1.1 Engineering Materials

Er.Saurav Shrestha

Engineering Materials

- Stones
- Bricks
- Tiles
- Cement
- Lime
- Timber
- Metal/alloys
- Paints/varnishes
- Asphalt/Bitumen/tar

- Properties(Physical, Chemical, Mechanical and thermal)
- Types
- Characteristics
- Composition
- Selection
- Usage/function of engineering materials

Properties(Physical, Chemical, Mechanical and thermal)

- Physical Properties: Density, Specific Gravity, Porosity,Permeability, water absorption, fire resistance, Durability(resistance to disintegration)
- Mechanical Properties: Strength, Hardness, Elasticity, Plasticity, Ductility, Brittleness, Malleability, Toughness (Tenacity), Creep, Fatigue, Resilience
- Thermal Properties: Specific Heat, Thermal Conductivity
- Chemical and Electrical Properties: Resistivity, Conductivity, Dielectric Strength, Corrosion Resistance

Physical Properties:

1. Specific gravity:

- It is the ratio of density at material to the density of water at standard condition.

2. Sp. Gr. = $\frac{\text{density of material}}{\text{density of water}}$

3. Density:

- It is the ratio of mass of material to the total volume of the materials.

4. Density = $\frac{\text{M}}{\text{V}}$

5. Porosity:

- It is the ratio of volume of voids in the material to the total volume of the materials.

Physical Properties:

6. Porosity = $\frac{\text{volume of voids}}{\text{total volume of materials}}$

7. Permeability:

- It is the property where by the material allows water to pass through its pore.

8. Water absorption:

- It is the ability of material to absorb & retain water.

9. Fire resistance:

- It is the property of material to resist fire

10. Durability:

- It is the resistance of material to disintegrate by natural agencies like humidity variation, chemical attack, action of atmosphere gases etc.

Mechanical properties of material

Mechanical properties are important to determine the load resisting capacity, durability etc. These are:

- **Strength:**

It is defined as property of material to resist the applied load without failure.

- **Elasticity:**

It is the property of material by which material tends to regain its shape after the removal of applied load. Elasticity of material is defined upto limit called elastic limit. After crossing this limit material become plastic.

- **Plasticity:**

Plasticity is property of material to change in the shape or to produce permanent deformation when the load applied to the material is released.

- *Mechanical properties of material*
- **Hardness**:

  It is the ability of material to resist the effect of wear & tear, scratching etc.
- **Ductility:**

  It is the ability of material to withstand elongation or bending.
- **Brittleness:**

  When a material breaks down easily if subjected to shock is known as brittle material.
- **Toughness (Tenacity):**

  It is the ability of material to absorb energy due to straining action undergoing the plastic deformation.

- *Mechanical properties of material*
- **Malleability**:

  It is the property of material by virtue of which a material may be bitten/ hammered/ rolled into thin sheet without rupture.
- **Fatigue:**

  It is the deformation produced by the repeated cyclic loading over the material.
- **Creep:**

  It is the property of material to undergo deformation due to the time interval under the action of constant load.
- **Impact strength:**

  It is the property of material to the resist certain sudden shock or impact over the material.

Thermal properties of material

The thermal properties of material are important in the structure where there is frequent change in temperature.

- **Specific heat capacity:**

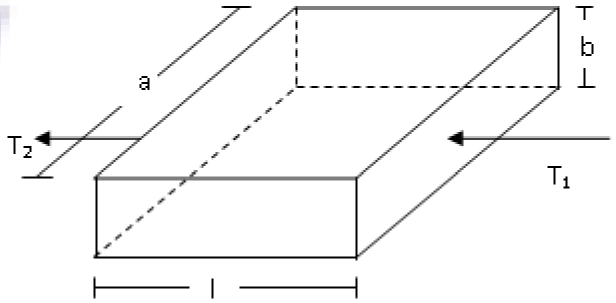
  It is defined as the amount of heat required to raise the temperature of unit mass of material by 1^oC.

- **Thermal conductivity:**

  It is the amount of heat transmitted in unit time through unit area over unit length perpendicular to the direction of heat flow when the temperature gradient across the heat considering unit is 1^oC.

  The rate at which heat can be flow through a material under the influence of given temperature gradient is determined by thermal conductivity (K).

  It is expressed as $K = \dfrac{\frac{d\theta}{dt}}{(T_2 - T_1)\frac{A}{l}}$



  where, $\dfrac{d\theta}{dt}$ = Rate of heat flow

  A = a×b = area through which heat flow occurs.

  l = distance separating the surface at temperature T_1&T_2.

Chemical and Electrical properties

- Corrosion Resistance:

It refers to the ability of material to withstand destructive attack by environment.

- Dielectric Strength-

Dielectric strength refers to the maximum electric field that a dielectric material can withstand without experiencing electrical breakdown. In simpler terms, it's a measure of how well an insulating material can resist electrical breakdown when subjected to an electric field.

Electrical properties:

It is the property of material to permit or resist the flow of electricals.

- **Resistivity:**

It is the property of material to resist the flow of electricity through it.

$$\rho = \frac{RA}{l}$$

where, ρ = resistivity

R = resistance of conductor

A = area of conductor section

l = length of conductor

- **Conductivity:**

It is the reciprocal of electrical resistivity. It is that electrical property of material due to which the electric current flows easily through the material. It is expressed as,

$$\sigma = \frac{1}{\rho} = \frac{l}{RA}$$

1. Deformation produced by repeated cyclic loading is:

a) Creep

b) Fatigue

c) Brittleness

d) Ductility

2. When a constant load is applied for a long period of time, it undergoes deformation, and the phenomenon is known as

a) Creep

b) Fatigue

c) Brittleness

d) Ductility

3. Hardness is:

a) Strength of material

b) ability of material to undergo deformation

c) ability of material to resist applied load

d) ability of material to resist wear and tear

4.Strength is

a) ability of material to undergo deformation

b) ability of material to resist applied load without breaking

c) ability of material to resist wear and tear

d) ability of material to resist scratches

Stones

Types of Stones:

Igneous Stones: Formed from the solidification of molten rock material. Examples include granite, basalt, and diorite.

