COURSE OBJECTIVE

To study the construction material used in civil engineering with the properties.

UNIT 2  LIME CEMENT AGGREGATES MORTAR STEEL


LIME

Limestone (calcium carbonate)

Burnt in a kiln

loses carbon dioxide and becomes quicklime (calcium oxide)

Contact with water

Producing great heat, to form slaked lime (calcium hydroxide), also called lime putty.

This gradually takes up carbon dioxide again from the air and changes back to calcium carbonate.

This ‘setting’ is called carbonation.

Lime putty mixed with sand makes mortar. This then hardens into an artificial stone made up of grains of sand embedded in a mass of calcium carbonate.

TYPES OF LIME

Lime used shall conform to IS: 712-1984 Building limes are classified as follows:
Class A: Eminently hydraulic lime used for structural purposes.
Class B: Semi hydraulic lime used for masonry mortars.
Class C: Fat Lime used for finishing coat in plastering, white washing etc. and addition of Pozzolanic material for Masonry Mortar.
Class D: Magnesium lime used for finishing coat in plastering, white washing etc.
Class E: Kankar lime used for masonry mortars.
Class F: Siliceous dolomite lime is used generally for under coat and finishing coat of plaster.

Quick Lime: Quick Lime shall be supplied in the form of lumps and not in powder. Soon after delivery, lump lime shall be separated from powder and all under burnt/over burnt lumps and the powder removed. Quick lime shall not be used directly in the work and shall invariably be slaked and converted to lime putty before use.

Hydrated Lime: Hydrated lime shall be in the form of a fine dry powder. It shall be supplied in suitable containers such as jute bags lined with waterproof membrane. The bags shall bear marking indicating the class of lime net weight, date of manufacture and the brand name. It shall be used within 4 months of its date of manufacture.

**PREPARATION OF LIME MORTAR**

**Lime Mortar**

Lime mortar shall be prepared using lime putty obtained by slaking quick-lime or dry hydrated lime powder and sand with or without the addition of pozzolana in the specified proportions.

**Slaking of Lime**

If lime is supplied in the form of quick lime, it shall be slaked and run into putty, if necessary, in accordance with IS: 1635-1975.

**Mixing of Lime Mortars**

- Putty and sand in the specified proportions shall be mixed with or without addition of water on a dry waterproof platform or in a mixer.
- The mix shall then be fed into a mortar mill with the required addition of water.
- The mortar shall be raked continuously during grinding, particularly in the angular edges of the mortar mill.
- Water may be added during grinding as required, but care shall be taken not to add more water than to bring the material to the working consistency.
- The mixing shall be done till every particle of the aggregate is coated uniformly with the cementation material.

Dry hydrated lime and sand in specified proportions shall be mixed dry first and shall then be fed into a mortar mill with required additions of water.

Generally, only as much quantity of lime mortar (except made with Class A lime) as would be sufficient for day’s work shall be mixed at a time. If eminently hydraulic lime (Class A) is present as an ingredient, the mortar shall be used within 4 hours after grinding.

**CEMENT**

- Most important material in building construction
- Term “cement” means Portland Cement
“cement” refers to the natural manufactured form limestone and clay and made available in powder form, which when mixed with water can set to a hard durable mass over under water

**INGREDIENTS (Main Constituents in cement that gives cementing properties)**

(a) Dicalcium silicate \(2\text{CaO} \text{SiO}_2\) (denoted as \(\text{C}_2\text{S}\))
(b) Tricalcium silicate \(3\text{CaO} \text{SiO}_2\) (denoted as \(\text{C}_3\text{S}\))
(c) Tricalcium Aluminate \(3\text{CaOAl}_2\text{O}_3\) (denoted as \(\text{C}_3\text{A}\))
(d) Tetracalcium aluminium Ferrite \(4\text{CaOAl}_2\text{O}_3\text{Fe}_2\text{O}_3\) (denoted as \(\text{C}_4\text{AF}\))

**Cement Ingredients**

- Lime (\(\text{CaO}\))
- Silica (\(\text{SiO}_2\))
- Alumina (\(\text{Al}_2\text{O}_3\))
- Calcium sulphate (\(\text{CaSO}_4\))
- Iron oxide (\(\text{Fe}_2\text{O}_3\))
- Magnesia (\(\text{MgO}\))
- Sulphur (\(\text{S}\))
- Alkalies

**Composition of Ordinary Cement**

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Percent</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lime ((\text{CaO}))</td>
<td>62</td>
<td>62 – 67</td>
</tr>
<tr>
<td>Silica ((\text{SiO}_2))</td>
<td>22</td>
<td>17 – 25</td>
</tr>
<tr>
<td>Alumina ((\text{Al}_2\text{O}_3))</td>
<td>5</td>
<td>3 – 8</td>
</tr>
<tr>
<td>Calcium sulphate ((\text{CaSO}_4))</td>
<td>4</td>
<td>3 – 4</td>
</tr>
<tr>
<td>Iron oxide ((\text{Fe}_2\text{O}_3))</td>
<td>3</td>
<td>3 – 4</td>
</tr>
<tr>
<td>Magnesia ((\text{MgO}))</td>
<td>2</td>
<td>1 – 3</td>
</tr>
<tr>
<td>Sulphur ((\text{S}))</td>
<td>1</td>
<td>1 – 3</td>
</tr>
<tr>
<td>Alkalies</td>
<td>1</td>
<td>0.2 – 1</td>
</tr>
</tbody>
</table>

