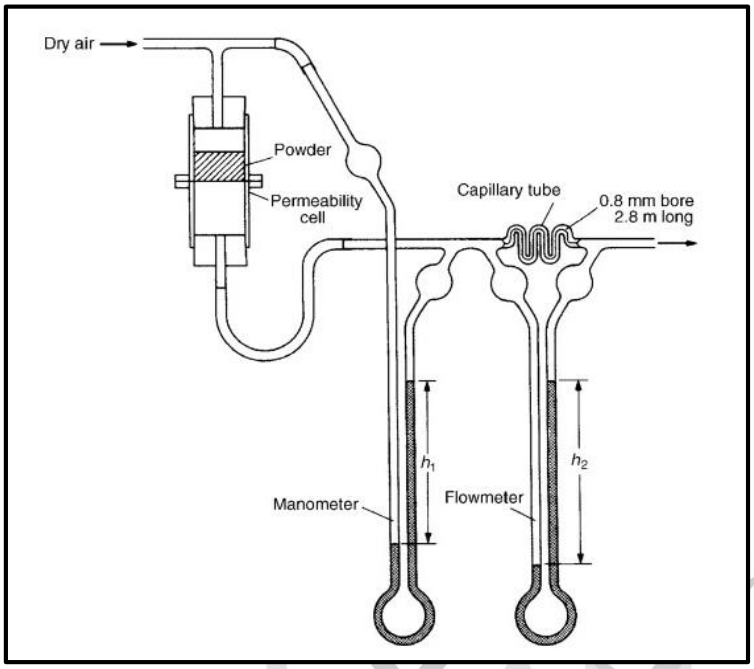
All of us do not have Equal talent.
But, all of us have an Equal Opportunity
to Develop our Talents.

A.P.J. Abdul Kalam

The content of this book covers all PSC exam syllabus such as MPSC, RPSC, UPPSC, MPPSC, OPSC etc.

(b) Air Permeability Method:

- Fineness of cement is determined by Nurse and Blaine's method using an apparatus developed by Lea and Nurse.

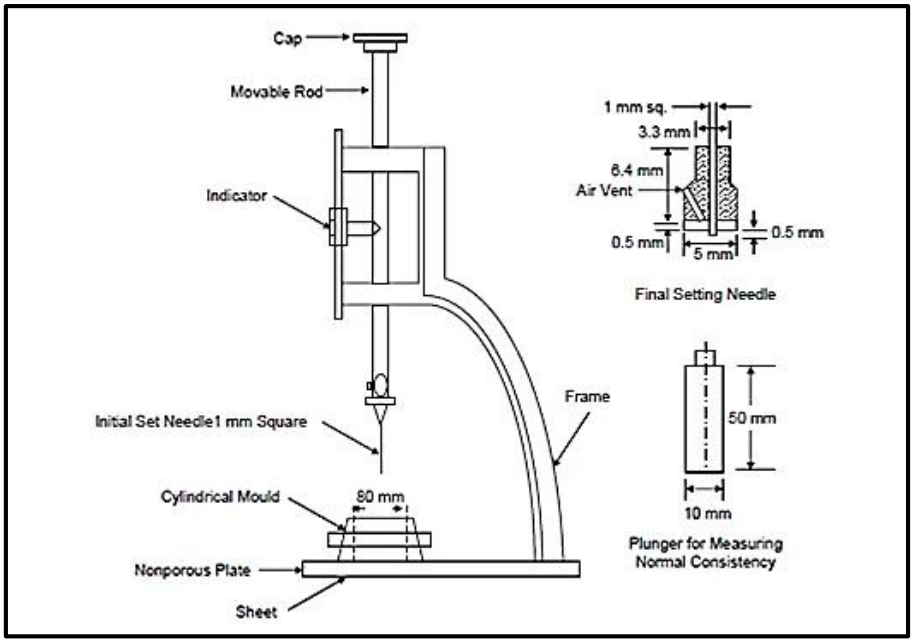


Apparatus

- Consists of a permeability test cell—where cement is placed and air pressure is applied, flowmeter—to determine the quantity of air passing per second through its capillary tube per unit difference of pressure, and manometer—to measure the air pressure.

Minimum Specific Surface of Cements

Time of Cement	Designation	Specific surface not less than cm^2/g
Ordinary Portland Cement	(OPC)	2250
High Alumina Cement	(HAC)	2250
Portland Pozzolana Cement	(PPC)	3000
Low Heat Cement	(LHC)	3200
Rapid Hardening Cement	(RHC)	3250
Super Sulphate Cement	(SSC)	4000



Vicats apparatus

Attachment	Use
10 mm ϕ Plunger	Consistency test
1 mm^2 needle	Initial setting time
5 mm ϕ annular colar	Final setting time

Procedure

1. The requirements for the test are :
   - Vicat's Apparatus Conforming to IS : 5513-1976.
   - Balance of capacity 1 Kg and sensitivity to 1 gram.
   - Gauging trowel conforming to IS : 10086-1982.
2. Unless otherwise specified, this test shall be conducted at a temperature 27 ± 20°C and the relative humidity of laboratory should be 65 + 5%.
3. Prepare a paste of weighed quantity of cement (300 gms) with weighed quantity of potable or distilled water, taking care that the time of gauging is neither less than 3 minutes nor more than 5 minutes and the gauging is completed before any sign of setting occurs.

this period it is possible to remix the paste and this period is called initial setting time.

- It is defined as the time elapsed between the moments the water is added and the paste starts losing its plasticity, is regarded as initial setting time. As per Vicat's test, it is the time elapsed till the paste stiffens to such an extent that the Vicat's needle cannot go into it within 5 ± 0.05 mm measured from the bottom of the mould.
- It is assumed that no hardening will start in this period. As the time passes, the reaction is continued and cement begins to harding and time elapse at the times of mixing water to hardened is known as final setting time.
- It is defined as the time elapsed between the moments the water is added and the paste completely loses its plasticity is regarded as final setting time. As per Vicat's test, it is the time elapsed till the paste attains such firmness that the attachment to the needle fails to leave any mark on it (though the needle will make an impression).

(a) Initial setting time test

Procedure

- The setting times are determined through Vicat's test.
- A cement paste is prepared by gauging cement with 0.85 times the water required to prepare a paste of standard consistency.
- The stop watch is started at the instant water is added.
- The mould rests on a non-porous plate. It is completely filled with the paste and its surface is levelled smooth with the top of the mould.
- The mould is then placed on Vicat's apparatus and the needle is lowered to contact the test block and is quickly released. The needle (square needle 1 mm^2) penetrates the test block completely at the beginning (40 mm from the top)
- After sometime the needle is unable to pierce the block for more than 33-35 mm from the top as the paste starts to lose its plasticity.

Why Initial and Final Setting Test is done?

Initial setting time test in done because:

- Concrete once placed should not be disturbed till the initial setting has taken place.
- The transportation of concrete from the place where concrete is prepared to the placing of concrete required some finite time that should be within the initial setting time otherwise cold joints will result.
- Final setting time test is done because the concrete should achieve the desired strength as early as possible so that the shuttering can be removed and reused.

Note
- The initial setting time mostly depends upon tricalcium aluminate
- Fine cement sets faster than coarse cement and thus have lower setting time

4. Soundness Test

- Purpose of this test is to detect the change in volume of cement after setting.
- Unsoundness in cement does not come to surface for a considerable period of time. Therefore, accelerated tests are required to detect it.
- It can be tested with Le-Chatelier method or by autoclave method.
- Le chatelier method is used in case of unsoundness due to free lime only as it does not indicate the presence and after effects of excess of Magnesia.
- For magnesia content exceeding 3%, Autoclave test has to be used as it is sensitive to both free lime and magnesia.
- It is a significant test to assure the quality of cement since an unsound cement produces cracks, distortion and disintegration (due to expansion), ultimately leading to failure.

9. For OPC, RHC, LHC and PPC it is limited to 10mm, whereas for High Alumina Cement and Super Sulphate Cement it should not exceed 5mm.
10. The Le-chatelier's method detect unsoundness due to free lime only.

Autoclave test

- In India the occurance of low magnesia lime stone is limited so Indian standard specification recommender that cement having a magnesia content > 3% be tested for soundness by autoclave test.
- This test is sensitive to both free magnesia and free lime.

Procedure

- A 25×25×250 mm specimen is made with neat cement paste.
- The moulded specimen is removed from the moist atmosphere after 24 hours and measured for length.
- It is then placed in an autoclave at room temperature, making sure that four sides of the specimen are exposed to saturated steam.
- The temperature is raised at such rate so as to allow the gauge pressure of the steam to rise from 2.1 N/mm^2 in 1 to 1.25 hours from the moment heat is turned on.
- The pressure is maintained for 3 hours
- After the heat supply is turned off, the autoclave is cooled at such a rate that pressure is less than 0.1 N/mm^2 after 1 hour.
- The Autoclave is opened and test specimen is placed in water at temperature of 90°C which is gradually brought down to 27 ± 2°C in 15 minutes.
- It is then maintained at this temperature for next 15 minutes and then taken out
- The length of the specimen is measured again.
- The % difference in two lengths gives unsoundness of the cement.
- For sound cement the expansion should not exceed 0.8%.

Procedure

1. A mixture of cement (200 gm) is mixed with standard sand 600 gm (Ennore sand) in proportion of 1:3 by weight is mixed for one minute and then water $\left(\frac{p}{4}+3\right)$ % is added until the mixture is of uniform colour, where P = percentage of water required to produce a paste of standard consistency.
2. Temperature of water and test room should be 27°C ± 2°C.
3. Material for each three specimen cube is mixed separately.
4. Mould is filled completely with the cement paste and is placed on the vibration table. Vibrations are imparted for about 2 minutes at a speed of 12000 ± 400 per minute.
5. Three specimen cubes are prepared of size 70.6 mm (having face area of about 5000 mm^2).

Note
- Large size specimen cubes cannot be made since cement shrinks and cracks may develop.

6. At the end of vibration, keep the filled moulds in moist room for 24 hrs.
7. At the end of that period, Cubes are then removed from the moulds and submerged in clean fresh water and are taken out just prior to testing in a compression testing machine.
8. Load is applied starting from zero at a rate of 35 N/sq mm/minute.
9. Compressive strength is calculated from the crushing load divided by the average area over which the load is applied. The result is expressed in N/mm^2.
10. Compressive strength is taken to be the average of the results of the three cubes.

New Batches are going to start.....

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Test Series Available..

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Mock test : 16

Total test : 80

1. Mixture of cement and sand is gauged in the proportion of 1:3 by weight.
2. Percentage of water to be used is [(P/5) + 2.5] %, where P = percentage of water required to produce a paste of standard consistency.
3. Mix is filled in the briquette moulds and surface of mould be finished with the blade of a trowel.
4. Now they are left for 24 hours at a temperature of 27 ± 2°C having 90% atmospheric humidity.
5. Briquettes are then kept in clean fresh water and are taken out before testing. 6 briquettes are tested and the average tensile strength is calculated.
6. Load is applied steadily and uniformly, starting from zero and increasing at the rate of 0.7 N/mm^2 in 12 seconds.
7. Ordinary Portland cement should have a tensile strength of not less than 2.0 N/mm^2 after 3 days and not less than 2.5 N/mm^2 after 7days.

Note
- Strength increases when the loading rate is increased from that specified.
- In tension test of cement the load on the briquettes should be applied centrally. Since briquettes become brittle with age, the effect of slight eccentricity or any torsional strain is pronounced in long-time tests.

Condition affecting strength

- Cement is very strong at early ages if high lime or high alumina content is there.
- Gypsum and Plaster of Paris in small percentages also tend to increase the strength slightly, but when present in quantities larger then 3 per cent, these substances provide variable effects.
- Strength of cement is greatly influenced by the degree of burning, the fineness of grinding, and the aeration it receives subsequent to final grinding. An underburnt cement is likely to be deficient in strength.

7. *Specific Gravity Test*

- Specific gravity of hydraulic cements is obtained by using Le-chatelier's flask.
- Generally specific gravity of OPC = 3.15

Procedure

- Flask is filled with either kerosene free of water, or naphtha having a specific gravity not less than 0.73

$$\textbf{Specific gravity} = \frac{\textbf{wt.of cement in gms}}{\textbf{wt.of displaced vol of liquid}}$$

Conditions Affecting Specific Gravity

- Due to Long seasoning unadulterated cement has low specific gravity because freshly ground cement when exposed to air rapidly absorbs moisture and carbon dioxide.
- Cement with high contents of iron oxide have a higher specific gravity.
- Effect of fineness of grinding upon specific gravity is slight. Very finely ground cements are likely to have lower specific gravities.

Qu4 Which of the following pairs in respect of Ordinary Portland Cement (OPC) are correctly matched?

1. Initial setting time … 30 minutes
2. Final setting time ... 10 hours
3. Normal consistency ... 10%

Select the correct answer using the codes given below :

(a) 1, 2 and 3
(b) 2 and 3
(c) 1 and 2
(d) 1 and 3

Qu5 High alumina cement is produced by fusing together a mixture of

(a) Limestone and bauxite
(b) Limestone, bauxite and gypsum
(c) Limestone, gypsum and clay
(d) Limestone, gypsum, bauxite, clay and chalk

Qu6 Consider the following statements:
High early strength of cement is obtained as a result of
1. find grinding
2. decreasing the lime content
3. burning at higher temperatures
4. increasing the quantity of gypsum
Which of these statements are correct?

(a) 1 and 2
(b) 1 and 3
(c) 2. 3 and 4
(d) 1. 3 and 4

CHAPTER – 8

MORTAR

Mortar is a workable paste used to bind construction blocks together and fill the gaps between them. The word comes from Latin moratorium meaning crushed.

Mortar may be used to bind masonry blocks of stone, brick, etc.

Mortar becomes hard when it sets, resulting in a rigid aggregate structure.

Mortar can also be used to fix, or point, masonry when the original mortar has washed away. Mortars are usually named according to the binding material used in their preparation.

They are essentially required for masonry work, Plastering and Pointing etc.

FUNCTIONS OF MORTAR

To bind together the bricks or stones properly so as to provide strength to the structure.

To form a homogenous mass of the structure so as to resist all the loads coming over it without disintegration.

COMPOSITION OF MORTAR

Modern mortars are typically made from a mixture of

- Sand
- A binder such as cement or lime
- Water

- It uses to improve the general appearance of the structure.
- It also uses for various ornamental works to improve the general appearance of a building or structure.

WATER RETENTIVITY & AIR CONTENT

This is the property of mortar that resists water loss by absorption into the masonry units (suction) and to the air, in conditions of varying temperature, wind and humidity. Water retentivity is related to workability.

The air content of the mortar in its plastic state is also important. In order to achieve good durability it is necessary that there is sufficient air content (entrained air) to enable freeze-thaw cycles to be resisted without disrupting the matrix of the material.

STIFFENING AND HARDENING

The progression of stiffening, defined in the European Standard as workable life, refers to the gradual change from fresh or plastic mortar to setting or set mortar.

Hardening refers to the subsequent process whereby the set mortar progressively develops strength.

PROPERTIES OF HARDENED MORTAR

1. Durability

Durability of mortar may be defined as its ability to endure aggressive conditions during its design life. A number of potentially destructive influences may interact with the mortar these include water, frost, soluble salts and temperature change.

2. Compressive Strength

The use of too much cement will produce a more rigid mortar, which may result in vertical cracking passing through units and mortar joints as stresses are imposed

EXAM ACHARYA
EDUCATION REDEFINED

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Reinforced Cement Concrete

Education's purpose is to
replace an empty mind with an open one.

Malcolm Forbes

The content of this book covers all PSC exam syllabus such as MPSC, RPSC, UPPSC, MPPSC, OPSC etc.

FUNCTION OF SAND AND SURKHI IN MORTARS

Functions of Sand

- It reduces shrinkage of the building material.
- It prevents development of cracks in the mortar on drying.
- It helps in making mortars and concretes of desired strength by varying its proportions with the binding material.
- A well graded sand adds to the density of mortars and concretes.

Functions of Surkhi

- It provides brick color and make the mortar economical

CLASSIFICATION OF MORTARS

The mortars are classified on the basis of the following:

(1) Bulk density

(2) Kind of binding material

(3) Nature of application

(4) Special mortars.