Sedimentary Stones: Formed by the accumulation and compression of sediments over time. Examples include limestone, sandstone, and shale.

Metamorphic Stones: Formed by the transformation of existing rock types through heat, pressure, or chemical processes. Examples include marble, slate, and quartzite.

Characteristics of Stones:

Durability: Stones are known for their resilience and ability to withstand various environmental conditions.

Texture: Stones can have smooth, rough, porous, or polished textures, influencing their appearance and suitability for different applications.

Color: Stones come in a wide range of colors, allowing for diverse design possibilities.

Hardness: Stones vary in hardness, affecting their resistance to scratching, abrasion, and wear.

Density: Density influences the weight and structural integrity of stones.

Composition of Stones:

Minerals: Stones are composed of minerals such as quartz, feldspar, calcite, and mica, which give them their unique properties.

Matrix: The matrix is the material that binds the mineral particles together within the stone.

Selection Criteria:

Application: Consider the intended use of the stone, whether for flooring, countertops, facades, landscaping, or decorative purposes.

Durability: Choose a stone that can withstand the anticipated environmental conditions and wear.

Aesthetics: Consider the color, texture, and pattern of the stone to ensure it complements the design scheme.

Maintenance: Evaluate the maintenance requirements of the stone, including cleaning, sealing, and potential repairs.

Cost: Factor in the cost of the stone, including materials, installation, and long-term maintenance expenses.

Usage/Function of Stones:

1. ***Construction, 2. Landscaping 3. Interior Design, 4. Monuments and Sculpture, 5. Infrastructure***

Stones

Usage of Stones:

- ***Construction***: Walls, floors, stairs, and facades for their strength.
- ***Landscaping:*** Pathways, retaining walls, and garden features.
- ***Interior Design:*** Flooring, countertops, and decorative accents.
- ***Monuments and Sculptures***: Traditional use in architectural ornamentation.
- ***Infrastructure:*** Bridges, dams, and roadways for stability.

Testing Methods for Stones:

Physical Testing: Includes assessing hardness, density, and porosity.
Chemical Testing: Determines chemical composition and reaction to acids.
Mechanical Testing: Measures resistance to compression, flexure, and impact.
Weathering Tests: Simulate environmental conditions to assess durability.
Non-destructive Testing: Techniques like ultrasound to evaluate internal structure.

Bricks

Types of Bricks:

1. Based on Material

Burnt Clay Bricks: Traditional bricks made by firing clay in kilns.
Concrete Bricks: Made from concrete and aggregates, often used for construction.
Fly Ash Bricks: Manufactured using fly ash, a by product of coal combustion.
Sand Lime Bricks: Made by mixing sand, lime, and water, then pressing and curing.
Engineering Bricks: High-strength bricks for structural applications.

2. Based on quality, strength and durability

First-Class Bricks:

- These are high-quality bricks that have uniform shape, size, and color.
- They have sharp edges and smooth surfaces.
- First-class bricks are well burnt, which ensures uniformity in color and strength.
- They produce a clear metallic sound when struck against each other.

Second-Class Bricks:

- Second-class bricks are of lower quality compared to first-class bricks.
- They may have irregular shapes, sizes, and colors.
- The surfaces may be slightly uneven, and the edges may be less sharp.
- These bricks are less uniform in terms of burning, resulting in variations in color and strength. Second-class bricks are commonly used for internal walls, where appearance is less critical.

Third-Class Bricks:

- Third-class bricks are the lowest quality bricks and are often used for temporary or non-load bearing structures.
- They may have irregular shapes, sizes, and colors, and their surfaces may be rough and uneven.
- These bricks are less uniform in burning and may have significant variations in strength and color.

Fourth-Class Bricks:

- Sometimes referred to as "overburnt" or "jakhra" bricks, fourth-class bricks are bricks that have been over-fired during the manufacturing process.
- These are typically used as aggregate material or for filling gaps in walls.

Ingredients of Good Brick Earth

- Silica: 50-60%, Retains Shape of Brick, Imparts durability, prevents shrinkage and warping, excess of silica makes brittle and weak
- Alumina: 20-30%, it absorbs water and renders the clay plastic, excess of it creates crack and wrap
- Lime: 10%: it reduces shrinkage on drying, excess of lime causes brick to melt
- Magnesia <1%: affects the color in burning
- Ferric Oxide<7%: gives red color on burning, improves impermeability, durability and gives strength and hardness
- Alkalis <10%

Note:
a. The combined percentage of Magnesia, Ferric oxide and Alkalis must be less than 20%

Bricks

Characteristics of Bricks:

1. ***Durability:*** Bricks are durable and resistant to weathering.
2. ***Compressive Strength***: Ability to withstand compressive loads.
3. ***Absorption***: Porosity affecting moisture absorption.
4. ***Color and Texture***: Varied colors and textures for aesthetic appeal.
5. ***Size and Shape***: Standard sizes and shapes for easy installation.

Composition of Bricks:

1. ***Clay****:* Primary component in clay bricks, providing plasticity for molding.
2. ***Sand****:* Adds strength and reduces shrinkage during firing.
3. ***Water***: Necessary for plasticity and bonding of clay particles.
4. ***Additives****:* Depending on the type of brick, additives like lime, fly ash, or cement may be included.