**MANUFACTURE OF ORDINARY CEMENT**
It involves the following steps

- Mixing of raw material
- Burning
- Grinding
- Storage and packaging

**MIXING OF RAW MATERIAL**

**Dry process**

1. The raw materials are reduced in size of about 25mm in crushers.
2. A current of dry air is then passed over these dried materials
3. These dried materials are then pulverized into fine power in ball mills and tube mills.
4. All these operations are done separately for each raw material and they are stored in hoppers.
5. They are then mixed in correct proportions and made ready for the feed of rotary kiln.
6. This finely ground powder of raw materials is known as the raw mix and it is stored in storage tank

**Widely used at present because of the following reasons:**

- Competition
- Power
- Quality of cement
- Technology

**PROCEDURE OF MANUFACTURE OF CEMENT BY THE DRY PROCESS**

(a) The boulders up to 1.2 m size are transported in huge dumpers up to 300KN capacity and dumped into the hopper of the crusher
(b) The crushed limestone now of 75mm size is moved from the crushed by a series of conveyors for stacking.
(c) The argillaceous or clay materials found in the quarry are also dumped into the crusher and stacked along with the limestone.
(d) The crushed materials are checked for calcium carbonate, lime alumina, ferrous oxide and silica contents.
(e) The additive material and crushed limestone are conveyed to the storage hoppers.
(f) The materials are ground to the desired fineness in the raw mill.
(g) The material is dropped merely by gravity from the blending to the storage silo thereby conserving power.
(h) The material from the bottom of the preheater is fed to the rotary kiln.
PROCEDURE OF MANUFACTURE OF CEMENT BY THE WET PROCESS

(a) In this process, the calcareous materials such as limestone are crushed and stored in silos or storage tanks.
(b) The argillaceous materials such as clay is thoroughly mixed with water in a container known as the wash mill and this washed clay is stored in basins.
(c) The crushed limestone from silos and wet clay form basins are allowed to fall in a channel in correct proportions.
(d) This channel leads the materials to grinding mills where they are brought into intimate contact to form what is known as the slurry.
(e) The grinding is carried out either in ball mill or tube mill or both.
(f) The slurry is led to correcting basin where it is constantly stirred.
(g) At this stage the chemical composition is adjusted as necessary.
(h) The corrected slurry is stored in storage tanks and kept ready to serve as feed for rotary kiln.
FLOW DIAGRAM OF WET PROCESS

Calcareous Materials Lime Stone / Argillaceous Materials Clay

Crusher/Wash mill

Storage basin(Silos)

Channel

Wet grinding mill (Ball mill ) to make slurry

Blending of slurry to correct composition

Storage of corrected slurry

Fuel fed from lower end

(Coal, oil or natural gas)

Corrected slurry fed to rotary Kiln (from upper end)

Slurry converted to Clinkers

Addition of 2 to 3% of gypsum

Clinkers are ground in Ball mill

Cement silos

Packing plant

BURNING

A rotary kiln is formed of steel tubes and the diameter varies from 2.50m to 3.0m
Lengths vary for 90m to 120m. Laid at a gradient of about 1 in 25 to 1 in 30.
The kiln is supported at intervals by columns of masonry or concrete.
The refractory lining is provided on the inside surface of rotary kiln. It is so arranged that the kiln rotates at about one to three revolutions per minute about its longitudinal axis.
The corrected slurry is injected at the upper end of kiln. The hot gases or flames are forced through the lower end of kiln.
Dry zone  The portion of the kiln near its upper end is known as the dry zone. And in this zone, the water of slurry is evaporated. As the slurry gradually descends there is rise in temperature and in the next section of kiln, the carbon dioxide form slurry is evaporated. The small lumps, known as the nodules are formed at this stage. These nodules then gradually roll down passing through zones of rising temperature and ultimately reach to the burning zone where e temperature is about 1400° C to 1500° C
Burning zone  Calcined product is formed and nodules are converted into small hard dark greenish blue balls which are known as the clinkers.
GRINDING

The clinkers as obtained from the rotary kiln are finely ground in ball mills and tube mills. During grinding, a small quantity, about 3 to 4 percent of gypsum is added. Gypsum controls the initial setting time of cement (gypsum acts as a retarder and it delays the setting action of cement)

The grinding of clinkers in modern plants is carried out in the cement mill which contains chromium steel balls of various sizes. These balls roll within the mill and grind the mixture which is collected in a hopper and taken in the bucket elevator for storage in silos. The cement from silos is fed to the packer machines and stored in a dry place.

FLOW DIAGRAM OF BURNING AND GRINDING OPERATION OF CEMENT

PACKING OF CEMENT... Plastic and paper bags are more suitable of protecting the cement from moisture. Largely packed in 50 kg.
### TYPES OF CEMENT AND RESPECTIVE INDIAN STANDARDS