Bulk Density

According to the bulk density of mortar in dry state, there are two types of mortars:

(i) ***Heavy Mortars***

The mortars having bulk density of 15 kN/m^3 or more are known as the heavy mortars and they are prepared from heavy quartzes or other sands.

hardens slowly. It is generally used for lightly loaded above-ground parts of buildings.

Surkhi Mortar

This type of mortar is prepared by using fully surkhi instead of sand or by replacing half of sand in case of fat lime mortar. The powder of surkhi should be fine enough to pass BIS No. 9 sieve and the residue should not be more than 10% by weight.

The surkhi mortar is used for ordinary masonry work of all kinds in foundation and superstructure. But it cannot be used for plastering or pointing since surkhi is likely to disintegrate after some time.

Cement Mortar

In this type of mortar, the cement is used as binding material. Depending upon the strength required and importance of work, the proportion of cement to sand by volume varies from 1:2 to 1:6 or more. It should be noted that surkhi and cinder are not chemically inert substances and hence they cannot be used as adulterants with matrix as cement.

Thus the sand only can be used to form cement mortar. The proportion of cement with respect to sand should be determined with due regard to the specified durability and working conditions. The cement mortar is used where a mortar of high strength and water-resisting properties is required such as underground constructions, water saturated soils, etc.

Gauged Mortar

To improve the quality of lime mortar and to achieve early strength, the cement is sometimes added to it. This process is known as the ganging. It makes lime mortar economical, strong and dense.

The usual proportion of cement to lime by volume is about 1:6 to 1:8. It is also known as the composite mortar or lime-cement mortar and it can also be formed

Fire-Resistant Mortar

This mortar is prepared by adding aluminous cement to the finely crushed powder of fire-bricks. The usual proportion is 1 part of aluminous cement to 2 parts of powder of fire-bricks. This mortar is fire-resistant and it is therefore used with fire-bricks for lining furnaces, fire places, ovens, etc.

Lightweight Mortar

This mortar is prepared by adding materials such as saw dust, wood powder, etc. to the lime mortar or cement mortar. Other materials which may be added are asbestos fibres, jute fibres, coir, etc. This mortar is used in the sound-proof and heat-proof constructions.

Packing Mortar

To pack oil wells, special mortars possessing the properties of high homogeneity, water resistance, predetermined setting time, ability to form solid water-proof plugs in cracks and voids of rocks, resistance to subsoil water pressure, etc. have to be formed.

The varieties of packing mortars include cement-sand, cement-loam and cement-sand-loam. The composition of packing mortar is decided by taking into consideration the hydrogeologic conditions, packing methods and type of timbering.

Sound-Absorbing Mortar

To reduce the noise level, the sound-absorbing plaster is formed with the help of sound-absorbing mortar. The bulk density of such a mortar varies from 6 to 12 kN/m^3 and the binding materials employed in its composition may be Portland cement, lime, gypsum, slag, etc. The aggregates are selected from lightweight porous materials such as pumice, cinders, etc.

X-Ray Shielding Mortar

This type of mortar is used for providing the plastering coat to walls and ceiling of X-ray cabinets. It is a heavy type of mortar with bulk density over 22 kN/m^3. The aggregates are obtained from heavy rock and suitable admixtures are added to enhance the protective property of such a mortar.

(iii) The upper brick is suspended from an overhead support and the weights are attached to the lower brick.

(iv) The weights are gradually increased till separation of bricks occurs.

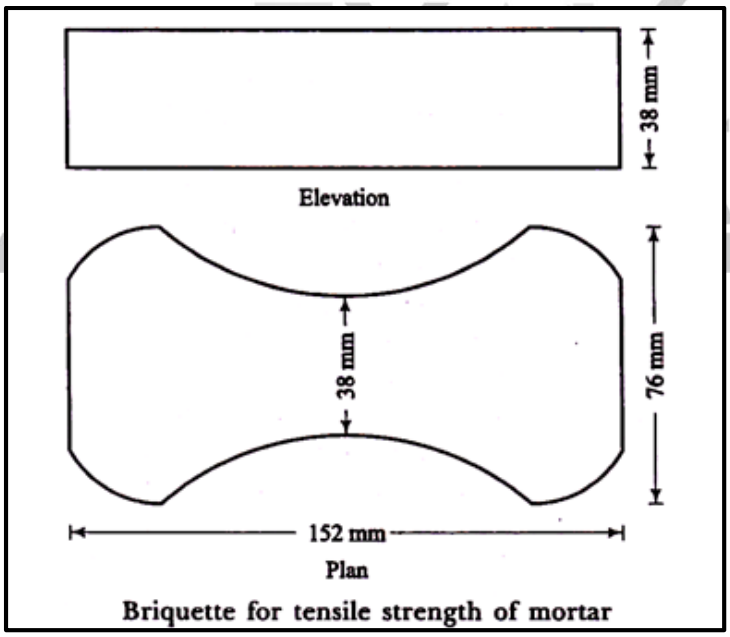
(v) The ultimate adhesive strength of mortar per mm^2 area is obtained by dividing maximum load with 810.

Crushing Strength

For this test, the brickwork is carried out with mortar to be tested. A sample of this brickwork is taken and it is gradually loaded in a compression testing machine till failure occurs due to crushing. The ultimate crushing strength is obtained by dividing maximum load with cross-sectional area.

Tensile Strength

For this test, the mortar to be tested is placed in the briquette moulds as shown in fig.



Briquette for tensile strength of mortar

The briquettes are then tested in a tension testing machine. The cross-sectional area of central portion is 38 mm x 38 mm or 1444 mm^2. The ultimate tensile stress per mm^2 is obtained by dividing failing load with 1444.

Qu5. A gauged mortar is obtained by adding which of the following ingredients to cement?

a) Sandstone

b) Sand and surkhi

c) Sand and lime

d) Surkhi alone

Qu6. Lime mortar is generally made with

a) Quick lime

b) Fat lime

c) Hydraulic lime

d) White lime

Qu7. One of the main demerits in using lime mortar is that it

a) Is not durable

b) Does not set quickly

c) Swells

d) Is plastic

TEST YOUR SELF

Qu8. Which of the following mortars is most suitable for construction work in water logged areas?

a) Lime mortar

b) Gauged mortar

c) Cement mortar

d) Mud mortar

CHAPTER – 9

CONCRETE

INTRODUCTION

- Concrete is a composite man made material and is most widely used building material in the construction industry.
- It is a mixture of binding material such as lime or cement, well graded coarse and fine aggregate water and sometimes admixtures.
- Most of the ancient structures and historical buildings had been constructed with lime concrete but with the invention of cement, use of lime concrete is limited to making bases of concrete foundations and roof terracing.
- Also production of good concrete is found difficult. Now a question arise what is "Good concrete".
- Basic requirement of Good concrete is that it should be satisfactory in its hardened state, and also in its fresh state while being transported from mixture and placed in form work.
- In fresh state, consistency of mix should be such that it can be compacted by the desired means without excessive effort and also the mix should be cohesive enough for the methods of transporting and placing used so as not to cause segregation.
- In hardened state satisfactory compressive strength and an adequate durability is required.

CLASSIFICATION

1. Based on Cementing Material

(a) Lime concrete

(b) Gypsum concrete

(c) Cement concrete

Grade of Cement Concrete

Grade Characteristic	M5	M7.5	M10	M20	M25	M30	M35	M40	M45	M50	M55
Strength	5	7.5	10	20	25	30	35	40	45	50	55

- Further we can classify these on the basis of their strength.

(a) Low strength concrete (< 20 N/mm^2)

(b) Medium strength concrete (20 - 40 N/mm^2)

(c) High strength concrete (> 40 N/mm^2)

5. Based on Bulk Density

Extra light weight	< 500 kg/m^3
Light weight	500-1800 kg/m^3
Dense weight	1800-2500 kg/m^3
Super heavy weight	> 2500 kg/m^3

6. Based on Place of Casting

In-situ concrete

When concrete is placed in position at the site it is known as In-situ concrete.

Precast concrete

When concrete is used for making prefabricated units in a factory is called as precast concrete.

MANUFACTURING OF CONCRETE

- As discussed before concrete is a mixture of cement, aggregate, and water.
- Each of the above constituent has a special function.

New Batches are going to start.....

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Test Series Available..

Total weekly test : 35

Total mid subject test : 16

Total full length test : 13

Mock test : 16

Total test : 80

Volume Batching

- Amount of each solid ingredient is measured by loose volume using standard box known as gauge box.
- For example, volume of moist sand in a loose condition weighs much less than the same volume of dry compacted sand.
- Therefore correction for bulking of sand is done if volume batching is adopted.

Weight Batching

- In weight batching water is not added by graduated buckets as the water may spill over during its addition. A horizontal or vertical tank is fitted to the mixer.
- Cement is always measured by weight, irrespective of method of batching.
- Water is measured in kg or litres as density of water is 1 kg/liter.
- Volume of 1 bag of cement is 0.035 m^3 (or sometime also said 35 liters).

2. Mixing

- Objective of mixing is to obtain homogenous, uniform colour and consistent concrete of desired strength.
- Mixing time depends on the type and capacity of mixer but IS-456 suggest approximately mixing time as 2 min.
- Generally 20 revolution of concrete in mixture provides sufficient mixing.
- A poor quality of concrete is obtained if mixing time is reduced whereas if it is increased it is uneconomical.
- If mixing time is increased upto 2 minutes the compressive strength of concrete produced is enhanced and beyond this time the improvement in compressive strength is insignificant and prolonged mixing may cause segregation as, due to longer mixing periods the water may get absorbed by the aggregates or evaporate resulting in loss of workability and strength.

Batching plant

- These plants consist of all arrangements for receiving raw material of concrete from storage bins, weighing out each ingredient for each batch of the mix, and mixing the ingredients thoroughly to form a concrete of required specification.
- Batches are available in three categories i.e

(a) **Manual**

(b) **Semi-automatic:** In semi-automatic batching, the charging and discharging of the batchers are activated manually but are automatically terminated.

(c) **Fully automatic:** A single starter switch activates the batching sequence, the weights and volumes of which have been previously programmed into the system.

Concrete Mixers

- Mixing time is usually 2 to 3 minutes.
- Some mixers have a timing device which controls the mixing time and does not permit discharge from it till mixing for specified time is completed.
- Concrete mixers are specified by the volume of mixed concrete discharged after mixing of each batch, expressed in m^3 (such as 0.25, 0.38, 0.57, 0.75, 1.5, 2.25 and 3 m^3)
- Sometimes the total volume of the unmixed ingredients in m^3 is given as a prefix. i.e. 1.0/0.75 mixer takes 1 m^3 of unmixed material and gives 0.75 m^3 of mixed concrete in each batch.

3. Transporting

- Specification states that the process of mixing, transporting, placing and compacting the concrete should not take more than initial setting time of cement (30 minutes using O.P.C).

5. *Compaction*

- The process of removal of entrapped air and of uniform placement of concrete to form a homogeneous dense mass is termed compaction.
- The density and consequently the strength and durability of concrete depends upon the quality of compaction.
- The presence of even 5% and 10% voids in hardened concrete left due to incomplete compaction may result in a decrease in compressive strength by about 30% and 60% respectively.

Compaction of the concrete can be achieved in four ways.

(i) Hand Rodding

(ii) High pressure and shock

(iii) Centrifugation or spinning

(iv) Mechanical vibration: Reduces the internal friction between the different particles of concrete by imparting oscillation (in the form of SHM) to the particles and thus consolidates the concrete.

The various types of vibrators used are

(a) Immersion or Internal vibrators

- They are also called needle or Poker vibrator.
- These vibrators consists of a steel tube (Poker) which is inserted in fresh concrete.
- The frequency of vibration is about 4000 to 12000 rpm.
- The needle diameter varies from 20 mm to 75 mm and its length 25 cm to 90 cm.
- These vibrators are more efficient than other types or vibrated and hence they are most commonly used.

- The specimens are not to be allowed to become dry at any time until they have been tested.
- Cement gains strength and hardness because of the chemical action between cement and water.
- The water in a concrete mix takes one of the following three forms as a consequence of hydration are:

Combined Water

Which is chemically combined with the products of hydration, it is non-evaporable

Gel water

Which is held physically or adsorbed on the surface area of the cement gel.

Capillary water

Which partially occupies the 'capillary pores' that constitute the space in the cement paste remaining after accounting for the volumes of cement gel and unhydrated cement this water is easily evaporated.

- Curing is name given to procedures that are imployed for actively promoting the hydration of cement in a suitable environment during early stages of hardening of concrete.
- IS: 456 define curing as the process of preventing the loss of moisture from the concrete while maintaining a satisfactorily temperature regime.
- Curing of freshly placed concrete is very important for optimum strength and durability. The major part of the strength in the initial period is contributed by the clinker compound C_3S and partly by C_2S and is completed in about 3 weeks.
- Increase in strength of concrete is very rapid from 3 to 7 days and continues slowly for indefinite period.

EXAM ACHARYA

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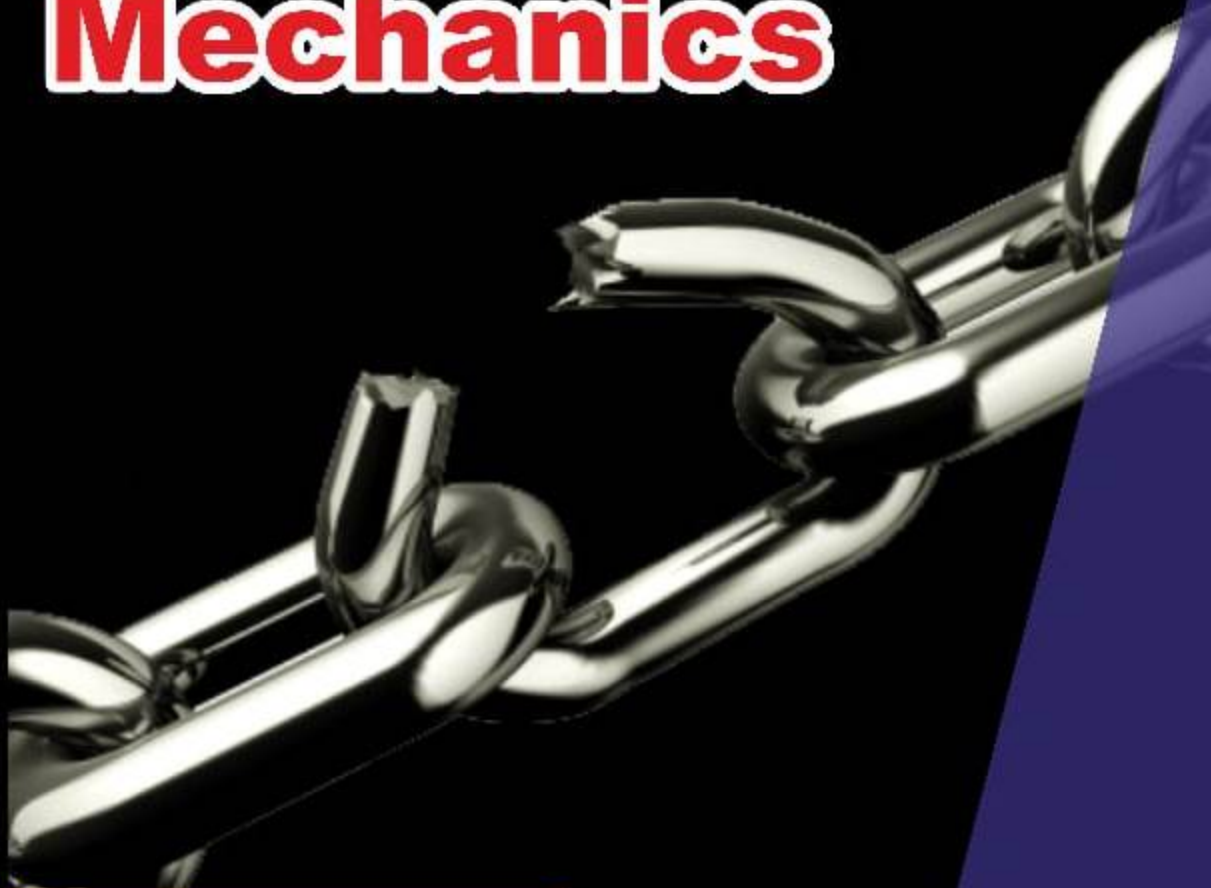
Solid Mechanics



"Education is the most Powerful Weapon which you can use to change the world."