Selection Criteria:

1. ***Application****:* Consider whether bricks will be used for load-bearing walls, facades, or decorative purposes.
2. ***Strength****:* Choose bricks with appropriate compressive strength for the intended use.
3. ***Absorption Rate****:* Low absorption rates are desirable for outdoor applications to prevent water damage.
4. ***Appearance****:* Select bricks based on color, texture, and finish to achieve the desired aesthetic.
5. ***Cost****:* Balance quality with budget constraints.

Usage of Bricks:

1. ***Construction****:* Load-bearing walls, partitions, and facades in residential and commercial buildings.
2. ***Paving****:* Bricks used for driveways, walkways, and patios in landscaping.
3. ***Fireplaces and Chimneys****:* Fire-resistant bricks used in fireplace construction.
4. ***Retaining Walls****:* Bricks used for retaining soil and creating terraced landscapes.
5. ***Decorative Elements****:* Bricks employed for accent walls, arches, and other architectural features.

Testing Methods for Bricks:

1. ***Compression Test****:* Measures the maximum compressive load a brick can bear.
2. ***Water Absorption Test****:* Determines the porosity and moisture absorption rate.
3. ***Efflorescence Test****:* Assess the presence of soluble salts on the brick surface.
4. ***Dimensional Stability Test****:* Checks for shrinkage or expansion under different conditions.
5. ***Flexural Strength Test****:* Measures the ability of bricks to resist bending forces.

Bricks

Manufacturing of Brick

Selection of Raw Materials: The primary raw materials for brick manufacturing are clay and shale. Sometimes, other materials like fly ash, coal waste, or sand are also used, depending on the desired properties of the bricks. The raw materials are usually dug from quarries or obtained from mining operations.

Preparation of Raw Materials: The raw materials are crushed and ground into fine particles to ensure uniformity and consistency in the final product. This process removes any large particles or impurities present in the raw materials.

Mixing: The finely ground raw materials are mixed thoroughly with water to form a plastic clay-like mass. This mixture is called the brick clay or brick earth.

Molding: The prepared brick clay is then molded into the desired shape and size using various methods. The most common method is extrusion, where the clay is forced through a die to produce continuous strips of clay called "green bricks." Alternatively, the clay can be pressed into molds to form individual bricks.

Drying: After molding, the green bricks are dried to remove excess moisture. This is typically done by air drying or using drying chambers or kilns. Proper drying is crucial to prevent cracking or warping during firing.

Firing: The dried bricks are fired in kilns at high temperatures to harden them and develop their final strength and durability. Firing temperatures can range from around 900°C to 1200°C, depending on the type of bricks being produced and the desired properties. During firing, chemical reactions occur that transform the clay minerals into a dense, durable ceramic material.

Cooling: Once the firing process is complete, the bricks are allowed to cool gradually inside the kiln to prevent thermal shock and cracking. After cooling, the bricks are ready for packaging and distribution.

Quality Control: Throughout the manufacturing process, quality control measures are implemented to ensure that the bricks meet the required standards for strength, size, color, and uniformity. Samples of the bricks may be tested in laboratories to verify their properties.

Packaging and Distribution: The finished bricks are stacked, packaged, and prepared for transportation to construction sites or distribution centers, where they are sold to builders, contractors, and other customers.

Test for Bricks

Water Absorption Test on Brick

1.Sample Preparation: Select a representative sample of bricks from the manufacturing batch. These bricks should be fully cured and have undergone the firing process.
2.Initial Weight Measurement: Weigh each brick individually using a precise weighing scale and record their initial weights. This weight serves as the baseline for comparison after the water absorption test.
3.Immersion in Water: Place the bricks in a container filled with water. Ensure that the water completely covers the bricks. Allow the bricks to soak in water for a specified period, usually 24 hours. This duration may vary depending on the standards or specifications being followed.
4.Removal from Water: After the soaking period, remove the bricks from the water and wipe off any excess water from their surfaces using a cloth or paper towel.
5.Final Weight Measurement: Weigh each brick again individually and record their final weights after being removed from the water.
6.Calculation of Water Absorption: Calculate the water absorption of each brick using the formula:
7.Water Absorption (%)= $\frac{Final\ Weight - Initial\ Weight}{Initial\ Weight}$ *100%

Compressive Strength Test of Bricks

1. **Sample Preparation**: Prepare the bricks by cleaning their surfaces to remove any dirt, debris, or loose particles. If necessary, trim any irregularities from the edges to ensure uniformity.
2. Moisture Conditioning (Optional): Depending on the testing standards or specifications being followed, the bricks may be subjected to moisture conditioning to achieve a specific moisture content. This step helps standardize testing conditions and ensures accurate results.
3. Testing Apparatus Setup: Set up the compression testing machine according to the manufacturer's instructions. The machine typically consists of a hydraulic or mechanical system capable of applying a gradually increasing compressive force to the specimen.
4. Brick Placement: Place the brick specimen on the compression testing machine's lower platen, ensuring that it is positioned centrally and aligned properly.
5. Load Application: Gradually apply a compressive load to the brick specimen at a uniform rate (usually at a rate specified in testing standards), until the brick fails or fractures. The load is applied perpendicular to the bed faces of the brick.
6. Recording Load and Deformation: Measure and record the applied load at regular intervals throughout the test until failure occurs. Simultaneously, measure and record the deformation or displacement of the brick specimen under the applied load.
7. Determination of Compressive Strength:= $\frac{Maximum\ Load\ Applied}{Cross\ Sectional\ Area\ of\ the\ Brick}$

Standards for Bricks

Size of Brick

As per NS

- L*B*H = 240mm * 115mm *57mm for 10mm mortar joint

*Note: length of brick= 2*width of brick + 1* Vertical mortar joint*

As per IS

- Non-Modular Size of Brick = 230mm*110mm*70mm
- As per IS 1077:1992, common burnt clay bricks shall be classified on the basis of average compressive strength as:

Class Designation	**35**	**30**	**25**	**20**	**17.5**	**15**	**12.5**	**10**	**7.5**	**5**	**3.5**
Average Compressive Strength not less than (N/mm^2	35	30	25	20	17.5	15	12.5	10	7.5	5	3.5

Note: after immersion in cold water for 24 hours, water absorption shall not be more than 20 % by weight up to class 12.5 and 15 % by weight for higher class

- Water absorption and crushing strength of different class of brick

Class of Brick	Water Absorption (when immersed in cold water for 24 hrs)	Crushing Strength(N/mm^2
First class	12-15% of its dry weight	Should not be less than 10.5
Second Class	16-20% of its dry weight	Should not be less than 7
Third Class	25% of its dry weight	Should not be less than 3.5

1. Quartzite is a

a) metamorphic rock
b) argillaceous rock
c) calcareous rock
d) Igneous rock

2. Granite is

a) sedimentary rock
b) metamorphic rock
c) igneous rock
d) volcanic rock.

3. Sand stone is

a) sedimentary rock
b) metamorphic rock
c) igneous rock
d) volcanic rock.

4. Metamorphic rock with the most weather resisting property is

a) Marble
b) Quartzite
c) Slate
d) Lime stone

5.Which of the following term is used to indicate the art of building the structures in stones?

a) Mortar

b) Brick

c) Bond

d) Masonry

6. The clay to be used for manufacturing bricks for a large project, is dugout and allowed to weather throughout

a) the monsoon
b) the winter
c) the summer
d) none of these.

7. Minimum compressive strength of first class brick is:

a) 75 kg/cm2
b) 90 kg/cm2
c) 100 kg/cm2
d) 120 kg/cm2

8. Minimum compressive strength of second class brick is:

a) 75 kg/cm2
b) 90 kg/cm2
c) 100 kg/cm2
d) 120 kg/cm2

Tiles

Types of Tiles:

1. **Ceramic Tiles**: Made from clay materials, ceramic tiles are kiln-fired and come in various styles, including glazed and unglazed.
2. **Porcelain Tiles**: A type of ceramic tile with a denser body and lower water absorption rate, making them highly durable and suitable for both indoor and outdoor use.
3. **Natural Stone Tiles**: Quarried from natural stone materials such as marble, granite, limestone, slate, and travertine, these tiles offer unique colors and patterns.
4. **Glass Tiles**: Made from glass materials, these tiles are available in various shapes, sizes, and finishes, adding a reflective and modern touch to spaces.
5. **Mosaic Tiles**: Small tiles arranged in patterns or designs, typically used as decorative accents or for creating intricate designs.

Characteristics of Tiles:

1. **Durability**: Tiles are known for their durability and resistance to wear, moisture, and stains.
2. **Surface Finish**: Tiles can have different finishes such as matte, glossy, textured, or polished, affecting their appearance and slip resistance.
3. **Color and Design**: Available in a wide range of colors, patterns, and designs to suit various aesthetic preferences.
4. **Size and Shape**: Tiles come in various sizes and shapes, from small mosaics to large-format tiles, allowing for diverse design possibilities.
5. **Water Absorption**: Porosity varies among tiles, affecting their suitability for different applications, such as wet areas or outdoor use.

Composition of Tiles:

1. **Clay**: Ceramic tiles are primarily composed of clay materials, while porcelain tiles contain clay, sand, and other minerals.
2. **Glaze**: Glazed ceramic tiles have a protective layer of glaze applied to the surface, providing color, texture, and added durability.
3. **Natural Stone**: Natural stone tiles are made from quarried stone materials, such as marble, granite, or slate, which are cut into tiles and finished according to desired specifications.
4. **Glass**: Glass tiles are manufactured from molten glass materials, which are cooled and shaped into tiles of various sizes and finishes

Selection Criteria:

1. **Application**: Consider where the tiles will be installed, such as floors, walls, backsplashes, or outdoor areas.
2. **Durability**: Choose tiles with appropriate hardness, abrasion resistance, and water absorption properties for the intended use.
3. **Aesthetic Appeal**: Select tiles that complement the overall design scheme, including color, pattern, and texture.
4. **Maintenance**: Assess the ease of cleaning and maintenance required to keep the tiles looking their best over time.
5. **Cost**: Balance quality, aesthetics, and budget constraints when selecting tiles for a project.

Tiles

Usage of Tiles:

1. **Flooring**: Tiles are commonly used for flooring in residential, commercial, and industrial spaces due to their durability and versatility.
2. **Wall Cladding**: Tiles are applied to walls for decorative purposes, protection, and ease of maintenance, particularly in kitchens and bathrooms.
3. **Backsplashes**: Tiles are used as backsplashes in kitchens and bathrooms to protect walls from water, grease, and stains while adding visual interest.
4. **Countertops**: Certain types of tiles, such as porcelain and natural stone, are suitable for use as countertops in kitchens, bathrooms, and other areas requiring durable surfaces.
5. **Outdoor Spaces**: Porcelain, natural stone, and some ceramic tiles are used for outdoor patios, decks, walkways, and pool surrounds due to their resistance to weathering and moisture.

Testing Methods for Tiles:

1. **Water Absorption Test**: Determines the porosity of tiles, particularly important for assessing suitability for wet areas and outdoor use.
2. **Abrasion Resistance Test**: Measures the resistance of tiles to wear and abrasion, particularly relevant for flooring applications.
3. **Coefficient of Friction Test**: Evaluates the slip resistance of tiles, essential for areas prone to moisture and potential slipping hazards.
4. **Breaking Strength Test**: Assesses the load-bearing capacity and structural integrity of tiles under pressure.
5. **Chemical Resistance Test**: Determines the resistance of tiles to chemicals and stains, important for assessing suitability for specific applications and maintenance requirements.