<table>
<thead>
<tr>
<th>Sl. NO</th>
<th>Types of Cement</th>
<th>Reference Indian</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ordinary Portland Cement 33 Grade</td>
<td>IS: 269</td>
</tr>
<tr>
<td>2</td>
<td>Ordinary Portland Cement 43 Grade</td>
<td>IS: 8112</td>
</tr>
<tr>
<td>3</td>
<td>Ordinary Portland Cement 53 Grade</td>
<td>IS: 12269</td>
</tr>
<tr>
<td>4</td>
<td>Rapid Hardening Cement</td>
<td>IS: 8041</td>
</tr>
<tr>
<td>5</td>
<td>Extra Rapid Hardening Cement</td>
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<tr>
<td>6</td>
<td>Sulphate Resisting Cement</td>
<td>IS: 12330</td>
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<tr>
<td>7</td>
<td>Portland Slag Cement</td>
<td>IS: 455</td>
</tr>
<tr>
<td>8</td>
<td>Quick Setting Cement</td>
<td>-</td>
</tr>
<tr>
<td>9</td>
<td>Super Sulphated Cement</td>
<td>IS: 6909</td>
</tr>
<tr>
<td>10</td>
<td>Low Heat Cement</td>
<td>IS: 12600</td>
</tr>
<tr>
<td>11</td>
<td>Portland Pozzolana Cement (Calcined based)</td>
<td>IS: 1489P-1</td>
</tr>
<tr>
<td>12</td>
<td>Portland Pozzolana Cement (Calcined based)</td>
<td>IS: 1489P-2</td>
</tr>
<tr>
<td>13</td>
<td>Air Entraining Cement</td>
<td>-</td>
</tr>
<tr>
<td>14</td>
<td>Coloured Cement: White Cement</td>
<td>IS: 8042</td>
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<tr>
<td>15</td>
<td>Hydrophobic Cement</td>
<td>IS: 8043</td>
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<td>16</td>
<td>Masonry Cement</td>
<td>IS: 3466</td>
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<tr>
<td>17</td>
<td>Expansive Cement</td>
<td>-</td>
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<tr>
<td>18</td>
<td>Oil Well Cement</td>
<td>IS: 8229</td>
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<tr>
<td>19</td>
<td>Rediset Cement</td>
<td>-</td>
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<tr>
<td>20</td>
<td>Concrete Sleeper Grade Cement</td>
<td>IRS-R 40</td>
</tr>
<tr>
<td>21</td>
<td>High Alumina Cement</td>
<td>IS: 6452</td>
</tr>
</tbody>
</table>

### Grade of Cement

- **Grade 33** --as per IS-269 (1989) designated at C-33
- **Grade 43** --as per IS-8112 (1989) designated at C-43
- **Grade 53** --as per IS-2269 (1989) designated at C-53
Sleeper cement as per IRS- T40-85 (this will be between C43 and C53) supplied only to railways.

**Properties of cement**

**Physical properties**
- Depend upon its chemical composition, thoroughness of burning ad fineness of grinding
- Gives strength to the masonry
- An excellent binding material
- Easily workable
- Offers good resistance to the moisture
- Possesses a good plasticity
- Stiffens or hardens early
- A thin paste of cement with water should feel sticky between the fingers.
- A cement thrown in water should sink and should not float on the surface

**Mechanical properties**
- The compressive strength at the end of 3 days should not be less than 11.5 N/mm² and that at the end of 7 day should not be less than 17.5N/mm².
- The tensile strength at the end of 3 days should not be less than 2N/mm² and that at the end of 7 days should not be less than 2.50N/mm².

**Chemical properties**
- The ratio of percentage of alumina to iron oxide should not be less than 0.66
- The ratio of percentage of lime to alumina, iron oxide and silica, known as Lime Saturation Factor (LSF) should not be less than 0.66 and should not be more than 1.02.
- Total loss of ignition should not be more than 4 per cent.
- Total sulphur content should not be more than 4 per cent.
- Weight of insoluble residue should not be more than 1.50 per cent.
- Weight of magnesia should not exceed 5%

**Mortar**

Paste prepared by adding required quantity of water to a mixture of binding material like cement or lime and fine aggregate like sand.
**Classification of mortars**

Based on

- Bulk density
- Kind of binding material
- Nature of application
- Special mortars

**PROPERTIES OF CEMENT MORTARS**

- Capable of developing good adhesion with the building units such as bricks, stones etc.
- Capable of developing the designed stresses
- Capable of resisting penetration of rain water
- Should be cheap
- Should be durable
- Should be easily workable
- Should not affect the durability of materials with which it comes into contact
- Should set quickly so that speed in construction may be achieved
- Joints formed by mortar should not develop cracks and they should be able to maintain their appearance for a sufficiently long period.

**HYDRATION**

- The reaction of cement with water is exothermic
- The reaction liberates a considerable quantity of heat.
- This liberation of heat is called Heat of Hydration.
- Study and control of the heat of hydration becomes important in the construction of concrete dams and other mass concrete constructions.
- Different compounds hydrate at different rates and liberate different quantities of heat.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Heat of hydration at the given age (cal/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3 Days</td>
</tr>
<tr>
<td>C_3S</td>
<td>58</td>
</tr>
<tr>
<td>C_2S</td>
<td>12</td>
</tr>
<tr>
<td>C_3A</td>
<td>212</td>
</tr>
<tr>
<td>C_4AF</td>
<td>69</td>
</tr>
</tbody>
</table>

Heat of hydration of cement is an additive property \(H\)

\[ H = aA + bB + cC + dD \]

Where, A, B, C, and D are the percentage contents of C_3S, C_2S, C_3A and C_4AF. And a, b, c and d are coefficients representing the contribution of 1% of the corresponding compound to the heat of hydration.
COMPRESSIVE STRENGTH (CEMENT MORTAR)

- Compressive strength is the basic data required for mix design.
- By this test, the quality and the quantity of concrete can be controlled and the degree of adulteration can be checked.
- The test specimens are 70.6 mm cubes having face area of about 5000 sq. mm.
- Large size specimen cubes cannot be made since cement shrinks and cracks may develop.
- The temperature of water and test room should be 27°± 2°C.
- A mixture of cement and standard sand in the proportion 1:3 by weight is mixed dry with a trowel for one minute and then with water until the mixture is of uniform colour.
- Three specimen cubes are prepared. The material for each cube is mixed separately.
- The quantities of cement, standard sand and water are 185 g, 555 g and \((P/4) + 3.5\), respectively where P = percentage of water required to produce a paste of standard consistency.
- The 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.
- The 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.
- Compressive strength is taken to be the average of the results of the three cubes.
- The load is applied starting from zero at a rate of 35 N/sq mm/minute.
- The 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/mm².