A.P.J. Abdul Kalam

The content of this book covers all PSC exam syllabus such as MPSC, RPSC, UPPSC, MPPSC, OPSC etc.

GPSC - CIVIL

Solid Mechanics

Steam Curing

- For concrete, mixes with water-cement ration ranging from 0.3 to 0.7, the increased rate of strength development can be achieved by resorting to steam curing.
- This method of curing is also known as accelerated curing since an increased rate of strength development can be achieved.
- Concrete members are heated by steam at 93 ºC either at low pressure or high pressure.
- By low pressure steam curing about 70 per cent of the 28-day compressive strength of concrete can be obtained in about 16-24 hours and high pressure steam curing is usually applied to precast concrete members and gives 28-day compressive strength at 24 hours.
- It reduces shear strength of concrete.
- It also results in increased resistance to sulphate action and to freezing and thawing.
- Mixes with low water-cement ration respond more favourably to steam curing than those with higher water/cement ration.
- Early rise in temperature at the time of setting of concrete may be detrimental because the green concrete may be too weak to resist the air pressure set up in the pores by the increased temperature.
- Rate of increase or decrease of temperature should not exceed 10 to 20º C per hour to avoid thermal shocks.
- Steam curing should be followed by water curing for a period of at least 7 days. This supplementary wet curing is found to increase the later age strength of steam-cured concrete by 20 to 35 per cent.
- Rapid gain of strength can also be obtained with the help of infra red radiation and the rate is even more than steam curing.
- Rapid initial rise of temperature does not affect the ultimate strength.
- Other techniques used are electrical curing and chemical curing.

(iii) Trowelling

Final operation of finishing be done after all excess water has evaporated by steel float in conical shape giving a very smooth finish.

MATURITY OF CONCRETE

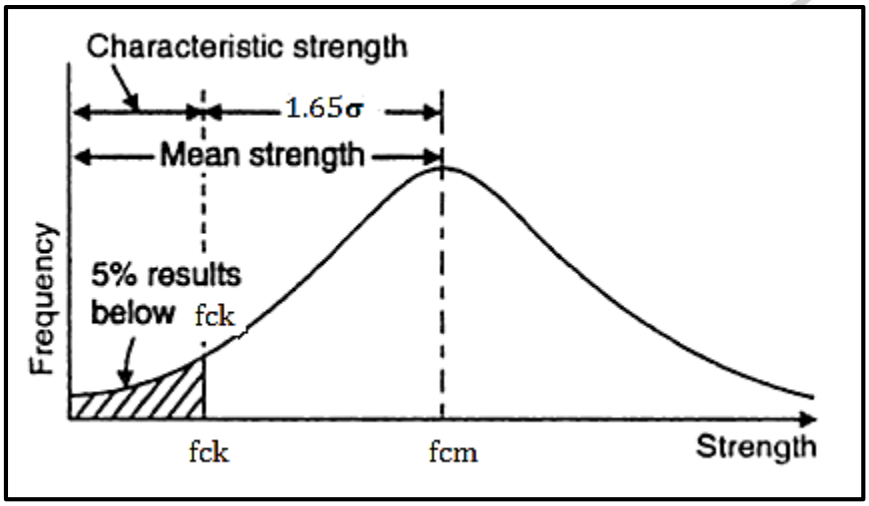
- The strength of concrete depends on both period of curing (i.e. age) and temperature during curing.
- The product (period × temperature) is called the maturity of concrete.
- It is measured in ºC hours or ºC days.
- The maturity of concrete is defined as the summation of product of time and temperature.
- Maturity = Σ (time × temperature)

Its units are ºC hr or ºC days.

WATER CEMENT RATIO

- Water-cement ratio (w/c) is one of the major factor, but not the only one influencing the strength of concrete. It is responsible mainly for the porosity of the hardened cement paste.
- Water-cement ratio, defined as the mass of 'free water' (i.e., excluding that absorbed by the aggregate) to that of cement in a mix, is the major factor that controls the strength and many other properties of concrete.
- If pozzolana is used with cement, then the ration after referes to water to cement plus pozzolana ratio i.e., w/(c+p).

- Number is usually preceded by the letter 'M', which refers to 'mix'. For example, M 20 grade concrete denotes a concrete whose mix is so designed as to generate a characteristic strength of 20 MPa.
- Till date no relation exists between compressive, tensile, bending, and shear strengths of concrete.
- But it is observed that tensile and bending strength of the concrete are of the order of 10 and 15 per cent, respectively of the compressive strength and shear is approximately 20 per cent of the uniaxial compressive strength.
- Characteristic strength is defined as strength of material below which not more than 5% of test results are expected to fall.
- It means that accordingly, the mean strength of the concrete f_m (as obtained from 28-days compression tests) has to be significantly greater than the 5 percentile characteristic strength f_{ck} that is specified by the designer



- Since the strength of concrete is related to the structure of hardened cement paste, it assumes more importance. Indian Standard specifies compression test, flexure and tensile strength test for assessing the strength of concrete.

A. Compressive Strength Test

- Cement, fine aggregate and coarse aggregate (up to 38 mm) to be used for making concrete are weighed in the ratio to be

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Influence of Size of Test Specimen

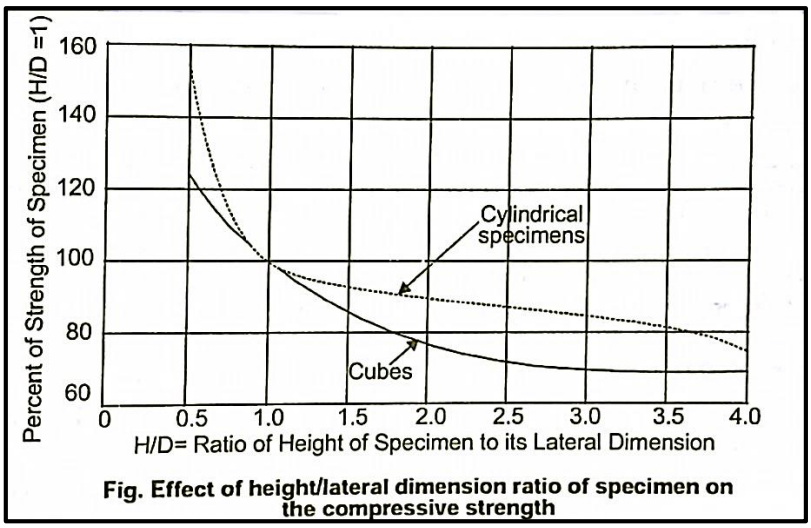

Fig. Effect of height/lateral dimension ratio of specimen on the compressive strength

- The cylinder (150 Dia & 300 height) and prism (100 X 100 X 500 mm) of a ratio of height or length to the lateral dimension 2 gives strength of about 75 to 85% of the cube strength of normal – strength concrete.
- The cube strength is ≈ 1.25 times cylinder strength.
- Cube compressive strength of concrete obtained from 15 cm cube is higher than 15 X 30 cm cylinder compressive strength because contact area of a standard cube mould with the upper plate in the testing machine is more which results in more confinement. More confinement resist against specimen expansion resulting in more compressive strength.

B. Flexural Tensile Strength Test (Modules of Rupture Test)

- Direct measurement of tensile strength of concrete is difficult.
- Neither specimens nor testing apparatus have been designed which assure uniform distribution of the "pull" applied to the concrete.
- Flexural tensile strength test is done to determine the tensile land at which concrete may crack.
- It is an indirect test for assessing the tensile strength of concrete.

C. Split Tensile Strength Test

- Due to difficult in applying uniaxial tension to a concrete specimen, the tensile strength is determined by indirect methods.
- It is the standard test to determine the tensile strength of concrete in indirect way in accordance with IS: 5816-1970
- A standard test cylinder of concrete specimen of 300mm X 150 mm diameter is placed horizontally between the loading surfaces of compression testing machine.
- The compression load is applied diametrically and uniformly along the length of cylinder until the failure of the cylinder along vertical diameter.
- On application of load, a uniform tensile stress acts over two-third of the loaded diameter
- The magnitude of the tensile stress is obtained by -

$$\sigma = \frac{2P}{\pi DL}$$

Where,

P = Applied load

D = Diameter of the cylinder

L = Length of the cylinder

- The load is applied gradually and increased continuously until failure at a rate with the range of 1.2 MPa/min to 2.4 MPa/min.
- Between the loading platens and the specimen cylinder, packing strips of plywood are placed for uniform distribution of load and to avoid high compression stresses near the point of application.

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Test Series Available..

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Mock test : 16

Total test : 80

FACTORS AFFECTING STRENGTH OF CONCRETE

1. Water - Cement Ratio

- According to Abram's law, the strength of workable concrete is only dependent on water-cement ratio.
- The volume of water in fresh concrete is related directly to the volume of empty pore space in hardened concrete. Similarly, the volume of cement in fresh concrete is related directly to the solid volume in hardened concrete. Water – cement ratio is therefore a measure of the void volume relative to the solid volume in hardened cement paste, and its strength goes up as the void volume goes down. So, the lower the water-cement ratio, the lower is the void volume-solid volume ratio, and stronger the hardened concrete.
- In a hardened state concrete, strength is inversely proportional to the water/cement ratio

2. Size of Specimen

- It is observed that a cube 150 mm of concrete is expected to have 25% more strength than a cylinder specimen (150mm dia, 300mm height).
- If size of cube is decreased compressive strength tends to increase.

Relative Strength of Concrete from Cubes of Different Sizes

Cube size (mm)	**100**	**150**	**200**	**300**
Relative strength to 150 mm cubes	**1.05**	**1.0**	**0.95**	**0.87**

3. Stress Situation

- Concrete is tested for uniaxial compression with the line of action of load on a cube specimen at right angles to the axis of cube about which it is cast.
- However, in actual structure, the concrete at any point is in a complex stress condition and not in a uniaxial compression.

Age (Month)	Age factor for low strength concrete
7 days	0.65 – 0.7
1	1.00
3	1.10
6	1.15
12	1.20

8. Cement aggregate ratio

- Provided all the other factors kept constant and increasing cement to aggregate ratio the ultimate strength will increase to some extent.

9. Type and size of aggregate

- Aggregate shape affects their packing and hence void content also.
- The crushed stone and gravels give higher strength
- Reduction in the void content of the coarse aggregate by better packing, means that the amount of mortar can be reduced and hence sand and cement.
- Thus, if coarse aggregate to sand ratio is increased and although the overall mix may be leaner, the mortar may be richer, and by virtue of reduction in water/cement ratio which may thereby be permitted, the strength of concrete may be increased.
- Rounded spherical or cubical shaped aggregate when compacted contains less voids than an irregular and flaky aggregate of the same nominal size and they give more strength.
- It is observed that high strength concrete gives lower strength as compared to lean concrete if large size aggregate is used
- Generally it is believed that larger the maximum size of aggregate, denser and stronger will be concrete because large aggregate have lower total surface area and require lower water to cement ratio resulting in higher strength. But in

Factors Affecting Workability

Water Content

- In order to obtain higher degree of workability higher water content is required but with the increase in water-cement ratio, the strength of the concrete is decreased hence in order to maintain the strength, along with water content, proportion of cement should be increased.
- For a given maximum size of coarse aggregate, the slump or consistency of concrete is a direct function of the water content; i.e., within limits it is independent of other factors such as aggregate grading and cement content.
- At a constant water/cement ratio reduction in the aggregate/cement ratio causes increase in the water content, which consequently results into the increases in consistency of concrete.

Cement Content

- In normal concrete, at given water content, a considerable lowering of the cement content tends to produce harsh (i.e., low workable) mixtures with poor finishability.
- Concretes containing a very high proportion of cement or a very fine cement show excellent cohesiveness but tend to be sticky.

Mix Proportions

Aggregate-cement ratio influences the workability to a large extent. The higher the ratio leaner will be the concrete. Lean concrete, paste available for lubrication of per unit surface area of aggregates will be less and hence the workability is reduced.

Aggregate Size

Big size aggregate the total surface area to be wetted is less, also less paste is required for lubricating the surface to reduce internal friction. For a given water content big size aggregate give high workability.

Note

- Workability of concrete increase with increase in the quantity of water, use of rounded aggregates, decreasing the quantity of fine sand, proportioning the fine to coarse aggregate so that neither the total specific area increases nor the particle interference increases.

POZZOLANAS

Mineral additives also called supplementary cementing materials or pozzolana are fine grained siliceous inorganic materials which as such, do not possess cementing properties in themselves, but react chemically with calcium hydroxide $Ca(OH)_2$ released from the hydration of Portland cement at normal temperature to form compounds of low solubility having cementing properties. The action is termed as pozzolanic action.

Advantages

(i) Improved workability with lesser amount of water.

(ii) Lower heat of hydration & thermal shrinkage.

(iii) Improved resistance to attack from salts & suplhates from soils & sea water.

(iv) Reduced susceptibility to dissolution & leaching of calcium hydroxide.

(v) Reduced Permeability.

(vi) Lower costs.

Undesirable Side Effects of Pozzolanas

- Reduction in the rate of development of strength.
- Reduction in durability.

- Dimensions of the mould Bottom diameter = 200 mm, Top diameter = 100 mm, and Height = 300 mm.
- A steel tamping rod of 16 mm dia, 0.6 m long with bullet end in used.
- The mould is placed on a smooth, horizontal, rigid and non-absorbent surface.

- It is then filled in 4 layers, each approximately ¼ of height of mould.
- Each layer is tamped 25 times by the tamping rod evenly.
- After the top layer has been rodded, the concrete is struck off level with a trowel and tamping rod.
- The mould is removed immediately by lifting it vertically carefully.
- The concrete will then subside and this subsidence is referred as slump of concrete.
- The difference between the height of mould and the highest point of subsided concrete in mm is taken as slump of concrete.
- The pattern of slump also indicates the characteristic of concrete.
- An even slump is called true slump, and if one half of concrete slides down, it is called shear slump. It may collapse in case of very wet concretes.
- In case of shear slump, the slump value is measured as difference between the height of mould and average value of subsidence.
- Shear slump indicates a non-cohesive concrete and may lead to segregation.