Cements

Natural cement: manufactured from stones containing 20 to 40 % clay and remaining % occupied by calcareous material, either $CaCo_3$ or mixture of $CaCO_3$ and $MgCO_3$

Artificial cement: manufactured by burning appropriately proportioned mixture of calcareous material and clay material at high temperature, resulting in formation of clinker , which is grinded with addition of small % of gypsum.

Basic Ingredients of Cement(OPC)

Lime (CaO)- 60-67%
Silica (SiO_2)- 17-25%
Alumina (Al_2O_3)- 3-8%
Calcium sulphate ($CaSO_4$)- 3-5%
Ferrous Oxide (Fe_2O_3)- 0.5-6%
Magnesium oxides (MgO)- 0.1 - 4%
Sulphur Trioxides (SO_3)- 1.3 - 3%
Alkalies – 0.4 – 1.3%

Lime:

- Major constituents of cement
- Presence of lime in sufficient quantity is required to form silicates and aluminates of calcium
- Make cement sound and strong (if in right proportion)
- Excess lime causes cement unsound, causes expansion and disintegration

Silica:

- Major constituent of cement
- Helps in formation of di-calcium silicate and tri-calcium silicates
- Responsible for the strength of cement
- Excess silica increases the strength

Alumina:

- Imparts quick setting property to cements
- As flux, lowers the clinkering temperature of cement
- Excess amount reduces the strength of cement

Calcium sulphate:

- added to the cement in the form of gypsum in clinker during grinding
- Increases the initial setting time of cement

Ferrous oxides:

- Increases the hardness of cement
- Provides the color to the cement
- Acts as flux and helps to fuse raw materials of cement

Magnesium oxides:

Imparts hardness to the cement
Imparts color to the cement
Excess amount causes unsoundness of the cement

Sulphur trioxides:

Makes cement sound if in proper amount

Alkalies:

Should be present in small quantity
Excess alkalies causes efflorescence
Excess amount causes alkali-aggregate reaction in concrete, masonry works.

Harmful Ingredients of Cement

- Excess alkali oxides in cement such as potassium oxides and sodium oxides causes cracks in mortar made from such cement.
- K_2O and Na_2O <1 %
- MgO < 5%

Cements

Types of Cement

- OPC (Ordinary Portland Cement)
- High Alumina Cement
- Portland Slag cement
- Rapid Hardening Cement
- Low heat Cement
- Quick Setting Cement
- White Cement
- Colored Cement
- Portland Pozzolana Cement

Consistency Test of Cement

- 300gm of cement is taken with 25% water
- Fill the mould of Vicat's apparatus
- The interval between the addition of water to the commencement of filling of mould is known as the time of *gauging* and it should be $3^{3/4}$ to $4^{1/4}$ minutes
- Vicat's apparatus is attached with plunger having diameter and length as 10mm and 50mm respectively
- **Square needle(1mm*1mm) for initial setting time, plunger for consistency test, needle with annular collar for final setting time**
- Settlement of plunger is noted and if the penetration is bet^{n} 5 to 7mm from bottom of mould, the water added is correct.

Initial Setting Time Test

- Take a cement sample of 300gm and mixed with water (quantity from consistency test)
- Filled the Vicat's mould with the cement paste
- Using the square needle of 1mm*1mm or $1mm^2$ X-sectional area try to find the penetration of about 5 mm from bottom of the mould.(35 mm from top of mould)
- The initial setting time is the interval between the addition of water to cement and the stage when the needle ceases to penetrate completely. This time is to be 30 minutes for OPC.

Final Setting Time Test

- Cement paste is prepared as above and it is filled in the Vicat's mould as previously done.
- 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.
- The needle is gently released. The time at which the needle makes an impression on the test block and the collar fails to do so is noted.
- The final setting time is the difference between the time at which water was added to cement and time as recorded when needle only penetrates the paste. This time should be about 10 hrs for OPC.

Cements

Compressive Strength Test of Cement

% of water by wt of cement = (P/4 +3.5),

P= % of water for normal consistency

3 Moulds of either cube size 70.6mm or 76mm

Dry mix cement and sand then mix with water for uniform colour with in 3-4 mintues

Rod the mortar placed in mould 20 times in about 8 secs for full compaction

Store specimen of cubes for 24 hours in place of relative humidity 90 % and temperature 27 +_ 2^{O}C.

Cubes are tested in compression testing machine at end of 3 days and 7 days

Load is applied uniformly at the rate of 350kg/cm^2

C.S > 115kg/cm^2 (3days),

C.S >175kg/cm^2(7 days)

Average of 3 moulds give compressive strength

Tensile Strength Test of Cement

% of water by wt of cement= (P * 0.2 +2.5),

P= % of water for normal consistency

12 standard briquettes are prepared

Six briquettes are tested after 3 days and 7 days . Rate of loading 35kg/cm^2

X-sectional of briquette at least section is 6.45cm^2

Ultimate tensile stress = failing load/6.45

At 3 days T.S>20kg/cm^2, at 7 days T.S>25kg/cm^2

Soundness Test

- Test to detect the presence of uncombined lime and magnesia in cement
- Test performed with the help of Le-Chatelier apparatus.
- Brass mould of 30mm dia. and 30mm height
- There is split in mould and it doesn't exceed 0.50mm

Procedure

On either side of split there are two indicators with pointed ends

Thickness of mould cylinder is 0.50mm

Cement paste is prepared (water = 0.78 P)

Using glass plate at bottom, fill the mould with paste, then cover upper surface of mould with glass plate along with small weight at top.

Submerge in water for 24 hrs (25^0C to 29^0C)

Then measure the distance between the points of indicator (Say: x_1)

Again, submerge the mould in water and apply the heat in such a way that boiling temperature of water is reached in about 30 minutes and boiling is continued for 3 hours.