<table>
<thead>
<tr>
<th>Material</th>
<th>Compressive strength (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>14 days</td>
</tr>
<tr>
<td>Fat lime class</td>
<td>-</td>
</tr>
<tr>
<td>Class A</td>
<td>1.75</td>
</tr>
<tr>
<td>Class B</td>
<td>1.25</td>
</tr>
<tr>
<td>Cement 33 grade</td>
<td>22.0</td>
</tr>
</tbody>
</table>
TENSILE STRENGTH

- Generally used for the rapid hardening cement

Following Procedure is adopted:

- Mortar is prepared in 1:3 proportions and the quantity of water is 8% by weight of cement and sand and placed in briquette moulds.
- The mould is filled with mortar and then a small heap of mortar is formed at its top.
- It is beaten down by a standard spatula till water appears on the surface.
- Twelve standard briquettes are prepared by following same procedure and the quantity of cement may be 600 gm for 12 briquettes.
- The briquettes are kept in a damp cabin for 24 hours and after 24 hours the briquettes are carefully remove from the moulds and they are submerged in clean water for curing.
- The briquettes are tested in testing machine at the end of 3 days and 7 days.
- Six briquettes are tested in each test and average is found out.
- During the test the load is to be applied uniformly at the rate of 35Kg/Cm² or 3.50N/mm².
- The cross-sectional area of briquette at its least section is 6.45cm².

$$\text{Ultimate tensile stress} = \frac{\text{Failing load}}{6.45}$$

- The tensile stress at the end of 3 days should not be less than 20Kg/Cm² or 2 N/mm².
- And that at the end of 7 days should not be less than 25Kg/Cm² or 2.50 N/mm².
**FINENESS**

- Test is carried out to check proper grinding of cement.
- The fineness of cement particles may be determined by either by sieve test or by permeability apparatus test.
- In sieve test, the cement weighing 100 gm is taken and it is continuously passed for 15 minutes through standard BIS sieve no.9 and residue is then weighed and this weight should not be more than 10% of original weight.
- In permeability apparatus test. Specific surface area of cement particles is calculated. This test is better than sieve test and it gives an idea of uniformity of fineness. The specific surface acts as a measure of the frequency of particles of average size. The specific surface of cement should not be less than 2250 cm²/gm.

**SOUNDNESS**

**Purpose of the test**  
To detect the presence of uncombined lime in cement.

This test is performed with the help of Le Chatelier apparatus as shown in figure below

![Diagram of Le Chatelier apparatus](image)

It consists of a brass mould of diameter 30mm and height 30mm. There is a split in mould and it does not exceed 0.50mm. On either side of split, there are two indicators with pointed ends. The thickness of mould cylinder is 0.50mm.

**Procedure:**

i. The cement paste is prepared. The percentage of water is taken as determined in the consistency test.
ii. The mould is placed on a glass plate and it is filled by cement paste.
iii. A small weight is placed at top and the whole assembly is submerged in water for 24 hours. The temperature of water should be between 24°C to 35°C.
iv. The distance between the points of indicator is noted the mould is again placed in water and heat is applied in such a way that boiling point of water is reached in about 30 minutes. The boiling of water is continued for one hour.
v. The mould is removed from water and it is allowed to cool down.
vi. The distance between the points of indicator is again measured.
vii. The difference between the two readings indicates the expansion of cement and it should not exceed 10mm.

CONSISTENCY

Purpose – to determine the percentage of water required for preparing cement pastes for other tests.

Procedure:

I. Take 300gm of cement and add 30% by weight or 90 gm of water to it.
II. Mix water and cement on a non-porous surface. The mixing should be done thoroughly.
III. Fill the mould of Vicat apparatus. The interval between the addition of water to the commencement of filling the mould is known as the time of gauging and it should be $3\frac{3}{4}$ to $4\frac{1}{2}$ minutes.

IV. The vicat apparatus is shown in figure above and it consist of a frame to which is attached a movable rod weighing 300 grams and having diameter and length as 10mm and 50 respectively. And indicator is attached to the movable rod. This indicator moves on vertical scale and it gives the penetration. The vicat mould is in the form of a cylinder and it can be split into two halves. The vicat mould placed on non-porous plate. There are there attachment- square needle, plunger and needle with angular collar. The square needle is used for initial setting time test, the plunger is
used for consistency test and the needle with annular collar is used for final setting time test.

V. The plunger is attached to the movable rod of vicat apparatus. The plunger gently lowered on the paste in the mould.

VI. The settlement of plunger is noted. If the penetration is between 5mm to 7mm from the bottom of the mould, the water added is correct. If the penetration is not proper, the process is repeated with different percentage of water till the desired penetration is obtained.

**SETTING TIME**

This test is used to detect the deterioration of cement due to storage. It may be noted that this is purely a conventional type of test and it has got no relation with the setting or hardening of actual concrete. The test is carried out to find out initial setting time and final setting time.

**Initial setting time:**

(A) The cement weighing 300 gms is taken and its mixed with percentage of water as determined in consistency test.

(B) The cement past is filled in the vicat mould.

(C) Square needle of cross section 1mm * 1mm is attached to the moving rod of the vicat apparatus.

(D) The needle is quickly released and it is allowed penetrate the cement past. In the beginning, the needle penetrate completely. It is then taken out and dropped at a fresh place. The procedure is repeated regular intervals till the needle does not penetrate completely. The needle should penetrate upto 5mm measured from the bottom.

(E) The initial setting time is interval between the addition of the water to the cement and the stage when needle ceased to penetrate completely. This time about 30 minutes of the ordinary cement.

**Final setting time:**

(a) The cement paste is prepared as about and it is filled in the vicat mould.

(b) The needle with annular collar is attached to the moving rod of the vicat apparatus. This needle has a sharp point projecting in the centre with annular collar.