VALUES OF WORKABILITY FOR DIFFERENT PLACING CONDITIONS

Degree of Workability	Consistency	Slump (mm)	Compaction factor	Vee-Bee degree (sec)	Characteristics	Uses
Extremely Low	Moist Earth	0	0.65-0.7	>20	Particles of coarse aggregate in the concrete are adhesive, but concrete does not clot, risk of segregation.	Precast paving slabs
Very Low	Very Dry	0-25	0.7-0.8	12-20	Concrete has the consistency of very stiff porridge, forms a stiff mound when dumped, and barely tends to shake or roll itself to form an almost horizontal surface when conveyed for a long time in, say, a wheel-barrow.	Roads (power vibrator)
Low	Dry	25.50	0.8-0.85	6-12	Concrete has the consistency of very stiff porridge, forms a mound when dumped, and shakes or rolls itself to form an almost horizontal surface when conveyed for a long time in, say, a wheel-barrow.	Mass concereting, light reinforced section, roads (hand vibrator)
Medium	Plastic	50-100	0.85-0.95	3-6	Concrete can be shaped into a ball between the palms of the hands, and adheres to the skin.	Flat slabs, heavily reinforced section RCC Sections (Manual Vibrator)
High	Semi-fluid	100-175	0.95-1	0-3	Concrete cannot be rolled into a ball between the palms of the hands, but spreads out even though slowly and without affecting the cohesion of the constituents so that segregation does not occur.	RCC with congested reinforcement (cannot be vibrated)

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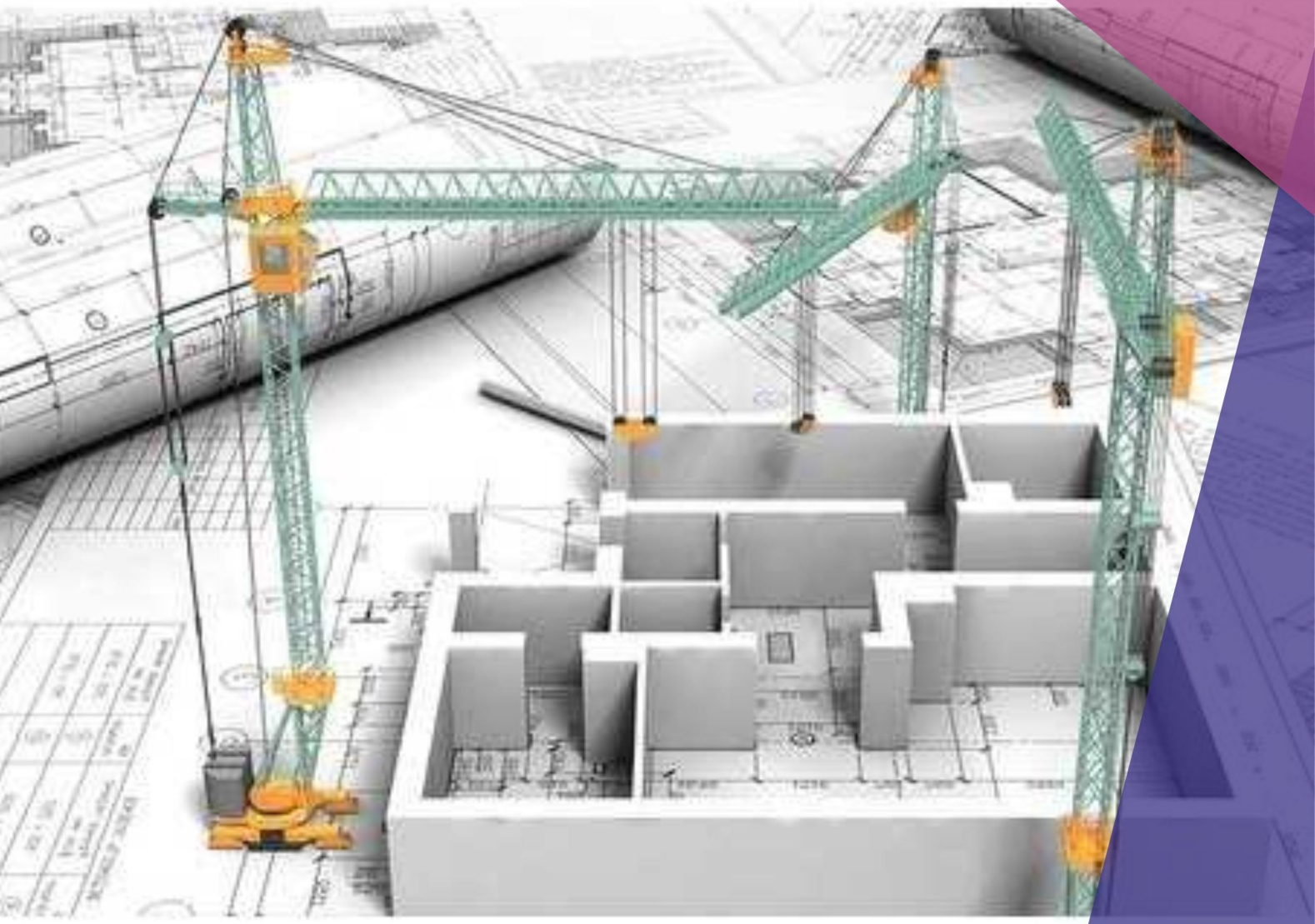

Structural Analysis

"All of us do not have Equal Talent.
But, all of us have an Equal Opportunity
to Develop our Talents."
A.P.J. Abdul Kalam

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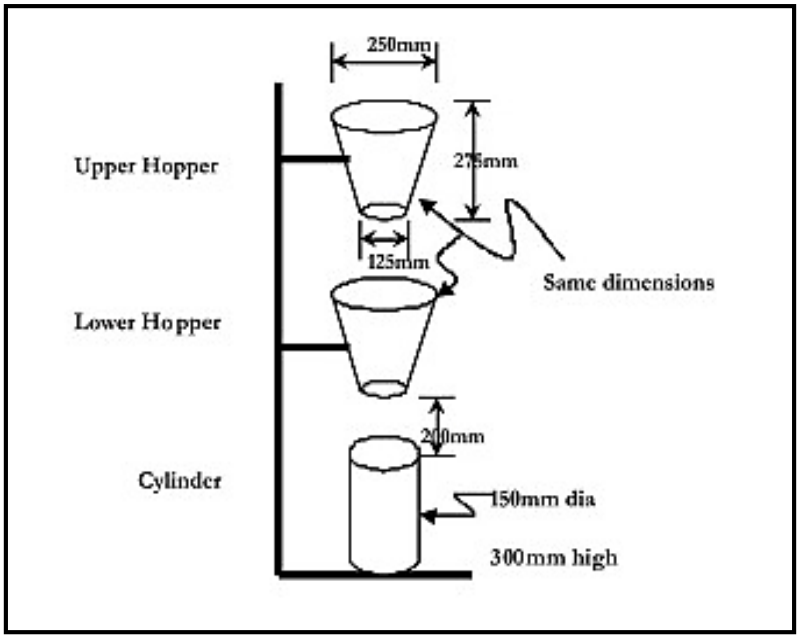
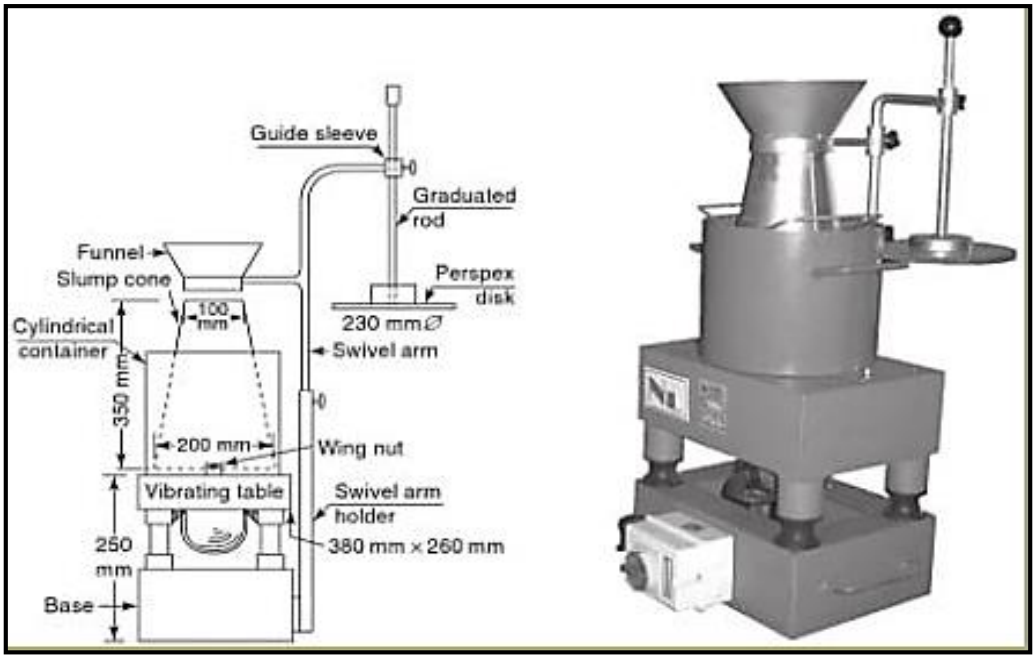


- Weight of the concrete in the cylinder is then determined to the nearest 10 gm this is known as wt of partially compacted concrete.
- Cylinder is refilled with concrete from the same sample in layers of 50 mm deep, each layer being heavily rammed or preferably vibrated so as to obtain full compaction.
- Top surface of the fully compacted concrete is carefully struck off level with the top of the cylinder.
- The mass of concrete in the cylinder should be measured and it is known as the mass of fully compacted concrete.
- Compacting factor is defined as ratio of the weight of partially compacted concrete to the weight of fully compacted concrete. i.e.

$$\mathbf{C.F.} = \frac{\boldsymbol{mass\ of\ partially\ compacted\ concrete}}{\boldsymbol{mass\ of\ fully\ compacted\ concrete}}$$

CF= 0.85	Low workability
CF = 0.92	Medium workability
CF = 0.95	High workability



4. Flow Test

It is appropriate for concrete of high and very high workability, including flowing concrete which would exhibit a collapse slump.

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Note

- Workability test methods in order of their application from low to high workability is Vee-Bee Consistometer, compacting factor test, slump test and flow test.

MIX DESIGN

- One of the ultimate aims of studying the various properties of the materials of concrete, is to design a concrete mix for a particular strength and durability; which is not a simple task on account of the widely varying properties of materials and the exposure condition.
- With better understanding of the properties, the concrete is becoming more and more an exact material than in the past.
- Concrete mix design is defined as process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of required strength, durability, surface finish and workability as economical as possible.

Where,

f_{cm} = Target mean strength

f_{ck} = Characteristic strength required.

σ = Standard deviation, which is calculated from previous record or obtained from code (IS:456) as per the table below.

Standard deviation calculation based on test strength of sample: Number of test results of samples shall be not less than 30.

Grade of Concrete	Standard Deviation for Different Degree of Control in N/mm^2		
	Very Good	Good	Fair
M10	2.0	2.3	3.3
M15	2.5	3.5	4.5
M20	3.6	4.6	5.6
M25	4.3	5.3	5.6
M30	5.0	6.0	7.0
M35	5.3	6.3	7.3
M40	5.6	6.6	7.6
M45	6.0	7.0	8.0
M50	6.4	7.4	8.4
M55	6.7	7.7	8.7
M60	6.8	7.8	8.8

2. Determine the water-cement ratio, based on the target strength of concrete from the relationship show in figure (a) or corresponding to target average strength from relationship shown in fig (b), using curve corresponding to the 28 days cement strength. This ratio should not exceed the limits specified in Table below (for durability considerations).

Table: Exposure conditions and requirements for RC work with normal aggregate (20 mm nominal size)

Exposure Category	Description	Min. Grade	Min. Cement content (kg/m^3) for RCC	Max. Free w/c
Mild	Protected against weather or aggressive-conditions, except if located in coastal area.	M 20	300	0.55
Moderate	Sheltered from severe rain or freezing whilst wet or Exposed to condensation and rain, or Continuously under water, or in contact with or buried under non-aggressive soil or ground water, or Sheltered from saturated 'salt air' in coastal area	M 25	300	0.50
Severe	Exposed to severe rain, alternate wetting and drying or occasional freezing whilst wet or severe condensation, or Completely immersed in sea water, or Exposed to coastal environment	M 30	320	0.45
Very Severe	Exposed to sea water spray, corrosive fumes or severe freezing whilst wet, or in contact with or buried under aggressive subsoil or ground water	M 35	340	0.45
Extreme	Members in tidal zone, or Members in direct contact with liquid / solid aggressive chemicals	M 40	360	0.40

3. Determine the water-content V_w based on workability requirements, and select the ratio of fine aggregate to coarse aggregate (by mass), based on the type and grading of the aggregate the former is generally in the range of 180-200 lit/m^3 (unless admixtures employed), and the latter is generally 1:2 or in the range of 1:1½ to 1:2½.

4. Calculate the cement content M_c (in kg/m^3) by dividing the water content by the water-cement ratio, and ensure that the cement content is not less than that specified

Note
- As per IS 456 : 2000, the characteristic strength is defined as that value below which not more than 5% of the test result are expected to fall. In such cases, k: 1.65 in above equation.

Table 1: (Table 1 of IS 10262:2009) assumed standard deviation for good control

S. No.	Grade of Concrete	Assumed Standard Deviation (N/mm²)
(i) (ii)	M10 M15	3.5
(iii) (iv)	M20 M25	4.0
(v) (vi) (vii) (viii) (ix) (x)	M30 M35 M40 M45 M50 M55	5.0

For example: For M20 of good control

$\sigma \rightarrow 4 N/mm^2$ (from table 1)

$F_m = 20 + 1.65 \times 4 = 26.6 \ N/mm^2$

IS 456 : 2000 recommends the above table for a good control which can easily be exercised at most of the sites by

(i) Proper storage of cement.

(ii) Weight matching of all materials

(iii) Controlled addition of water

(iv) Regular checking of all materials for aggregate grading & moisture content.

(v) Periodical checking of workability & strength.

Table 3 : (Table 2 of IS 10262 : 2009) Max water content allowed per cubic meter of concrete for nominal max. size of aggregate (slump 25 to 50 mm).

S. no.	Nominal max. size of aggregate (mm)	Max water content (kg/m^3)
(i)	10	208
(ii)	20	186
(iii)	40	165

Note

(i) Efffect of nature of coarse aggregate

The above water content values are for angular coarse aggregate. We should reduce these values for other aggregates as follows:

(a) For sub-angular aggregates it is reduced by 10 kg/m^2

(b) For Gravel with some crushed particles it is reduced by 20 kg/m^3

(c) For Rounded gravel it is reduced by 25 kg/m^3

(ii) Effect of increased slump

- The above values are for 25 to 50 mm slump.
- For increase in required slump. water content is increased by 3% for every additional 25 mm slump.

e.g. For 20 mm aggregate, max. water content = 186 kg/m^3 (for 25 to 50 mm slump)

If we have to calculate for 75 mm slump.

max. water content $= 186 + \frac{3}{100} \times 186$

$= 191.6\ kg/m^3$

(iii) Use of chemical admixture conforming to IS 9103.

Slump can be increased by addition of chemicals. Hence, with the addition of simple plasticizers, we can decrease the water content by about 5 to 10% and above. With super plasticizers, we can reduce the water content by about 20% and above.

4. Calculation of cementitious material content

The cement and supplementry Cementitious material content per unit volume of concrete may be calculated from the free water-cement ratio and the quantity of water per unit volume of concrete. The cementitious material so calculated shall be checked against the min. content for the requirements of durability and greater of the two values adopted.

The max. cement content shall be in accordance with IS 456.

Wt. of cement required $= \frac{\text{weight of water to be used}}{\text{w/c}}$

Check the cement content with min, as per (table 2).

Note

- Zone 4 is fine sand & zone 1 is coarse sand.
- The value of volumes of course aggregate given in Table 4 is for w/c ratio of 0.50.
- In case the water cement ratio arrived at is lesser than this value, there should be lesser fine aggregate & hence the volume of coarse aggregate has to be increased.
- Hence, for change in water-cement ratio from 0.50, we follow the following rules:
  (a) For every decrease of 0.05 in water-cement ratio from 0.50, we increase the proportion of volume of coarse aggregate, as given in table 4 by 0.01.
  (b) For every increase of 0.05 in water-cement ratio from 0.50, we decrease the proportion of volume of coarse aggregate, as given in table 4 by 0.01.
- For pumpable concrete-for this type of concrete, amount of course aggregate shown in table 4 is to be reduced by 10%

8. Estimation of volume & weight of fine aggregate.

$$\text{Vol. of fine aggregate } V_4 = V_2 - V_3$$

Weight of fine aggregate = Vol. x unit weight per cubic metre.

Results

From the above calculations, we get the values for $1m^3$ concrete of the mix.

1. Weight of water for the mix;
2. Weight of cement required
3. Volume and wt. of coarse aggregate required.
4. Volume and wt. of fine aggregate required.

DURABILITY

- A durable concrete is one that performs satisfactorily under anticipated exposure conditions for its stipulated life.
- Various factors affecting durability of concrete are as follows.

1. Permeability

- Ingress of water leads concrete susceptible to chemical attack, frost action, rusting of steel etc.
- We can reduce permeability by

4. Mineral Oils

Pertroleum and its products do not directly affect hardened concrete.

5. Organic Acids

- Acetic acid, lactic acid, and butyric acid severally attack concrete.
- Formic acid is corrosive to concrete.

6. Sugar

- It is a retarding agent and gradually corrodes concrete. Can be reduced by surfacing with sodium silicate solution, tar or asphalt.

7. Sewage

H_2S gas evolved from septic sewage promotes, the formation of H_2SO_4 affecting the concrete. However, sewers running full are not affected.

of that state, total water content of aggregate is equal to sum of absorption and moisture content.