The mould is taken out then left for cooling, again the distance between the points of indicators is again measured (say: X_2)

Difference between x_1 and x_2 must not exceed 10mm.

Lime

Lime is produced by heating limestone which is more or less pure calcium carbonate.

Uses

❖Used as binding material for mortar or concrete.
❖Used as aggregate in the form of crushed limestone.
❖Used as raw material for manufacture of glass.
❖Used as improving agent for good quality of soil.
❖Used in the purification of water, sewer treatment etc.

Properties

❖It posses good plasticity.
❖It is easily workable & durable.
❖It offers good resistance to moisture.
❖It gives strength to the masonry used as mortar.

❖**Fat lime (Rich, pure lime)**

❖ It is lime which has high CaO & is depended for setting & hardening on the absorption of CO_2 from atmosphere.

❖ It contains about 93% CaO & less than 5% impurities such as silica, alumina etc.

Components of lime

Clay:

- Its presence produces hydraulicity in lime. In lime it is desirable to have 8-30% of clay. It retards slaking when present in small quantity, arrests slaking when it is in excess. Clay makes lime insoluble in water.

Soluble silica:.

Magnesium carbonate:

Alkalies & metallic oxides:

Sulphates:

Iron compounds:

Carbonaceous matter

Types

Poor or lean lime

❖ It consists of impurities of about more than 5% in the form of silica, alumina. It takes longer time to slake than fat lime. It sets & hardens slowly.

Hydraulic lime:

❖ Hydraulic lime sets by absorbing CO_2 from atmosphere. This lime sets under water. It is used in building works when strength is required.

1.For the manufacture of Portland cement, the proportions of raw materials used, are

a) lime 63% ; silica 22% ; other ingredients 15%

b) lime 22% ; silica 63% ; other ingredients 15%

c) silica 40% ; lime 40% ; other ingredients 20%

d) silica 70% ; lime 20% ; other ingredients 10%.

- The apparatus used in consistency test of cement is:

a) Vicats needle

b) Vicats plunger

c) Vicats needle with annular collar

d) Le Chatliers apparatus

- Initial setting time for OPC cement should not be less than:

a) 45 mins

b) 600 mins

c) 40 mins

d) 30 mins

- The apparatus used for soundness test of cement is:

a) Vicats apparatus
b) compression testing machine
c) Le chatlier’s apparatus
d) Soundness apparatus

The initial setting time of lime-pozzolana, is

a) 30 minutes
b) 60 minutes
c) 90 minutes
d) 120 minutes.

- The apparatus used for initial setting time of cement is:

a) Vicats needle
b) Vicats plunger
c) Vicats needle with annular collar
d) Le Chatliers apparatus

- The apparatus used for final setting time of cement is:

a) Vicats needle
b) Vicats plunger
c) Vicats needle with annular collar
d) Le Chatliers apparatus

According to IS standard, maximum setting time for OPC should be

a) 30 minutes
b) 1 hour
c) 6 hours
d) 10 hours

The standard consist of cement is the condition when

a) Plunger penetrates to 5-7 mm from bottom of mould
b) Plunger penetrates to 5-7 mm from top of mould
c) Plunger penetrates to 50-70 mm from top of mould
d) Plunger penetrates to 25-30 mm from bottom of mould

Area of plunger used in consistency test of cement is:

a) 1.8 cm2
b) 1 cm2
c) 1.5 cm2
d) 2 cm2

Two consecutive readings for initial setting time of cement mustnot be less than

a) 1 cm
b) 1.9 cm
c) 1.5 cm
d) 1.8 cm

Standards for Cement

NS Code

1. NS 49:2041 Ordinary Portland Cement
2. NS 384:2054 Portland Slag Cement
3. NS 385:2054 Portland Pozzolana Cement

IS Code:

1. IS 269: Ordinary Portland Cement
2. IS 8112: High Strength Portland Cement
3. IS 12269: Portland Slag Cement
4. IS 1489: Portland Pozzolana Cement

NS 572:2076 Specification for 43 grade and 53 Grade OPC

- The minimum amount of clinker shall be 95% by mass of OPC
- No materials shall be added to clinker other than gypsum (natural, mineral or chemical), water and not more than (a total of 1.0% of air entraining agents or other agents including coloring agents, which have proved not to be harmful. Such additions shall be made before grinding.
- The net quantity of OPC per bag shall be 50 kg or 25 kg or 10 kg or 5 kg. the quantity of OPC in any of bags shall be ±1% of the market net quantity.

- The cement can be packed in
  - Jute Sacking bag
  - Multi-Wall paper sacks
  - Light weight jute
  - HDPE/PP Woven Sacks
  - Jute Synthetic Union Bags
  - Any approved composite bag
- Marking of each bag of cement should contain:
  - Manufacturer's Name and his registered trade mark
  - The name and designated grade of the ordinary Portland cement
  - Net quantity in kg
  - Batch No/Code number in terms of week, month and year of packing
  - Best before date (that is, not more than 3 months from the date of packing)
  - Need for testing of cement more than 3 months old to check conformity beforfe its use
  - Nepal standard certification mark with applicabe number and year.
  - Address of the manufacturer

Standards for Cement

- **Physical Requirements for OPC 43 Grade:**
- **Fineness**: The cement should have a specific surface area (Blaine) not less than 225 m²/kg.
- **Setting Time**: The initial setting time of cement should not be less than 30 minutes, and the final setting time should not be more than 600 minutes.
- **Soundness**: The ***autoclave expansion*** of the cement should not exceed 0.8%. And when measure with ***Le-Chatliers Appratus*** the cement should not go expansion more than 10mm.
- **Compressive Strength**: The compressive strength of OPC 43 Grade at various ages should meet the following requirements:
  - 3 Days: Not less than 23 MPa
  - 7 Days: Not less than 33 MPa
  - 28 Days: Not less than 43 MPa
- **Loss on Ignition (LOI)**: The loss on ignition of the cement should not exceed 5%.
- **Specific Gravity**: The specific gravity of cement should be between 3.10 to 3.20.