(c) The needle is gently released. The time at which the needle makes an impression on test block and the collar fails to do so is noted.

(d) Final setting time is the difference between the time at which water was added to the cement and time as recorded in (c). This time should be about 10 hours for ordinary cement.

**AGGREGATES**

Aggregates are the important constituents in concrete. They give body to the concrete, reduce shrinkage and effect economy. Aggregates can be classified as

1. Normal weight aggregates
2. Light weight aggregates
3. Heavy weight aggregates
Normal weight aggregates can be further classified as natural aggregate and artificial aggregates.

<table>
<thead>
<tr>
<th>Natural</th>
<th>Artificial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand, Gravel, Granite</td>
<td>Broken brick, Air-cooled slag</td>
</tr>
<tr>
<td>Quartzite, Basalt, Sandstone</td>
<td></td>
</tr>
</tbody>
</table>

Aggregates can be classified based on the size of aggregate as coarse aggregate and fine aggregate.

**NATURAL STONE AGGREGATES**

All natural aggregate materials originate from bed rocks. There are three kinds of rock namely igneous, sedimentary and metamorphic. These classifications are based on the mode of formation of rocks. Igneous rocks are formed by the cooling of molten magma at the surface of the crest. The sedimentary rocks are formed originally below the sea-bed and subsequently lifted up. Metamorphic rocks are either igneous or sedimentary rocks which are metamorphed due to extreme heat and pressure.

Most igneous rocks make satisfactory concrete aggregates because they are hard, tough and dense. The sedimentary rocks with the stratified structure are quarried and concrete aggregates are derived from it. Metamorphic rocks show foliated structure. Many metamorphic rocks such as quartzite and gneiss have been used for production of good concrete aggregate.

**CRUSHING STRENGTH**

The aggregate crushing value gives a relative measure of the resistance of an aggregate to crushing under a gradually applied compressive load. The aggregate crushing value should not be more than 45% for aggregate used for concrete other than for wearing surfaces and 30% for concrete used for wearing surfaces such as runways, roads and airfield pavements.

The standard aggregate crushing test is made on aggregate passing a 12.5mm sieve I.S Sieve and retained on 10mm I.S Sieve. About 6.5kg of the sample is taken. The aggregate is filled into the cylindrical measure in three layers of equal depth. Each layer is tamped 25 times with the tamping rod and leveled off. The weight of the sample contained in the cylinder is taken.(A). The apparatus with the test sample is placed on the compression testing machine and is loaded uniformly upto a total load of 10 tons. The load is then released and the whole material removed from the cylinder and sieved on a 2.36mm I.S Sieve. The fraction passing the sieve is weighed(B).

\[
\text{Aggregate crushing value} = \left( \frac{B}{A} \right) \times 100
\]

B = weight of fraction passing 2.36mm I.S sieve
A = weight of surface dried sample.

**IMPACT STRENGTH**
The aggregate impact value gives relative measure of the resistance of an aggregate to sudden shock or impact. The aggregate impact value should not be more than 45% by weight for aggregates used for concrete other than wearing surfaces and 30% by weight for concrete to be used as wearing surfaces such as runways, roads and pavements.

The test sample consists of aggregate passing through 12.5mm and retained on 10mm I.S Sieve. The aggregate shall be dried in an oven and cooled. The aggregate is filled about one-third full and tamped with 25 strokes by the tamping rod. A similar quantity is added and tamped in the standard manner. The measure is filled to overflowing and struck off level. The net weight of the aggregate is determined (weight A). The whole sample is filled into a cylindrical steel cup fixed on the base of the machine. A hammer is raised to a height of 380mm above the upper surface of aggregate and allowed to fall freely on the aggregate. The sample is subjected to 15 blows and the crushed aggregate is removed from the cup. It is sieved on 2.36mm sieve and the fraction passing the sieve is weighed. (weight B).

Aggregate impact value = \( \frac{B}{A} \times 100 \).

**FLAKINESS INDEX**

It is the percentage by weight of particles in it whose least dimension is less than \( \frac{3}{5} \) of their mean dimension. The Flakiness index is not applicable to sizes smaller than 6.3 mm.

The test is conducted by using a metal thickness guage. A sufficient quantity of aggregate is taken such that a minimum number of 200 pieces of any fraction can be tested. Each fraction is gauged in turn for thickness on the metal guage. The total amount passing in the guage is weighed. The flakiness index is the total weight of the material passing the various thickness gauges expressed as a percentage of the total weight of the sample taken.

**ELONGATION INDEX**

It is the percentage by weight of particles, whose greatest dimension is greater than 1.8 times their mean dimension. The elongation index is not applicable to sizes smaller than 6.3 mm. The test is conducted by using a metal length guage. A sufficient quantity of aggregate is taken such that a minimum number of 200 pieces of any fraction can be tested. Each fraction is gauged individually for length on the metal guage. The total amount retained by the guage is weighed. The elongation index is the total weight of the material retained on the various length gauges expressed as a percentage of the total weight of the sample gauged.

**ABRASION RESISTANCE**

Three tests are in common use to test aggregate for its abrasion resistance. They are Dorry Abrasion test, Deval Attrition test, Los Angels test. Aggregates which are used for road constructions and pavement construction are tested with respect to its resistance to wear. In Deval Attrition test, particles are subjected to wear in an iron cylinder. The proportion of material crushed finer than 1.7mm size is expressed as a percentage of the original material taken. this percentage is the attrition value of aggregate.
In Dorry Abrasion test a cylindrical specimen is subjected to abrasion against rotating metal disc sprinkled with quartz sand. The loss in weight of the cylinder after 1000 revolutions of the table is determined.