- Coarse aggregate contains rarely more than 1 percent of surface moisture but fine aggregate can contain in excess of 10%.
- Water on the surface of aggregate will contribute to the water in the mix and will occupy a volume in excess of that of aggregate particles.
- Therefore basic state of aggregate should be saturated and surface dry.
- Therefore the presence of moisture in aggregate necessitates correction of the actual mix proportions: the mass of water added to mix has to be decreased by the mass of the free moisture in the aggregate, and the mass of the wet aggregate must be increased by a like amount.
- In case of sand (i.e. fine aggregate) there is a second effect of the presence of moisture bulking.

Bulking

- Bulking is increase in the volume of given mass of sand caused by the films of water pushing the sand particles apart.
- Increase in the volume of a given mass of fine aggregate caused by the presence of water is known as bulking.
- Water forms a film over the fine aggregate particles, exerts force of surface tension and pushes them apart increasing the volume.
- Extent of bulking depends upon the percentage of moisture present in the sand and its finesses. With ordinary sand bulking varies from 15-30 percent. It increases with moisture content up to a certain point (4-6%), reaches maximum, the film of water on the sand surface breaks, and then it starts decreasing.
- In preparing concrete mixes if sand is measured by volume and no allowance is made for bulking, the moist sand will occupy considerably larger volume than that prepared by the dry sand and consequently the mix will be richer.

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Surveying

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Qu10. What is hydration of cement?

a) Chemical reaction of cement with acid

b) Chemical reaction of cement with water

c) Chemical reaction of cement with base

d) Chemical reaction of cement with salt, and acid

TEST YOUR SELF

Qu11. Which test gives good results for rich mixes?

a) Slump test

b) Compacting factor test

c) Flow table test

d) VeBe test

Qu12. If the creep effect is considered at a given load, the modulus determined is referred to as _____

a) Short term modulus of elasticity

b) Elasticity

c) Long term modulus of elasticity

d) Creep effect

Answer

1-(b), 2-(a), 3-(b), 4-(c), 5-(a), 6-(c), 7-(c), 8-(d), 9-(b), 10-(b), 11-(a), 12-(c)

MANUFACTURING PROCESS OF PIG IRON

The first step is referred as dressing. In this process. The iron ore obtained is crushed and washed of impurities. The next step is the calcination of the ore, which is the heating of the ore in presence of oxygen so that it is oxidised. This remoes the water and carbon dioxide from the ore. The next step is of roasting the ore to make it very hot and dry. Heating the ore helps in removing the volatile content of the ore especially sulphur. Roasting is not necessary if the ore is sulphur free. The next step is of smelting of iron which is to separate metal from the ore, which carried out in blast furnace.

WORKING OF BLAST FURNACE

The raw material fed to the furnace is the fluxing material and fuel. The fluxing material is a substance which easily combines with the impurities and forms a fusible slag. The most common fluxing material is limestone. Coke and charcoal are commonly used fuels. The temperature in the lower portion of the furnace is about 1300-1500°C during the process. The reactions taking place are

$$3Fe_2O_3 \longrightarrow 2Fe_3O_4 + \text{CO}$$

$$Fe_3O_4 \longrightarrow 3\text{Fe} + 4\text{CO}$$

$$3Fe_2O_3\,\text{CO} \longrightarrow 2Fe_3O_4 + CO_2$$

$$Fe_3O_4 + 4\text{CO} \longrightarrow 3\text{Fe} + 4CO_2$$

The pig iron formed collects in the hearth of the furnace and the slag (being lighter) floats over the pig iron.

not. As the carbon content increases steel becomes harder and tougher. Steel possesses sufficient tensile and compressive strength unlike cast iron (good compressive strength but poor tensile strength) and wrought iron (good tensile strength by virtue of fibrous nature).

MANUFACTURING OF STEEL

The processes commonly used for manufacturing of steel are

(1) Bessemer process (2) Cementation process

(3) Crucible steel process (4) Duplex process

(5) Open hearth process (6) Electric process

Physical Properties of Steel

The physical properties of steel are governed mainly by following three factors.

(1) Carbon content

As the carbon content is varied difficult types of grades of steel produced, with increase in the carbon content, strength, toughness and brittleness increase while ductility decreases.

The most commonly used steel grade, mild steel, has a carbon content of about 0.10 to 0.25 percent.

(2) Impurities

Silicon, Sulphur phosphorous and manganese are the common impurities.

(i) For silicon content up to 0.20 percent, it has no considerable effect on the physical properties. when the percentage content is between 0.02 to 0.10, it may however decrease the malleability and weldability of hot metal. At a content between 0.30 to 0.40 percent silicon considerably the elasticity and strength of steel without any considerable loss in ductility.

(ii) Phosphorous is detrimental to steel and hence its percentage is kept below 0.12 percent. It reduce the shock resistance, ductility and strength of steel.

Treatment of Steel

(a) Mechanical Treatment

Mechanical treatment is introduced to give desired shape to the steel so as to fit the purpose

i. **Drawing:** It refers to the reduction of cross section and to increase it length proportionately. The metal is drawn through dies or specially shaped tools. This is essentially used for making wires and rods.

ii. **Forging:** This process refers to the repeated blowing of the steel using a power hammer or a press. The metal is heated above the critical temperature before the blows. The process is implied to increase the density and improve the grain strength of steel.

iii. **Pressing:** The steel metal is pressed between a die and punch of an equipment known as press. The main advantage of this process is the absence of shock (unlike forging)

iv. **Rolling:** This operation is carried out in specially prepared rolling mills, the ignots are passed in successions through different rollers to obtain articles of desired shape. Angles, channels, joists, rails etc are obtained by rolling.

(b) Heat Treatment

Heat treatments are introduced to derive following changes.

(i) Increase the heat and cold resistance

(ii) Increase the surface hardness and strength

(iii) Increase the workability

(iv) To bring any derived change in the structure

(v) To alter magnetic and electrical properties of steel

Properties of Mild Steel

Mild steel possesses the following properties. It can be

(i) Easily forged and welded

(ii) It cannot be easily hardened and tempered

(iii) It has a fibrous structure

(iv) It is malleable and ductile

(v) It is susceptible to rusting

(vi) It has a melting point of about 1400°C

(vii) It has specific gravity of 7.70-7.80

(vi) Its compressive strength is between 0.8-1.2 kN/cm' and shear strength about 0.6 to 0.8 kN/mm^2

(ix) It is not susceptable to the action of salt water.

Qu4 Which of the following is the purest form of iron?

(a) Cast iron

(b) Wrought iron

(c) Mild steel

(d) High carbon steel

Qu5 Percentage of carbon content in mild steel is

(a) Less than 0.25

(b) Between 0.25 and 0.7

(c) Between 0.7 and 1.5

(d) Greater than 1.5

TEST YOUR SELF

Qu6 The stainless steel consists of

(a) 16% chromium

(b) 35% nickel

(c) 30% nickel

(d) 12-15% manganese

Qu7 Iron possess a _____ degree of allotropy

(a) High

(b) Low

(c) Medium

(d) None of these

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CHAPTER – 11

ALUMINIUM

Aluminium is one of the eight majorly used Non-Ferrous building materials. Other non-ferrous materials used are Cobalt, Copper, Lead, Magnesium, Nickel, Tin, Zinc. Aluminium occurs in various froms such as oxides, sulphates and silicates. It is commercially produced mainly from bauxite ($Al_2O_3.2H_2O$)

MANUFACTURING OF ALUMINIUM

Bauxite is ground and purified. It is then dissolved in a fused cryolite (double fluoride of aluminium, AlF_3 and sodium 3NaF). The solution is then taken to a electric furnace where aluminium gets separated by electrolysis.

PROPERTIES

1. It is good conductor of heat and electricity.
2. Aluminium is a non-magnetic, malleable and ductile substance.
3. Aluminium exhibits very bright luster on a freshly broken surface.
4. It possesses high resistance against corrosion.
5. It is a soft metal with melting point about 650°C and a boiling point about 2050°C.
6. It rapidly dissolves in hydrochloric acid.
7. It is light weight (specific gravity 2.7) and has a high strength to weight ratio.

Following are the properties which gives it a special place in the building material industry.

1. Air tightness: A properly designed aluminium can be air tight, sealing against dust and rain, making a strong low weight shielding structure.

makes aluminium more suitable building material. Asbestos sheets are brittle and also pose health hazards

Corrugated Galvanized Iron Sheets

These sheets are heavier and costly than aluminium sheets.

USES OF ALUMINIUM

High strength to weight ratio makes aluminium particularly useful for making parts of aero-plane, utensils, window frames, galvanized bars, balustrades etc. About 50% of the total aluminium is used in electrical industries. Other specific uses of aluminium are

1. Aluminium is used as a reducing agent in the manufacturing of steel.
2. It is used during the casting of steel.
3. It is also useful for making paints in powder forms.

Clay Products

Clays are formed as a result of chemical weathering of rocks. Usually feldspar mineral is abundant in igneous rocks, that too mainly in the form of orthoclase feldspar. Rocks with high orthoclase feldspar content disintegrate easily, and hence orthoclase feldspar is mainly responsible for occurrence of clay in nature. Feldspar mineral on decomposition gives kaolinite. In kaolinite, which is free from iron oxide and alkalies, alumina and silica compounds are held in a colloidal state and these compounds are the basic constituents in all clays.

Clays with right amount of water, possess high degree of tenacity and plasticity. These clays can be moulded into any shape. These moulds when dried and burned possess good strength.

The total amount of water that clays contain can be divided in two forms

1. **Combined water:** This represents the chemically combined water. To remove this water clay is heated to a high temperature.
2. **Free water:** This is the water that is loosely held in the structure of clay minerals and can be easily removed by simply air drying.

The major forms in which clay products are used as a building material are

1. Tiles	2. Terra-cotta (baked earth)
3. Earthen wares	4. Stone wares
5. Porcelain	6. Bricks

The four operations to be carried out for making tiles and terra-cotta are:

Preparation of clay, moulding, drying, burning.

Preparation

Tiles

Suitable clay is taken and freed from impurities (viz. grit, pebbles). This clay is then converted into fine powder in pug mills by pressing. In a tank, large

(a) Salt glazing

A small quantity of moist/wet NaCl is added to the kiln at a temperature of about 1280 degrees. The salt vapourizes forming a glass like glaze, at the surface of the article, of vapour of salt.

(b) Lead glazing

Here the article is burned and dipped in bath containing oxide of lead and tin. It is then taken out of the bath and reburned. The particles of lead/tin oxide melt forming a film over the exposed surface of the glaze. Here the glaze does not penetrate the body of ware but just forms a thin skin over the article which can be easily detached later. Terra-cotta, fire-clay wares, and earthenwares are glazed by this method only

Stone Wares

Stonewares are articles prepared from refractory clays (that is clays which retain their strength at high temperatures) mixed with stone and crushed pottery. This mixture is burnt at high temperature and cooled slowly. Stonewares are more compact and dense than earthenwares and are strong, impervious, durable and resistant. They have a very smooth surface and easy to maintain clean thus used in sanitary articles such as washbasins, sewer pipes, glazed tiles, water closets and gully traps. Stonewares produce a clear ringing sound when struck against each other.

Porcelain

Porcelain is fine earthenware essentially white, thin and semi-transparent. They are also referred as whitewares. Comparatively pure clay of high degree of plasticity is used for making porcelains. They are hard, brittle and non-porous and prepared from clay, feldspar, quartz and minerals. Porcelains are used as sanitary wares, electric insulators, storage vessels, reactor chambers and crucibles. Porcelains can be prepared by two ways

Dry Method**:** These are also called as low voltage porcelains.

Wet Method**:** These are called high voltage porcelain.

Cone Equivalent (PCE). Fire-clay and high alumina clay soften gradually over a range of temperature, whereas, others silica softens over a relatively narrow range. Magnesium oxide can withstand high temperatures (1650-2500°) without melting and is used extensively as a refractory.

The refractory materials can be classified in the following two ways

Classification on the Basis of Chemical Properties

Refractories can be classified into following type

(i) **Acidic:** Fire-clay, quartzite, silica.

(ii) **Basic:** bauxite, carbon, chromite, forsterite.

(iii) **Neutral:** dolomite, magnesia.

Classification on the Basis of Thermal Resistance

(i) Low quality

(ii) High quality

Low quality refractory materials have a melting point above 1580 degrees. They are used for making fire bricks. High quality refractories are able to resist even higher temperatures and are used in modern high temperature technologies such as parts of rockets and jets. These are made up of pure clays or metals or a combination of both. Metals commonly used are molyblendum, tungsten, zirconium and there alloys.

Qu5. The examples of glass maker's soap is

a) Nickel oxide

b) Cobalt oxide

c) Manganese dioxide

d) Cullets

Qu6. Crown glass is an example of

a) Soda-lime glass

b) Lead glass

c) Boro-silicate glass

d) Sheet glass

TEST YOUR SELF

Qu7. Which of the following glass is most suitable to withstand high temperatures?

a) Soda-lime glass

b) Lead glass

c) Boro-silicate glass

d) Tempered glass

Qu8. The metal oxide used to make emerald green glass is

a) MnO_2

b) Cr_2O_7

c) Cobalt oxide

d) Iron oxide

Answer

1-(c), 2-(d), 3-(b), 4-(a), 5-(c), 6-(a), 7-(c), 8-(b)

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Transportation Engineering

END is not the end if fact E.N.D. means
" Effort Never dies"

A.P.J. Abdul Kalam

The content of this book covers all PSC exam syllabus such as MPSC, RPSC, UPPSC, MPPSC, OPSC etc.

Physical properties of glass are as follows.

1. Glass absorbs, refracts or transmits light.
2. It can be polished finely and imparted with beautiful colours to substitute for costly gems.
3. Glass is an electrical insulator.
4. It is extremely brittle.
5. Glass exhibits excellent workability. Its properties such as fusibility, hardness, refractive power can be altered to suit different purposes. It is possible to weld pieces of glass together by fusing.

COMPARISON OF DIFFERENT TYPES OF GLASS

Soda Lime Glass

It contains silicates of sodium and calcium. It is also referred as soft glass. E.g window glass, plate glass, lab apparatus.

(a) It fuses at low temperature.

(b) It melts easily.

Potash Lime Glass

It contains silicates of potassium and calcium. It is also referred as bohemian glass i.e. hard glass

(a) It fuses at high temperature.

(b) It is not easily attacked by water and any other solvent.

(c) It is not easy to melt.

It is used for making articles, which have to with stand high temperatures such as combustion tubes.

The raw materials, cullets and decolourisers are weighed in proportion, finely powdered and mixed. This mixture is taken to furnace for melting.

Fabrication refers to the giving shape to the molten glass taken out from the furnace. It can be done by hand (small scale production) or by machine. Different ways adopted for fabrication are

1. Blowing: by a hollow (blow) pipe
2. Casting: using moulds
3. Drawing
4. Pressing
5. Rolling
6. Spinning

Annealing refers to the slow, homogenous gradual cooling of the glass articles. After cooling, following (all or some of these) operations are employed to make the glass fit for use.

1. Bending
2. Cutting
3. Opaque making
4. Silvering

Following substances are used for colouring of glass

COLOUR	SUBSTANCE
Blue	Cobalt oxide, cupric oxide
Dark blue, brown, dark violet	Cobalt, manganese and iron oxide
Green	Ferroso-ferric oxide (Fe_3O_4), chromium sesquioxide (Cr_2O_3)
Red	Cuperous oxide, metallic gold
Yellow or brown	Antimony trisulphide(Sb_2S_3), charcoal, silver borate.
Violet	Manganese oxide

Tin oxide and calcium phosphorite are added to impart glass white opaque.

load bearing but blocks do have compressive strength ranging from 400 to 500 pounds per square inch. (2757.903 to 3447.38 kpa)

- Glass block have excellent insulating properties and can reduce both thermal & sound transmission.
- They are available in a variety of pattens for directing or diffussing light

Foam Glass

- Technology for glass recycling is foam glass.
- It also referred to as cellular glass, was originally manufactured from a specially formulated glass composition using virigin glass only. Currently, there are a number of foam glass production plants that are using upto 98% post consumer waste glass in their product.
- The basic principle of foam glass manufacture is to generate a gas in glass at a temperature between 700°C and 900 °C. The gas expands thus producing a structure of cells to form a porous body.
- It is best suited as a rigid insulation material.
- It has excellent fire resistant properties.