- **Physical Requirements for OPC 43 Grade:**
- **Fineness**: The cement should have a specific surface area (Blaine) typically not less than 325 m²/kg.
- **Setting Time**:
  - Initial setting time: Not less than 30 minutes.
  - Final setting time: Not more than 600 minutes.
- **Soundness**: The ***autoclave*** expansion of the cement should not exceed 0.8% and the expansion measure using ***Le-Chatliers*** should not exceed 5mm.
- **Compressive Strength**:
  - 3 Days: Not less than 27 MPa
  - 7 Days: Not less than 37 MPa
  - 28 Days: Not less than 53 MPa
- **Loss on Ignition (LOI)**: The loss on ignition of the cement should not exceed 3%.
- **Specific Gravity**: The specific gravity of cement should typically be between 3.10 to 3.20.

Note: The aeration shall be done by spreading out the sample to a depth of 75mm at a relative humidity of 50 to 80% for a Total period of 7 days. The expansion of OPC so aerated shall be not more than 5mm and 0.6% when tested Le-Chatelier Method and autoclave test respectively

Standards for Cement

S.No	Characteristics	Requirements	
		OPC 43	OPC 53
1	Lime saturation factor(ratio of percentage of lime to percentage of silica, alumina and iron oxide	0.66-1.02	0.8-1.08
2	Ratio of percentage of alumina to that of iron oxide	0.66 minimum	0.66 minimum
3	Insoluble residue, percent by mass,	2 max	2max
4	Magnesia, percent by mass,	5.0 max	5.0 max
5	Total sulphur content calculated as sulphuric anhydrid present by mass		
	case a. content of C3A <5%	2.5 max	2.5max
	case b. content of C3A >5%	3.0 max	3.0 max
6	Loss on ignition, percentage by mass	4 max	4 max

Standards of Rebar

- NS 84:2042 Mild Steel Rod
- NS 191:2046 Deformed steel bars and wires for concrete reinforcement
- IS 1786: High Strength Deformed steel bars and wires for concrete Reinforcement Specimen

Note: mild steel: Fe 250

Tor(Toristeg Steel Corporation) ***Steel: Fe 415***

TMT: Fe 500

- Nominal Size of bars: 4,5, 6,8,10,12,16,20,25,28,32,36,40,45,50 mm

<u>Types of Rebar:</u>

1.Mild Steel Rebar (MSR): Also known as "black bar," mild steel rebar is the traditional type of rebar used in construction projects. It is primarily composed of carbon steel and is easily weldable.

2.High-Strength Reinforcement Steel (HSRS): This includes rebar with higher yield strength than traditional mild steel rebar. Examples include Fe 415, Fe 500, Fe 550, and Fe 600 grades.

3.Corrosion-Resistant Rebar: Rebar coated with epoxy or other corrosion-resistant coatings to protect against rust and corrosion in aggressive environments, such as coastal areas or structures exposed to chemicals.

4.Stainless Steel Rebar: Stainless steel rebar offers excellent corrosion resistance and durability, making it suitable for use in corrosive environments or where aesthetic considerations are important.

5.Galvanized Rebar: Rebar coated with a layer of zinc to provide corrosion protection. Galvanized rebar is commonly used in projects where exposure to moisture and chemicals is a concern.

<u>Tensile Test on Rebar</u>

- To determine yield stress, strain and ultimate tensile strength
- Apparatus: UTM, Extensometer, Vernier Calipers, Punching tool

Notes:

- The Stress upto the point where the material loses its elasticity and goes into plastic deformation is called a yield point/yield stress
- At this very point, we can experience that the specimen is getting narrow and thin. We can even experience a sudden drop in the curve
- After this, the bar goes into plastic deformation where specimen starts getting thin from center point and the metal specimen goes upto ultimate tensile stress which is the highest point.
- When the specimen reaches maximum stress it experiences “necking "process which is known as Ultimate tensile stress
- After this , the bar goes into more deformation and finally arrives at a fracture point where the metal breaks.
- Stiffness= Young’s modulus (Slope of stress-strain curve)
- Strength= Yield Stress
- Young's modulus can be calculated using the following formula:

  E= Stress/Strain

  Where:

  E = Young's modulus of elasticity (in Pascals, Pa)

  Stress = Force (in Newtons, N) applied to the material divided by the original cross-sectional area (in square meters, m^2) of the material

  Strain = Change in length of the material (in meters, m) divided by the original length (in meters, m) of the material

Standards for Aggregate

- Ns 297: 2050 Aggregate
- NS 298: 2050 Sampling Method for aggregates
- NS 305:2050 Methods of test for aggregates for Concrete
- IS 383:1970 Specifications for fine and Coarse aggregate

Class A	Consist of Igneous or quartzite rock from an approved source
Class B	Consist of Crushed quarry rock other than Class A from an approved source
Class C	consist of natural or partly crushed gravel, pebbles obtained from approved gravel deposit
Class D	consist of crushed gravel
Class E	consit of an artificial mixture of any of the above classes

Types of Aggregates:

1.Natural Aggregates:

1. **Sand**: Fine granular material, typically composed of particles ranging from 0.075mm to 4.75mm in size.
2. **Gravel**: Coarse granular material consisting of particles larger than sand, typically ranging from 4.75mm to 75mm in size.
3. **Crushed Stone**: Stone aggregates produced by crushing larger rocks, available in various sizes.

2.Manufactured Aggregates:

1. **Recycled Concrete Aggregate (RCA)**: Produced from demolished concrete, used as a sustainable alternative to natural aggregates.
2. **Slag Aggregates**: Byproducts of industrial processes, such as blast furnace slag or steel slag, used in construction.