Los Angeles test involves taking specified quantity of material along with specified number of abrasive charge in a standard cylinder and revolving it for specified revolutions. The particles smaller than 1.7mm sizes are separated out. The loss in weight gives the abrasion value of the aggregate.

**MORTAR**

Mortar is a paste prepared by adding required quantity of water to a mixture of binding material and fine aggregate. The binding material like cement or lime is referred as matrix and the fine aggregate like sand is referred as the adulterant. The matrix binds the particles of the adulterant and the durability, quality and strength of mortar depend on the quantity and quality of matrix.

**CLASSIFICATION OF MORTAR**

Mortars are classified based on the following:
1. Bulk density
2. Kind of binding material
3. Nature of application
4. Special mortars

Based on bulk density, mortar is classified into heavy mortars and light weight mortars. Mortars having a bulk density of 15 KN/m$^3$ or more are heavy mortars and that having a bulk density less than 15KN/m$^3$ are light weight mortars.

Based on the kind of binding material, mortar is classified into lime mortar, surkhi mortar, cement mortar, gauged mortar, gypsum mortar. In lime mortar, lime is used as the binding material. The lime may be fat lime or hydraulic lime. The fat lime shrinks to a great extent and hence it requires about 2 to 3 times its volume of sand. The proportion of lime to sand by volume is about 1:2 for hydraulic lime. It is used for lightly loaded above ground parts of building. Surkhi mortar is prepared by using surkhi instead of sand or by replacing half of sand in case of fat lime mortar. It is used for masonry work of all kinds in foundation and superstructure. In cement mortar, cement is used as the binding material. The proportion of cement to sand by volume varies from 1:2 to 1:6. It is used in underground constructions. Gauged mortar is also known as composite mortar or lime cement mortar. It is formed by the combination of cement and clay. It is used for bedding and for thick brick walls. Gypsum mortars are prepared from gypsum binding materials such as building gypsum and anhydrite binding materials.

Based on nature of application, mortar is classified into brick laying mortar and finishing mortars. Brick laying mortars are used for brick work and walls. Finishing mortars include common plastering work and mortars for developing architectural or ornamental effects.

Special mortars include fire resistant mortar, light weight mortar, packing mortar, sound absorbing mortar, X-ray shielding mortar etc. Fire resistant mortar is prepared by adding
aluminous cement to the finely crushed powder of fire bricks. It is used for lining furnaces, fire places, ovens etc.

Light weight mortar is prepared by adding, materials like saw dust, wood powder to the lime mortar or cement mortar. It is used in sound proof constructions. To pack oil wells, special mortars are formed, known as packing mortar. To reduce the noise level, the sound absorbing plaster is formed with the help of sound absorbing mortar.

X-ray shielding mortar is used for providing plastering coat to walls and ceiling of x-ray cabinets.

**PROPERTIES OF GOOD MORTAR**

a) It should be capable of developing good adhesion with the building units.
b) It should be capable of developing the designed stresses.
c) It should be capable of resisting penetration of rain water.
d) It should be cheap.
e) It should be durable.
f) It should be easily workable.
g) It should not affect the durability of materials with which it comes into contact.
h) It should set quickly so that speed in construction is achieved.
i) The joints formed by mortar should not develop cracks.

**USES OF MORTAR**

a) To bind the building units into a solid mass.
b) To carry out pointing and plastering work on exposed surfaces of masonry.
c) To form an even and soft bedding layer for building units.
d) To form joints of pipes.
e) To improve the general appearance of structure.
f) To prepare moulds for coping, corbels, cornice etc.
g) To serve as a matrix or cavity to hold coarse aggregates etc.
h) To hide the open joints of brickwork and stone work.
i) To fill up the cracks detected in the structure during maintenance process.
j) To distribute uniformly the super incumbent weight from upper layer to lower layer of bricks.
### Selection of mortar:

<table>
<thead>
<tr>
<th>No</th>
<th>Nature of work</th>
<th>Type of mortar</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Construction work in waterlogged areas and exposed positions</td>
<td>Cement or lime mortar prop. 1:3</td>
</tr>
<tr>
<td>2.</td>
<td>Damp proof courses and cement concrete roads</td>
<td>Cement mortar prop. 1:2</td>
</tr>
<tr>
<td>3.</td>
<td>General R.C.C work such as lintels, pillars, slabs, stairs etc.</td>
<td>Cement mortar prop. 1:3</td>
</tr>
<tr>
<td>4.</td>
<td>Internal walls and surfaces</td>
<td>Lime mortar prop 1:3</td>
</tr>
<tr>
<td>5.</td>
<td>Mortar for laying fire bricks</td>
<td>Fire resisting mortar</td>
</tr>
<tr>
<td>6.</td>
<td>Partition walls and parapet walls</td>
<td>Cement mortar prop. 1:3</td>
</tr>
<tr>
<td>7.</td>
<td>Plaster work</td>
<td>Cement mortar prop. 1:3</td>
</tr>
<tr>
<td>8.</td>
<td>Pointing work</td>
<td>Cement mortar prop. 1:1 to 1:2</td>
</tr>
<tr>
<td>9.</td>
<td>Reinforced brickwork</td>
<td>Cement mortar prop. 1:2</td>
</tr>
<tr>
<td>10.</td>
<td>Stone masonry with best varieties of stone</td>
<td>Lime mortar prop 1:2</td>
</tr>
<tr>
<td>11.</td>
<td>Stone masonry with ordinary stones</td>
<td>Lime mortar prop 1:2</td>
</tr>
<tr>
<td>12.</td>
<td>Thin joints in brickwork</td>
<td>Lime mortar prop 1:3</td>
</tr>
</tbody>
</table>

### MANUFACTURE OF STEEL

The steel is suitable for all constructional purposes and hence it has practically replaced cast iron and wrought iron in the present day practice of building construction. It is equally good in compression as well as in tension.