TEST YOUR SELF

Qu5 The example of glass maker's soap is

(a) Nickel oxide

(b) Cobalt oxide

(c) Manganese dioxide

(d) Cullets

Qu6 Crown glass is an example of

(a) Soda-lime glass

(b) Lead glass

(c) Boro-silicate glass

(d) Sheet glass

Qu7 Which of the following glass is most suitable to withstand high temperatures?

(a) Soda-lime glass

(b) Lead glass

(c) Boro-silicate glass

(d) Tempered glass

Qu8 The metal oxide used to make emerald green glass is

(a) MnO_2

(b) Cr_2O_7

(c) Cobalt oxide

(d) Iron oxide

Answers:

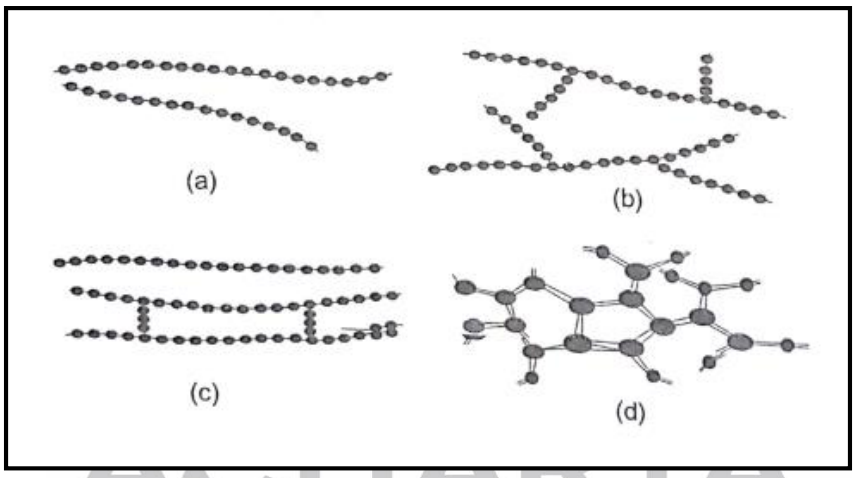
1-(c), 2-(d), 3-(b),4-(a), 5-(c), 6-(a), 7-(c), 8-(b)

Cross Linked Structure

This structure fig. (c) is formed when the adjacent chains combine to each other. Such a linking restricts the relative movement of chains and therefore greatly increase the strength of the structure.

Network Structure

It is a very complex structure fig. (d) formed by joining several individual monomers (units) forming a 3-dimnesional structure. In a network structure it is difficult to identify or separate single individual chains.



METHODS OF POLYMERIZATION

Depending on the way in which polymerization takes place, the process can be classified into following types:

Addition Polymerization

In this polymerization similar or different molecules combine with each other due opening of the double bond (pi bond). No loss of any substance or mass takes place and thus the weight of the formed polymer is equal to the combined weight of the joining units. The entire process can be said to occur in three steps opening of the bond (beginning of the process), expansion of the chain, end of the process. Examples of addition polymers are polythelene, polyvinlychloride (PVC), polystyrene, polyacrylates.

do not alter their form on further heating. At a temperature of about 340 degrees charring occurs which is due to the organic nature of these substances.

The above two fold classification is a very general classification with new sub divisions created time to time because of the advancement of the technology

Classification on the Basis of Structure

On the basis of types of atoms present in a polymer they can be classified into two types

Homogeneous Polymers

These polymers are composed of only carbon atoms.

Heterogeneous polymers

These polymers exhibit different types of atoms in their structure such as carbon, oxygen, nitrogen etc.

Classification on the Basis of Physical and Mechanical Properties

Rigid Plastics

These plastics possess a high modulus of elasticity and do not lose their shape under stresses applied at normal or moderately high temperatures.

Semi-Rigid Plastics

These plastics have moderate to high modulus of elasticity and thus regain their shape completely when the pressure is removed.

Soft Plastics

These plastics have a low modulus of elasticity and they regain their shape gradually (slowly) upon removal of external pressure.

Ductility

Plastics do not possess ductility and are susceptible to sudden failure.

Electrical Insulation

Plastics act as good insulators and find application in electrical industries.

Durability

Plastics possess sufficient durability.

Fire Resistance

Plastic are organic in nature and hence, all plastics are combustible.

Maintenance

Maintenance of plastic surfaces is easy.

Melting Point

Plastics have low melting point and thus cannot be used in positions where they are exposed to high temperature,

Sound Absorption

Plastics provide sufficient sound proofing.

Strength

Plastic are reasonably strong. Plastics cannot be used ideally as structural members but their strength may be increased by reinforcing with various fibrous materials. Plastics are particularly good in handling tension as for tension their strength to weight ratio is comparable to metals.

properly orient the fibres according to the loads assumed to be acting on the member. For 2 or 3 dimensional structures, fibres can be oriented forming a mesh so that no weak spot remains thus making the member equally strong in all the directions

FLY ASH

Fly ash is the residue produced during the combustion of coarse or powdered bituminous coal or any other form of coal, Fly ash is mainly produced in thermal power plants as a by-product and other plants which use pulverized coal or lignite as a source of fuel for boilers. About 30% of the coal is converted into ash on burning, out of which 75% is in fine fly ash form and rest (25%) in the form of coarse bottom ash. The fine fly ash escapes the power plant through the chimneys. Fly ash in atmosphere is a pollutant and therefore its control is very important. This escape of fly ash can be reduced or avoided by installing proper collection mechanism such as fabric filters, mechanical dust collectors and electronic precipitators (ESP). Fly Ash is also known as Coal Ash, Pulverized Flue Ash, and Pozzolona.

PROPERTIES OF FLY ASH

Fly ash particles are in general spherical in shape with size ranging from 0.5 μm to 100 μm. There main constituent is silicon dioxide (SiO_2), which is present in two forms: amorphous, which is rounded and smooth, and crystalline, which is sharp, pointed and hazardous. Fly ashes are in general highly heterogeneous, consisting of a concoction of glassy particles with various exacting crystalline phases such as quartz, mullite, and various iron oxides.

Fly ash usually also contains certain environmental toxics such as arsenic, barium, beryllium boron, chromium, lead, manganese and other heavy metals.

The chemical properties of the fly ash largely depend on the chemical content of the coal burned (i.e., anthracite, bituminous, and lignite).

Fly ash possess pozzolanic properties that is, it is not cementitious itself but combines with lime to form a material with cement like properties. Fly ash constitutes mainly of

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Total weekly test : 35

Total mid subject test : 16

Total full length test : 13

Mock test : 16

Total test : 80

1. Mixing with Portland cement.
2. Embankments and structural fill.
3. Waste stabilization and solidification.
4. Raw feed for cement clinkers.
5. Mine reclamation
6. Stabilization of soft soils.
7. As an aggregate material.
8. Mineral filler in asphaltic concrete.
9. Used as a sub-base product in pavement design.
10. Other applications include cellular concrete, geo polymers, & roofing tiles and fly ash bricks.

COMPOSITE COMPONENTS

Reinforcing Fibers

The fibers provide the strength and stiffness of an FRP. Because the fibers used in most structural FRP applications are continuous and are oriented in specified directions, FRPs are orthotropic, and they are much stronger and stiffer in the fiber direction(s). The functional requirements of fibers in a composite are:

i. High modulus of elasticity to give stiffness
ii. High ultimate strength
iii. Low variation of strength between individual fibers
iv. Stability during handling
v. Uniform Diameter

Generally, fiber can be used in different ways, with the performance changing for each:

- The highest performance in terms of strength and stiffness in one direction comes from unidirectional composites, when fibers are parallel and give their maximum possible performance in this single direction
- By arranging the fibers in a weave or mat, strength can be gained in more directions, although the limit strength is reduced.
- By chopping the fibers into short lengths and arranging them randomly, equal strength is achieved in all directions. This is generally the cheapest technique and used for the least structurally demanding cases.

GLASS FIBERS

Glass fibers are commonly produced by a process called direct melt, wherein fibers with a diameter of 3 to 25 microns are formed by rapid and continuous drawing from a glass melt. Glass fibers are used for the majority of composite application because they are cheaper than the others. There are different forms known by names like E-glass (the most frequent used), S-glass (is a stringer and stiffer fiber with a greater corrosion resistance), R-glass (is a higher tensile strength and modulus and greater resistance to fatigue and aging) and AR-glass (an alkali-resistant glass used to reinforced concrete).

The main characteristics of glass fibers are their high tensile strengths and moderate elastic modulus. Glass fibers are also excellent thermal and electrical insulators. Glass fibers are particularly sensitive to moisture, especially in the presence of salts and elevated alkalinity, and need to be well protected by the resin systems used in the FRP. Glass fibers are also susceptible to creep rupture and lose strength under sustained stresses.

CARBON FIBERS

Carbon fibers are produced by a process called controlled pyrolysis, wherein one of three potential precursor fibers is subjected to a complex series of heat treatments (stabilization, carbonization, graphitization, and surface treatment) to produce carbon filaments with diameters in the range of 5-8 microns. Although considerably more expensive than glass fibers, carbon fibers are beginning to see widespread use in structural engineering applications such as pre-stressing tendons for concrete and structural FRP wraps for repair and strengthening of reinforced concrete beams, columns, and slabs. Their steadily increasing use can be attributed to their steadily decreasing cost, their high elastic moduli and available strengths, their low density (low weight), and their outstanding resistance to thermal, chemical, and environment effects, they do not absorb moisture. Carbon fibers are an ideal choice for structures which are weight and/or deflection sensitive.

- Transfer stresses to the fibers efficiently
- Be chemically and thermally compatible with fibers
- Have appropriate fire resistance and limit smoke propagation
- Provide good aesthetic finish (color and surface).

There are several different polymer matrices which can be utilized in FRP composites, but in construction industry only a relatively small number are actually used. According to their nature, there are two major types of polymers, which determine the methods of manufacturing and the properties of the composite: (i) thermoplastic and (ii) thermosetting. The first FRP were all based on thermosetting polymers and, besides the fact that thermoplastic have seen rapid growth in recent years, thermosetting is yet the most used in Civil Engineering applications

THERMOPLASTIC MATRIX

Thermoplastics are polymers composed of long-chain molecules that are held together by relatively weak Vander Waals forces, but that have extremely strong bonds within individual molecules. These polymers can be amorphous, which implies a random structure with a high concentration of entanglement, or crystalline, with a high degree of molecular order (Cowie 1991). In these materials, the molecules are free to slide over one another at elevated temperatures, so thermoplastics can be repeatedly softened and hardened by heating and cooling without significantly changing their molecular structure. The semi-crystalline polypropylene and nylon are especially popular as matrices.

THERMOSETTING MATRIX

Thermosetting polymers are also long-chain molecules built from monomers, but for these materials the molecular chains are cross-linked through primary chemical bonds. Thus, thermosets cannot be reversibly softened and will deteriorate irreversibly at elevated temperatures. These are usually made from liquid or semi-solid precursors which harden irreversibly; this chemical reaction is known as cure and on completion,

Vinylester Resin

Vinylesters have similar mechanical and in-service properties to those of the epoxy resins and equivalent processing techniques to those of the unsaturated polyesters. Vinylesters are resistant to strong acids and alkalis, which is one reason that they are commonly used in the manufacture of FRP reinforcing bars for concrete (the environment inside concrete is highly alkaline). They also offer reduced moisture absorption and shrinkage as compared with polyesters. Vinylesters cost slightly more than polyesters.

ADVANTAGES AND DISADVANTAGES OF FRP

The advantages of FRPs over conventional reinforcing steel are cited often in the literature and include:

- FRPs are non-corrosive, although they may be susceptible to other forms of equally damaging environmental distress, usually caused by elevated temperatures and/or moisture
- High strength-to-weight ratios, as much as 10 to 15 times greater than steel
- It has high fatigue endurance limits and absorb impact energies
- Electromagnetic neutrality, which can be extremely useful in some special structures
- High tensile strength compared with steel
- Rapid and easy installation, significantly lowering construction costs and downtime.

There are however, a number of disadvantages to using FRPs. Some of the most pressing concerns include:

- High material cost, although prices have dropped drastically in the past 10 years as use has increased.
- Low strain at failure, requiring new design approaches and raising concerns over insufficient member ductility

CHAPTER – 16

BRICK MASONRY

The bricks are obtained by moulding clay in rectangular blocks of uniform size and then by drying and burning these blocks. As bricks are of uniform size, they can be properly arranged and further, as they are light in weight, no lifting appliance is required for them. The bricks do not require dressing and the art of laying bricks is so simple that the brickwork can be carried out even with the help of unskilled labourers. Thus, at places where stones are not easily available, but there is plenty of clay suitable for the manufacture of bricks, the stones are replaced by bricks.

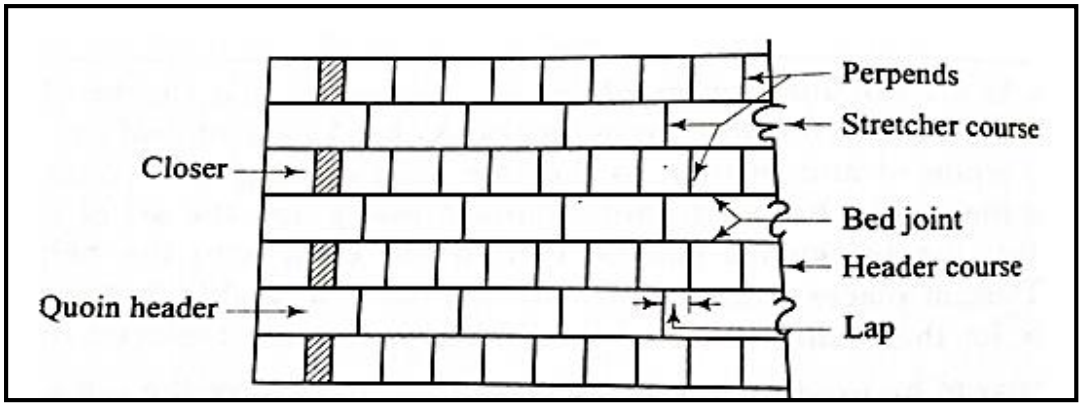
The mortar to be used for the brick masonry should have the same characteristics as the mortar used in the stone masonry. The mud mortar is sometimes used in brick masonry where low strength bricks are available and where the superimposed loads are not heavy.

SIZE AND WEIGHT OF BRICKS

The bricks are prepared in various sizes. The custom in the locality is the governing factor for deciding the size of a brick. Such bricks which are not standardized are known as the traditional bricks.

If bricks are large, it is difficult to burn them properly and they become too heavy to be placed with a single hand. On the other hand, if bricks are small, more quantity of mortar is required. Hence the BIS has recommended the bricks of uniform size. Such bricks are known as the modular bricks and the actual size of the modular brick is 190 mm × 90mm × 90mm. With mortar thickness, size of such a brick becomes 200 mm × 100 mm × 100 mm and it is known as the nominal size of the modular brick. Thus the nominal size of brick includes the mortar thickness.

It is found that the weight of 1 m^3 of brick earth is about 1800 kg. Hence the average weight of a brick will be about 3 to 3.50 kg.



Perpends

The vertical joints separating the bricks in either length or cross directions are known as the perpends and for a good bond, the perpends in alternate courses should be vertically one above the other.

Lap

The horizontal distance between the vertical joints in successive courses is termed as a lap and for a good bond, it should be one- fourth of the length of a brick.

Closer

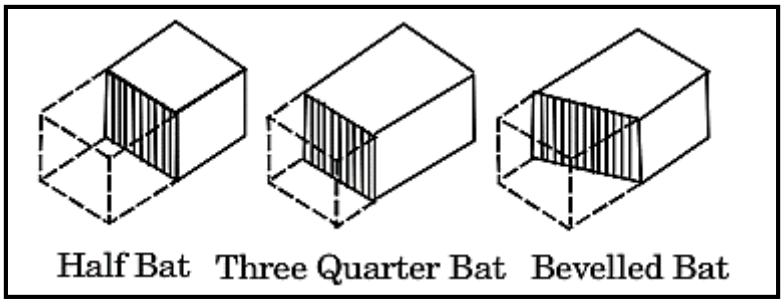
A piece of brick which is used to close up the bond at the end of brick courses is known as a closer and it helps in preventing the joints of successive courses to come in a vertical line. Generally the closer is not specially moulded. But it is prepared by the mason with the edge of the trowel. Following are the types of closers:

Queen Closer

This is obtained by cutting the brick longitudinally in two equal parts. It can also be made from two quarter bricks, known as the quarter closers, to minimize the wastage of bricks. A queen closer is generally placed near the quoin header to obtain the necessary lap.

Bat

This is a piece of brick, usually considered in relation to the length of a brick and accordingly known as half bat or three-quarter bat.



Bullnose

A brick moulded with a rounded angle is termed as a bullnose and it is used for a rounded quoin. A connection which is formed when a wall takes a turn is known as a quoin. The centre of the curved portion is situated on the long centre- line of the brick.

Cownose

A brick moulded with a double bullnose on end is termed as a cownose.

Squint Quoin

A brick which is cut or moulded such that an angle other than a right angle is formed in plan is known as a squint quoin.

Frog

A frog is a mark of depth about 10 mm to 20 mm which is placed on the face of a brick to form a key for holding the mortar. The wire cut bricks are not provided with frogs. A pressed brick as a rule has frogs on both the faces. A hand-made brick has only one frog.

Brickwork in c.m. (III Class)

This type of brickwork is same as II class except that bricks to be used 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 the rainfall is not heavy.

BONDS IN BRICKWORK

The bricks being of uniform size can be arranged conveniently in a variety of forms. Some of the rules to be observed for getting a good bond are as follows:

(i) The amount of lap should be minimum one- fourth brick along the length of the wall and one- half brick across the thickness of the wall.

(ii) The bricks should be of uniform size to get uniform lap.

(iii) The stretchers should be used in the facing. The hearting should be carried out with headers only.

(iv) The use of brickbats should be discouraged except under special circumstances.

(v) The vertical joints in the alternate courses should be along the same perpend.

The various types of bonds with their patented names have been constructed. Following are the types of bonds in brickwork:

(1) Stretcher bond
(2) Header bond
(3) English bond
(4) Flemish bond
(5) Garden wall bond
(6) Raking bond
(7) Dutch bond
(8) Brick -on -edge bond
(9) English cross bond
(10) Facing bond

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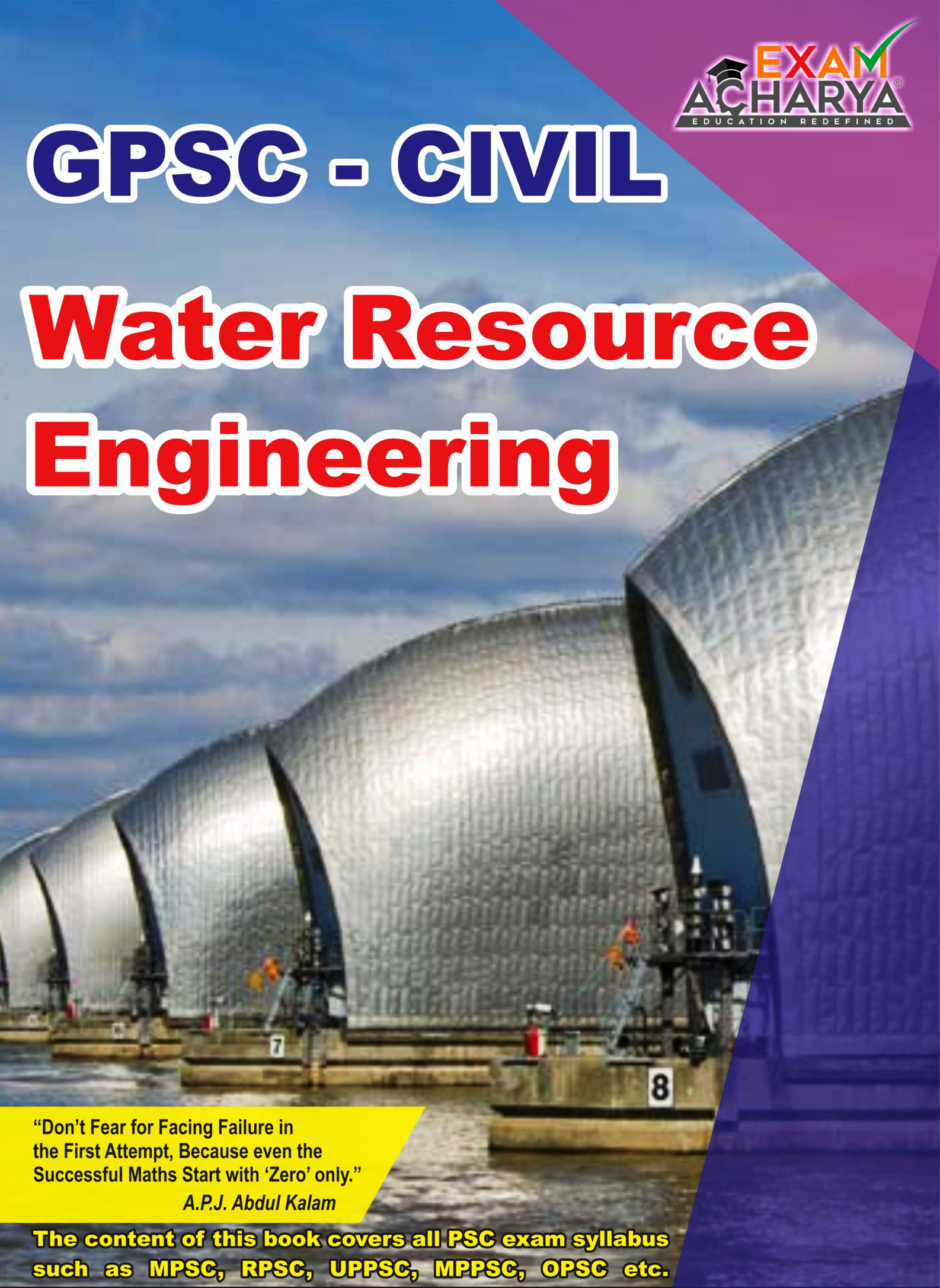


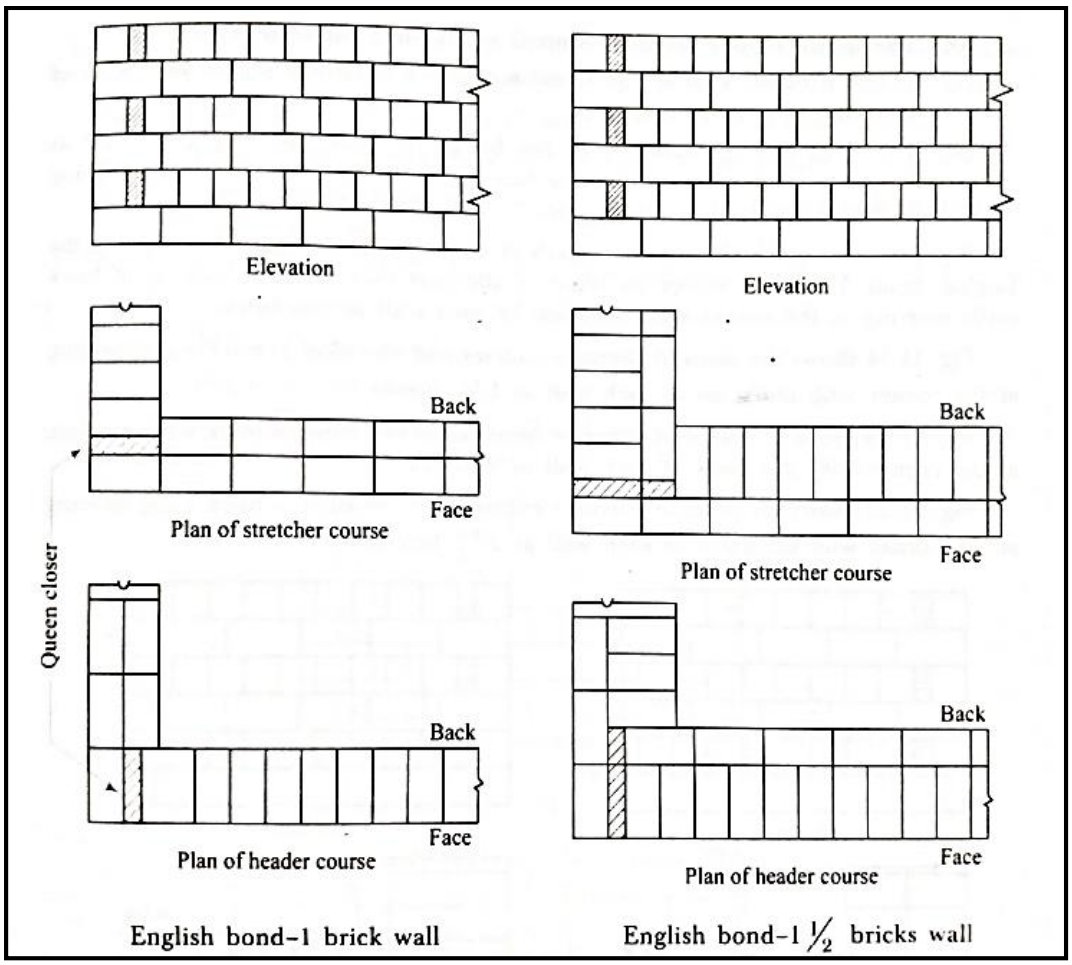
"Don't Fear for Facing Failure in the First Attempt, Because even the Successful Maths Start with 'Zero' only."

A.P.J. Abdul Kalam

The content of this book covers all PSC exam syllabus such as MPSC, RPSC, UPPSC, MPPSC, OPSC etc.

English Bond

This type of bond is generally used in practice. It is considered as the strongest bond in brickwork. Following are the features of an English bond.



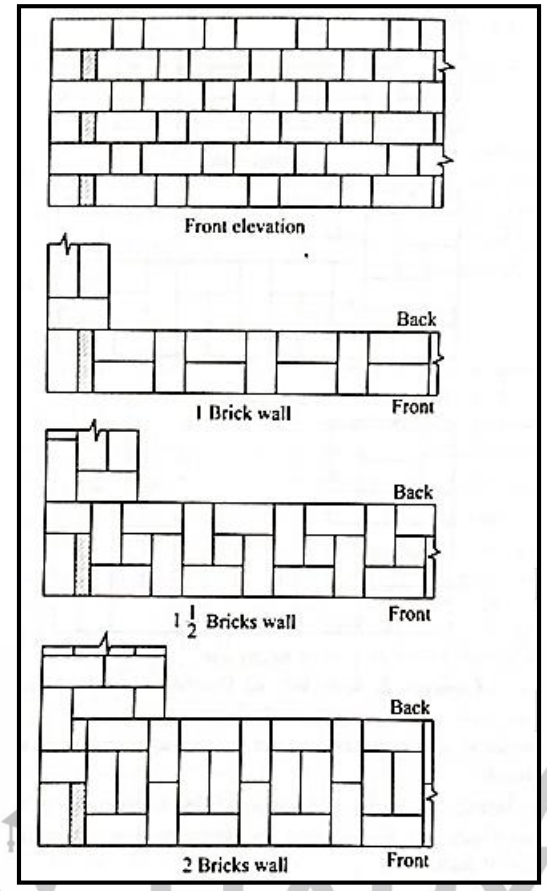
(i) The alternate courses consist of stretchers and headers.

(ii) The queen closer is put next to the quoin header to develop the face lap.

(iii) Each alternate header is centrally supported over a stretcher.

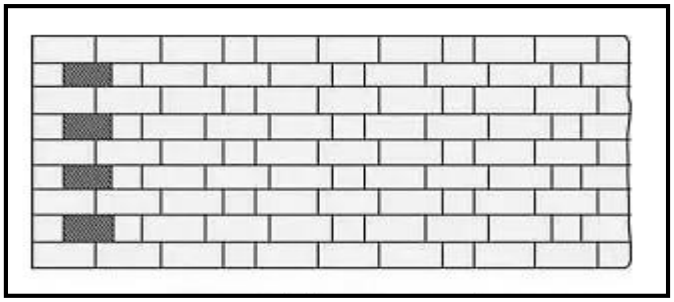
(iv) If the wall thickness is an even multiple of half- brick, the same course shows headers or stretchers in both the front and the back elevations. But if the wall thickness is an uneven multiple of half – brick, a course showing stretcher on the face shows header on the back and vice versa.

In Double Flemish bond, the headers and stretchers are placed alternatively in front as well as the back elevations.



For this type of bond, the half – bats and three – quarter bats will have to be used for walls having thickness equal to odd number of half bricks. For walls of thickness equal to even number or half bricks, no bats will be required and a stretcher or a header will come out as a stretcher or a header in the same course in front as well as back elevations. This bond gives better appearance than the English bond. But it is not so strong as the English bond as it contains more number of stretchers.

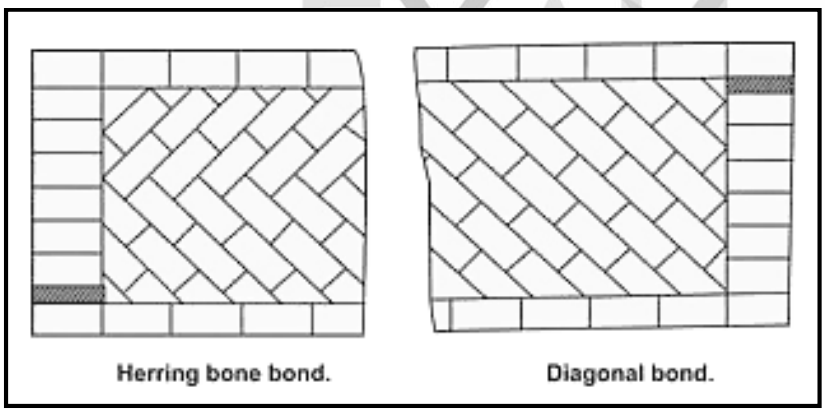
In Single Flemish bond the face elevation is of Flemish bond and the filling as well as backing are of the English bond. Thus, in this type of bond, an attempt is made to combine the strength of the English bond with the appearance of the Flemish bond. This type of bond is used when expensive bricks are used for the face work. But in order to construct this bond, a wall of minimum thickness 1 ½ bricks is required.



In the Flemish garden-wall bond each course contains one header to three or five stretchers. A three-fourth brickbat is placed next to quoin header in every alternate course to develop the necessary lap. A header is placed centrally over each middle stretcher. This type of bond is also known as the 'Scotch bond' or 'Sussex bond'.

Raking Bond

As the filling of thicker walls is done by headers only, such walls become weak in the longitudinal direction. The raking or inclined bonds are used in such cases as remedial measures.



Following points should be noted:

(i) In raking bonds, the courses are inclined.

(ii) The raking or inclination should be in opposite direction in alternate courses of the raking bond.

(iii) The successive courses of the raking bonds should not be provided. Generally, a course with raking bond is provided at regular interval of four to eight courses in the height of a wall.

In this bond, the bricks are laid as headers and stretchers in alternate courses in such a way that the headers are laid on bed and the stretchers are laid on edge. This bond is also referred to as the silvercock's bond.

Qu5. The portion of bricks cut across the width in half is called

a) Half split

b) Half closer

c) Half bed

d) Half bat

Qu6. What should be placed at the beginning of every header course in English bond to avoid vertical joint?

a) Queen closer

b) Half bat

c) Three fourth bat

d) King closer

Qu7. The bricks used for corners of walls of a structure are called

a) Spalls

b) Quoins

c) Hearting

d) Side

TEST YOUR SELF

Qu8. Which bond comprises of one course of a header to three or five courses of stretchers?

a) Dutch bond

b) Zig-zag bond

c) English garden-wall bond

d) Facing bond

CHAPTER – 17

STONE MASONRY

In a very strict sense, the term masonry is used to indicate the art of building the structures in stones. But broadly speaking, the term masonry is used to indicate the art of building the structures in either stones or bricks. The former type is called the stone masonry and the latter type is called the brick masonry.