The steel is manufactured by the following processes.

1. Bessemer process
2. Cementation process
3. Crucible steel process
4. Duplex process
5. Electric process
6. L.D. process
7. Open hearth process
1) Bessemer process:
This process can be acidic or basic based on the nature of lining material of converter. Acidic process is adopted when iron ores contain very small amount of sulphur and phosphorous. Basic process is adopted for pig iron containing impurities of any type. The converter is charged with molten pig iron and is brought in an upright position. A blast of hot air is forced through the tuyeres. Air oxidizes impurities of pig iron and a yellow flame is seen at the nose of the converter. When the blast is shut off, the required amount of ferro manganese is added to get steel of desired quality.

2) Cementation process
It consists of converting pig iron into pure wrought iron and then preparing steel by adjusting carbon content. The cementation furnace is heated and the bars of pure wrought iron are subjected to intense heat. The wrought iron combines with carbon and steel of desired quality is obtained.

3) Crucible steel process:
The fragments of blister steel are taken and they are mixed with charcoal. They are placed in fire clay crucibles and heated. The molten iron is poured into suitable moulds. The steel produced is known as cast steel. It is used for making surgical instruments.

4) Duplex process:
It is a combination of two processes. (1) acid Bessemer process (2) basic open hearth process.
The molten pig iron is treated in acid lined Bessemer converter. It is then treated in basic lined open hearth. The process is economical and it results in saving of time.

5) Electric process:
An electric furnace is used in this process. It is made from steel plates. Electricity is used for heating and melting the metal. The furnace is provided with electrodes. When electric current is switched on, the electric arcs are formed between the electrodes and the surface of metal and with the intense heat of arcs, the metal is heated and melted.

6) L.D. process:
This is a modification of Bessemer process. It is known as Lintz-Donawitz process. In this process pure oxygen is used instead of air. A jet of pure oxygen is blown at extra ordinary speed on molten metal. The high temperature developed in the converter burns away impurities of metal and low carbon steel is prepared.

7) Open hearth process:
The process is carried out in open hearth furnace. The hearth is filled with molten pig iron from cupola furnace. A mixture of pre-heated air and coal gas is allowed to pass over the hearth. This mixture catches fire and produces intense heat. The molten metal is poured into mould for forming ingots. These are treated to form steel of commercial pattern.
**USES OF STEEL**

Based on carbon content, steel is designated as mild steel, medium carbon steel or high carbon steel. The carbon content of mild steel is about 0.1 to 0.25%. The carbon content of low carbon steel is less than 0.1%. The carbon content of medium carbon steel is about 0.25 to 0.6%. The high carbon steels is also known as hard steel and its carbon content varies from 0.6 to 1.1%.

<table>
<thead>
<tr>
<th>Name of Steel</th>
<th>Carbon Content</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mils Steel</td>
<td>Upto 0.1%</td>
<td>Motor body, sheet metal, tin, plate etc</td>
</tr>
<tr>
<td>Medium carbon steel</td>
<td>Upto 0.25%</td>
<td>Boiler plates, structural steel etc.</td>
</tr>
<tr>
<td></td>
<td>Upto 0.45%</td>
<td>Rails, Tyres etc</td>
</tr>
<tr>
<td></td>
<td>Upto 0.6%</td>
<td>Hammers, Large stamping and pressing dies etc.</td>
</tr>
<tr>
<td>High carbon steel</td>
<td>Upto 0.75%</td>
<td>Sledge hammers, springs, stamping dies etc.</td>
</tr>
<tr>
<td>or</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hard steel</td>
<td>Upto 0.9%</td>
<td>Minor’s drills, smith’s tool, stone mason’s tools etc</td>
</tr>
<tr>
<td></td>
<td>Upto 1%</td>
<td>Chissels, hammers, wood working tools</td>
</tr>
<tr>
<td></td>
<td>Upto 1.1%</td>
<td>Axes, cutlery, drills, knives, picks, punches etc</td>
</tr>
</tbody>
</table>

**MECHANICAL TREATMENT OF STEEL**

Operations involved:
i) Drawing
ii) Forging
iii) Pressing
iv) Rolling

i) Drawing:

This operation is carried out to reduce the cross section and to increase the length proportionately. The metal is drawn through dies. The drawing is continued till wire of required diameter is obtained.

ii) Forging:
This operation is carried out by repeated blows under a power hammer or a press. The process increases the density and improves grain sizes of metals. It is used for the manufacture of bolt, cramps etc.

iii) Pressing:

It is carried out in equipment known as press. It does not involve any shock. The metal is pressed between die and punch and article of desired shape is obtained.

iv) Rolling:

It is carried out in specially prepared rolling mills. The ingots are passed in succession through different rollers until articles of desired shape are obtained. It is used for the manufacture of angles, channels, joists etc.