It is to be noted that the masonry work by itself is one of the most important traditional technology. Even though new principles of construction and new materials of construction are adopted in the building construction processes, the masonry has got as such the highest importance in the building industry.

The masonry is used for the construction of foundations, walls, columns and other similar components of a structure. The basic advantage of the masonry for the load bearing structures is that it performs a variety of functions like:

(i) Affording architectural effect,

(ii) Granting fire and weather protection,

(iii) Providing acoustic and thermal insulation,

(iv) Subdividing space,

(v) Supporting loads, etc.

MATERIALS REQUIRED FOR STONE MASONRY

For stone masonry, the following two materials are required:

(i) Stones

(ii) Mortar

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Test Series Available..

Total weekly test : 35

Total mid subject test : 16

Total full length test : 13

Mock test : 16

Total test : 80

Corbel

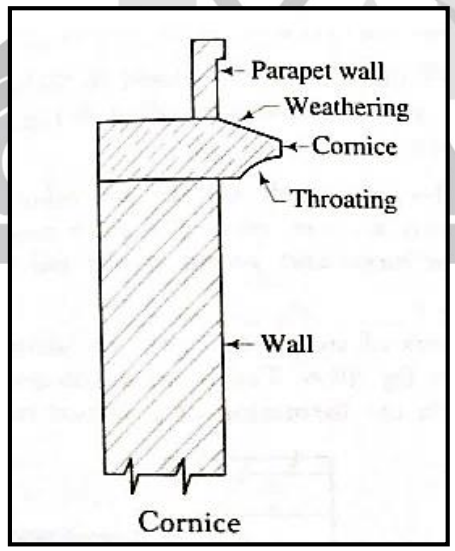
A corbel is a projecting stone which is usually provided to serve as support for roof truss, beam, weather shed, etc. The corbels are generally moulded and given ornamental treatment. The corbels should extend at least two-third of their length into the wall.

Course

A layer of stones or bricks is known as a course and its thickness is generally equal to the thickness of a stone or a brick plus the thickness of one mortar joint.

Cornice

A cornice is a course of stone provided at the top of wall. It is generally moulded and given ornamental treatment. It is weathered and throated to dispose off rain water. In order to prevent the overturning of the cornice, sufficient bearing and extra weight at the top in the form of a parapet wall should be provided.



Coping

A coping is a course of stone which is laid at the top wall so as to protect the wall from rain water. This course is generally provided at the top of a compound wall or a parapet wall and it is suitably weathered and throated. Sometimes the term coping is used to refer to cutting of the stones by means of feathers, plugs and wedges.

Spalls

The chips of stones used to fill up the empty spaces in the stone masonry are known as the spalls or snecks. They are obtained as a result of reducing big blocks of stones into the regular stone blocks.

Quoins

The external corners or angles of a wall surface are called the quoins and the stones or bricks forming the quoins are known as the quoin stones or quoin bricks. The quoin stones are selected from large and sound stones and their beds are properly dressed.

Bond

A bond is an arrangement of layers of stones or bricks by which no continuous vertical joints are formed. The bond distributes the load coming on the structure evenly and prevents the formation of a vertical crack.

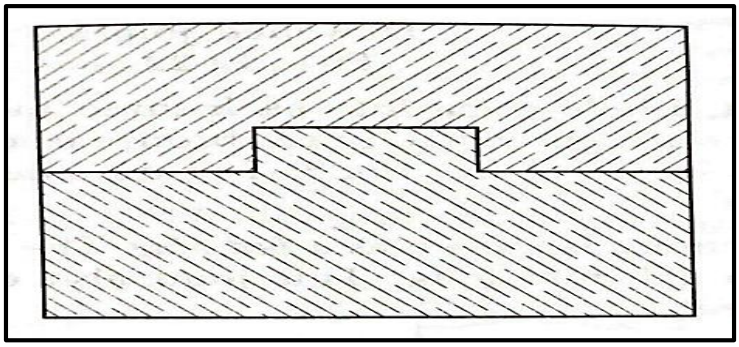
JOINTS IN STONE MASONRY

In order to secure the stones firmly with each other, the following joints are provided:

(1) Butt or square joint
(2) Rebated or lapped joint
(3) Tongued and grooved joint
(4) Tabled joint
(5) Saddled or water joint
(6) Rusticated joint
(7) Plugged joint
(8) Dowelled joint
(9) Cramped joint

Butt or Square Joint

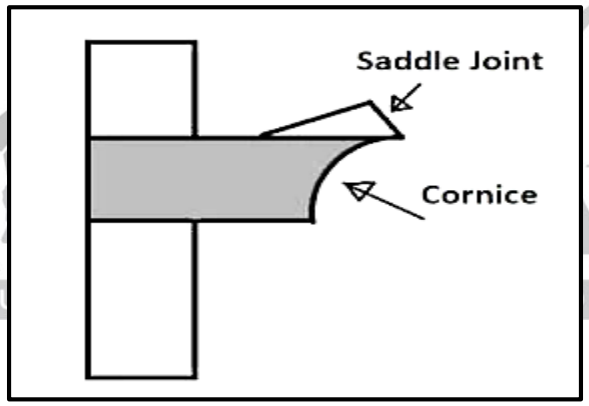
In this type of joint, the square surface of one stone is placed against that of another as shown in fig. This is the most common joint and is extensively used for ordinary work.



Saddled or Water Joint

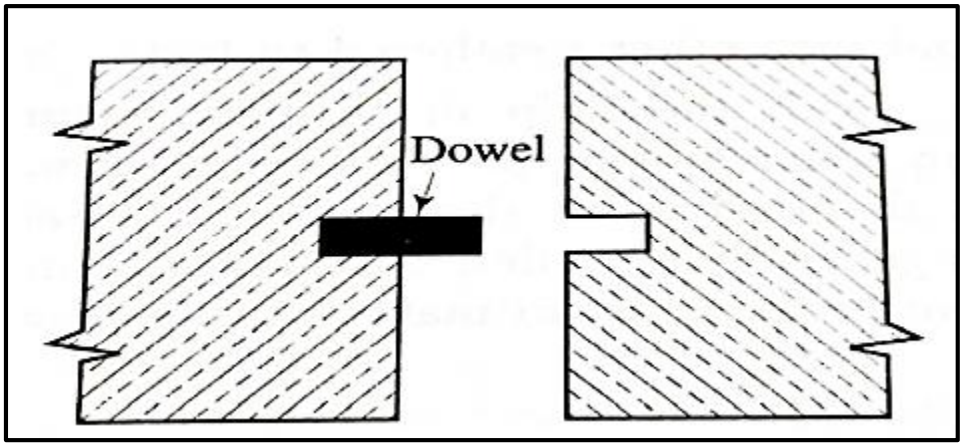
In this type of joint, the stone is rounded off as shown in fig. This type of joint is provided to protect the joints of the cornices and such other weathered surfaces.

With the help of this arrangement, any water moving on the weathered surface is diverted from the joints. The saddle is generally bevelled backwards from the front edge so as to make it inconspicuous.



Rusticated Joint

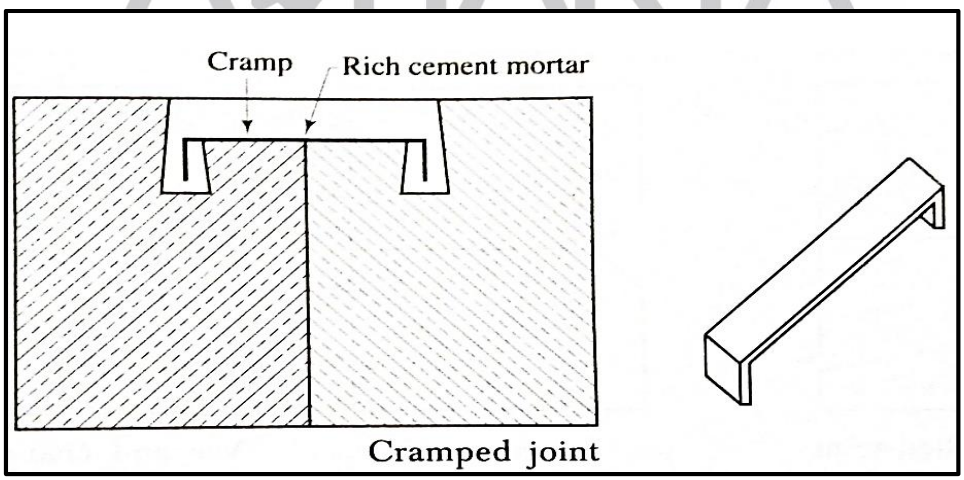
Sometimes the margins or edges of stones used for plinth, quoin, outer walls of lower storeys, etc., are sunk below the general level. The term rusticated is used to indicate such masonry. The three forms of rusticated joints are shown in fig. The channelled joint is more common. In this joint, the sinking is made on the lower joint so as to avoid the possibility of entry of water through the mortar joints.



Cramped Joint

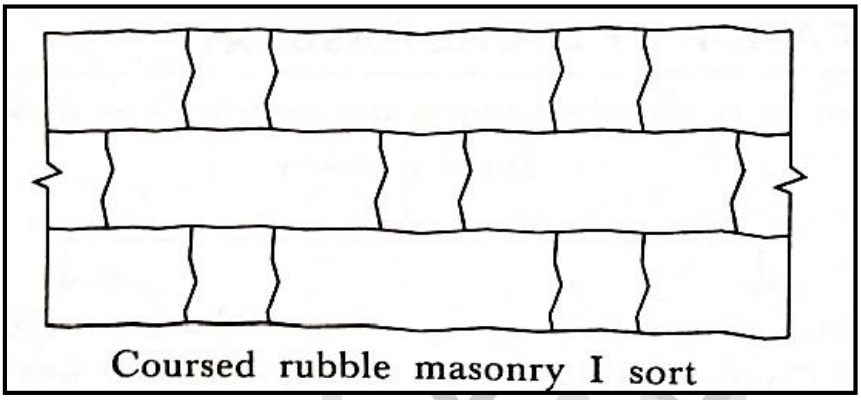
In this type of joint, the cramps are used instead of dowels. The cramps are the pieces of non- corrosive metals such as gunmetal, copper, etc. and their ends are turned down to a depth of about 40 mm to 50 mm. The length, width and thickness of the cramps vary from 200 mm to 300 mm, 25 mm to 50 mm and 5 mm to 10 mm respectively. The holes made on the stones should be of dovetail shape as shown in fig.

It prevents the tendency of the joint to be pulled apart. The cramps are placed in position, grouted and covered with cement, lead or asphalt. A typing cramp is also shown in fig.



is then carried out in courses such that the stones in a particular course are of equal heights. This type of masonry is used for the construction of public buildings, residential buildings, etc. The coursed rubble masonry is further divided into three categories:

(a) **Coursed rubble masonry I sort :** In this type, the stones of the same heights are used and the courses are also of the same heights. The face stones are dressed by means of a hammer and the bushings do not project by more than 40 mm. The thickness of mortar joint does not exceed 10 mm.


Coursed rubble masonry I sort

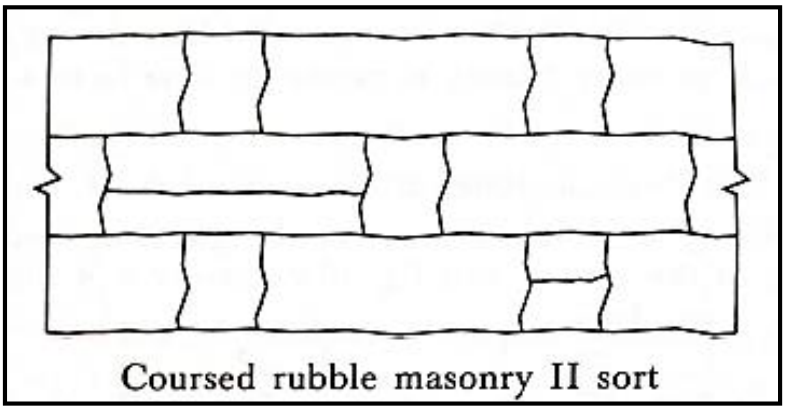
(b) **Coursed rubble masonry II sort :** It is similar to I sort except the following:

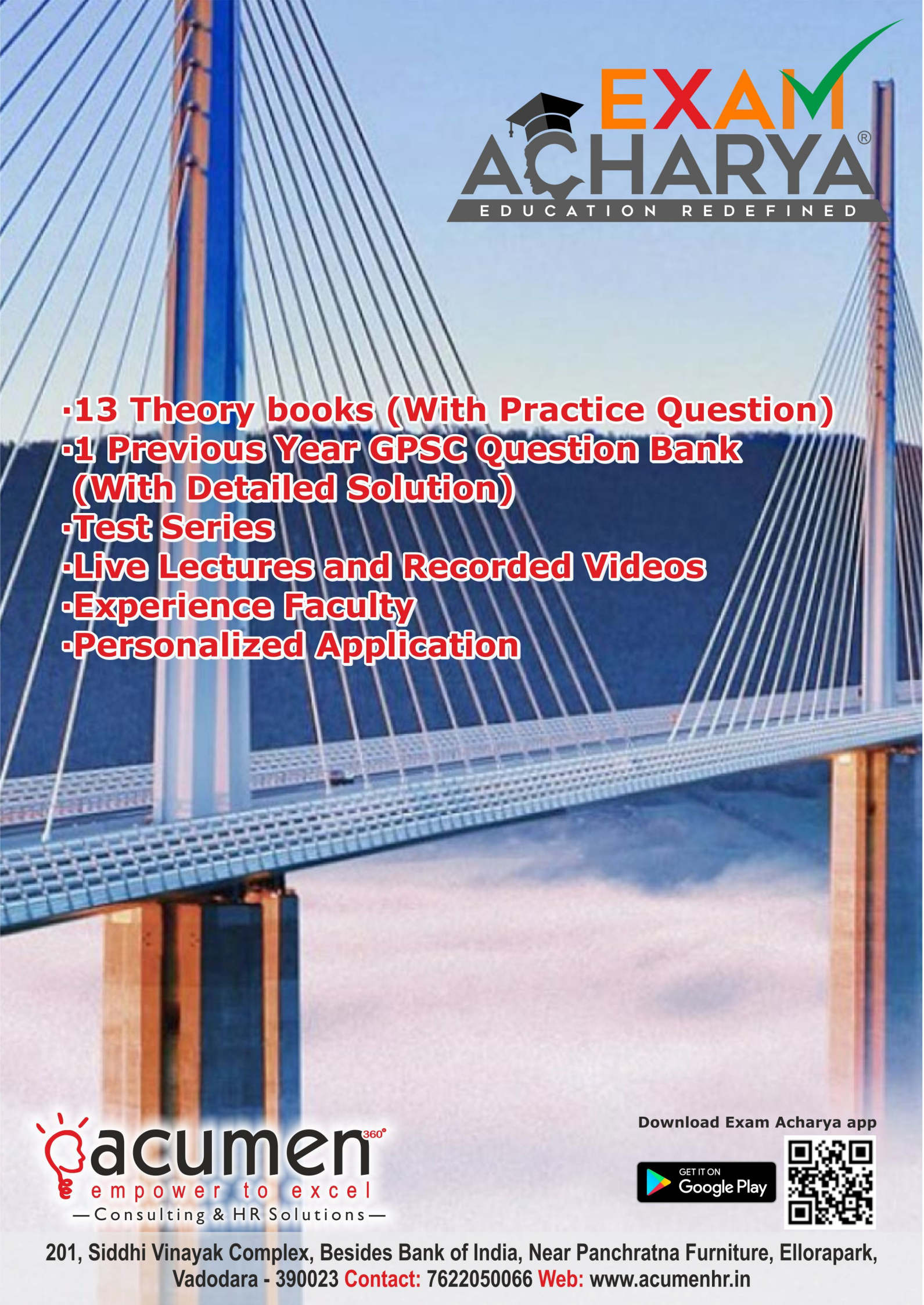
(i) The stones of be used are of different heights.

(ii) The courses need not be of equal heights.

(iii) Only two stones are to be used to make up the height of one course.

(iv) The thickness of the mortar joints is 12mm.


Coursed rubble masonry II sort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