HEAT TREATMENT PROCESS OF STEEL

i) Annealing

The object of the process is to make the steel soft so that it can be easily worked upon with a machine. The steel to be annealed is heated to the desired temperature and allowed to cool slowly in the furnace. The annealing reduces the tensile strength, but it increases ductility and brings back the steel to the best physical state to resist fracture.

ii) Case Hardening:

In this treatment, the outside surface becomes hard, the core of the materials retains original properties. The case hardening is important for components like gears, bearing surfaces etc.

iii) Cementing:

In this process, the skin of the steel is saturated with carbon. It consists of heating of steel in a carbon rich medium between 880 and 950°C.

iv) Cyaniding:

The process is used to produce hard cases on the surfaces of low or medium carbon steel. It consists of adding carbon and nitrogen to the surface layer of steel so as to increase its hardness, wear resistance and fatigue limit.

v) Hardening:
The process is the reverse of annealing process. The steel is made hard by this process whereas it is made soft by the annealing process. In hardening process, cooling is carried out at a controlled rate. Such a control rate of cooling is known as quenching.

vi) Nitriding:

The process of saturating the surface layer of steel with nitrogen by heating is known as nitriding. Heating is carried out between 480 to 650 degree Celsius in an atmosphere of Ammonia. Treatment makes the steel hard and increases its resistance to corrosion.

vii) Normalising:

The object of this process is to restore steel structure to normal condition, when it is disturbed due to mechanical work. The process is done by heating steel 40 to 50 degree Celsius above its upper critical temperature and maintained at that temperature and allowed to cool.

viii) Tempering:

The process is applied to steel which are treated with hardening process. The hardened steel is in a stressed condition and very brittle and cannot be used for practical purposes. Hence steels after hardening must be tempered to obtain good mechanical properties and to relieve internal stresses.

Properties of mild steel

a) It can be magnetized permanently
b) It can be readily forged and welded.
c) It cannot be easily hardened and tempered.
d) It has fibrous structure
e) It is malleable and ductile.
f) It is not easily attacked by salt water.
g) It is tougher and more elastic than wrought iron
h) It is used for all type of structural work.
i) It rusts easily and rapidly
j) Its melting point is about 1400 degree Celsius.

Properties of hard steel

a) It can be easily hardened and tempered.
b) It can be magnetized permanently
c) It cannot be readily forged and welded.
d) It has granular structure.
e) It is not easily attacked by salt water.
f) It is tougher and more elastic than mild steel.
g) It is used for finest cutlery, edge tools
h) It rusts easily and rapidly
i) Its melting point is about 1300 degree Celsius.
j) Its specific gravity is 7.90.
ANTICORROSIVE MEASURES FOR STEEL

a) Coal tarring
b) Electroplating
c) Embedding in cement concrete
d) Enamelling
e) Galvanizing
f) Metal spraying
g) Painting
h) Parkersing
i) Sherardising
j) Tin plating and terne plating

a) Coal tarring:

In this method, iron is dipped in hot coal tar so that a film of coal tar sticks to the surface. The film protects the iron surface from atmospheric actions leading to the corrosion.

b) Electroplating:

A thin layer of chromium, cadmium, copper or nickel is laid on the surface of ferrous metal with the help of electric current and by employing the principle of electrolysis.

c) Embedding in cement concrete:

If steel is embedded in cement concrete, it is not affected by corrosion. The cement concrete should be properly laid and cured so that it does not contain voids.

d) Enamelling:

The surface of iron is provided with a smooth surface by melting a suitable flux on it. It is used for ornamental iron works.

e) Galvanizing:

The surface of the metal is cleaned and treated with dilute solution of HCl and after washing it is then dipped in a bath of molten zinc.

f) Metal spraying:

The metal is covered with a spray of vaporized aluminium, lead, tin or zinc. The spraying gives a thin film of uniform thickness.

g) Painting

The metal surface is covered with a layer of paint. The surface is properly cleaned before the application of paint.

h) Parkersing:
The article is immersed in a hot water bath of a chemical known as Parco. The insoluble phosphates are formed on the surface of article due to reactions and these keep away the moisture.

i) Sherardising:
The article is washed with acid solution and with clean water. It is then dried and covered with dust of pure zinc. It is heated to a high temperature. zinc melts and combines with metal and forms a protective layer.

j) Tin plating and terne plating:
The metal is cleaned with dilute solution of acid and dipped in a bath of molten tin. The method of terne plating is similar to tin plating except that the lead tin alloy is used for coating instead of pure tin.

QUESTIONS FOR PRACTICE

PART A

1. What are the uses of limes?
2. Define hydraulicity?
3. List the ingredients of cement?
4. What are the uses of cement?
5. What are the properties of cement?
6. Differentiate Fat lime from Hydraulic lime?
7. Define consistency?
8. What is meant by calcination?
9. What is slaked lime?
10. What are the constituents of limestones?
11. What are the classification of limes?
12. Enumerate the sources of lime?
13. Compare fat lime with hydraulic lime?
14. What are the precautions to be taken in handling lime?
15. What are the varieties of cement?
16. What is soundness?
17. What are the properties of cement?
18. What is the purpose of testing of cement?
19. What is meant by bulking of sand?
20. What is grades of cement?
21. What are the sources of natural stone aggregates?
22. Explain the composition of ordinary cement?
23. Define Mortar?
24. Write any four uses of mortar?
25. Define abrasion resistance?
26. What is meant by flakiness index?
27. What is fineness of cement?
28. What is meant by setting time?
29. What is meant by elongation index?
30. What are the market forms of steel?
31. State the four field tests for cement?
32. What is grading?
33. What is lime mortar?
34. State the various uses of steel?

PART B

1. Write short notes on
   ii) Portland Pozzolana Cement ii) White Cement
2. Enumerate the laboratory tests for cement and describe any two of them?
3. Describe the Tests for mortar?
4. Explain about the manufacturing process of steel?
5. How to determine the compressive Strength and Tensile Strength of Cement?
6. Explain about Classification of Mortar?
7. Write short notes on
   i) Portland pozzolana cement ii) White Cement
8. Write short notes on High alumina Cement and hydrophobic Cement?
9. Mention the properties of Good Mortar?
10. What are the purposes of heat treatment processes for steel?
11. Explain about the manufacture of lime?
12. Briefly explain about the manufacture of cement?
13. Explain about the Anticorrosive measures for steel?
14. Explain about the properties and uses of different types of steel?
15. Discuss about natural stone aggregates?

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