Characteristics of Aggregates:

- **Shape**: Influences workability, strength, and durability of concrete. Angular and rough-textured aggregates provide better interlocking, while rounded aggregates reduce water demand.
- **Size Gradation**: Refers to the distribution of particle sizes within an aggregate sample, affecting the workability and strength of concrete.
- **Cleanliness**: Presence of contaminants like clay, silt, or organic matter can affect the performance and durability of concrete.
- **Specific Gravity**: Indicates the density of aggregates relative to water and influences the density and strength of concrete.
- **Absorption**: Measures the porosity of aggregates and affects the water-cement ratio in concrete mixtures.

Standards for aggregate

<u>Composition of Aggregates</u>:

1. **Minerals**: Aggregates primarily consist of mineral materials such as quartz, feldspar, limestone, granite, or basalt.
2. **Particle Size Distribution**: Aggregates are classified based on particle sizes, including coarse aggregates (gravel and crushed stone) and fine aggregates (sand).

Selection Criteria:

Application: Consider the intended use of aggregates, whether for concrete, asphalt, base course, or drainage.

Gradation: Ensure proper particle size distribution for optimal concrete workability, strength, and durability.

Quality: Assess cleanliness, grading, and absence of deleterious materials to meet project specifications and performance requirements.

Availability: Consider local availability and sourcing of aggregates to minimize transportation costs and environmental impact.

Cost: Balance quality requirements with budget constraints when selecting aggregates for construction projects.

<u>Usage of Aggregates:</u>

Concrete Production: Aggregates constitute the bulk of concrete mixtures, providing strength, durability, and volume stability.

Asphalt Mixtures: Aggregates are used as the main component in asphalt concrete for road construction and pavement.

Base Course Material: Aggregates serve as the foundation material for roads, railway tracks, and airport runways.

Drainage Systems: Coarse aggregates are used in drainage systems to facilitate water flow and prevent soil erosion.

Landscaping: Decorative aggregates are used in landscaping projects for pathways, gardens, and decorative features.

<u>Testing Methods for Aggregates:</u>

Gradation Analysis: Determines the particle size distribution of aggregates using sieving techniques.

Specific Gravity and Absorption: Measures the density and porosity of aggregates relative to water.

Particle Shape Analysis: Assesses the shape characteristics of aggregates using visual or mechanical methods.

Cleanliness Test: Determines the presence of contaminants such as clay, silt, or organic matter in aggregates.

Aggregate Crushing Value (ACV): Measures the resistance of aggregates to crushing under compressive loads.

Bulking of Sand

Bulking of sand refers to an increase in the volume of sand due to the presence of moisture. When dry sand absorbs water, the water coats the sand particles and fills the voids between them, causing the sand to expand. This phenomenon is important to consider in construction, especially in applications where accurate volume measurements are crucial, such as concrete mixtures.

Causes of Bulking:

1. **Surface Tension**: Water adheres to the surface of sand particles due to surface tension, causing the sand particles to repel each other and increase the volume.
2. **Capillary Action**: Water is drawn into the spaces between sand particles through capillary action, leading to an increase in volume.
3. **Film of Water**: A film of water forms around each sand particle, separating them and causing expansion.

Effects of Bulking:

1. **Reduced Yield**: Bulking of sand results in an apparent increase in volume, which can lead to a decrease in the amount of sand available for a given weight or volume.
2. **Inaccurate Measurements**: Bulking can cause inaccuracies in volume measurements, affecting the proportioning of materials in concrete mixtures and other applications.

Procedure:

Selection of Sand Sample:

Obtain a representative sample of the sand to be tested. Ensure that the sample is free from contaminants and large particles.

Initial Volume Measurement:

Fill the graduated cylinder or container with a known volume of dry sand, ensuring that it is compacted and leveled off to eliminate any voids or air pockets. Record the initial volume (V1) of sand.

Wetting of Sand:

Slowly add a measured quantity of water to the sand sample in the mixing bowl, ensuring thorough mixing to achieve uniform moisture distribution. The amount of water added should be sufficient to fully wet the sand but avoid excessive saturation.

Final Volume Measurement:

Transfer the wetted sand back into the graduated cylinder or container, filling it to the same level as before. Tap the container gently to settle the sand and remove any trapped air bubbles. Record the final volume (V2) of sand.

Calculation:

Calculate the bulking factor using the formula:

Bulking Factor=$V2/V1\times100\%$

Results Analysis:

Analyze the bulking factor obtained and compare it with known values or specifications for the sand type. Bulking factors can vary depending on factors such as sand particle shape, gradation, and moisture content.

Bitumen:

- **It is defined as non crystalline solid or viscous hydrocarbon material having adhesive properties & derived from petroleum either by natural or refining process.**

Properties:

- It is solid or semi-solid, black in colour & is sticky.
- It melts or softens as application of heat.
- It is completely soluble in carbon-disulphide.
- It is binder in all types of asphalt.

Uses:

- Used as road making materials.
- Used in damp proof coarse (DPC).
- Since it forms good expansion joint, it is used for filling up the joints in leaky roof.
- It is employed in manufacture of water proofing materials, paints etc.

- **Cut-back bitumen:**
- Cut back is defined as a bitumen **whose viscosity is maintained by addition of volatile diluents such as gasoline, kerosene etc.** Cut backs are manufactured in three groups from rapid curing, medium curing, and slow curing.
- **Emulsion:**
- **Emulsion is combination of water, bitumen & emulsifying agent. To prevent bitumen spheres from coagulation, an emulsifying agent is added. Mostly soap is used as an emulsifying agent.**

Emulsion may be classified as rapid setting, medium setting & slow setting.

- Rapid setting (10-30 mins)
- Medium setting (30-60 mins)
- Slow setting (2-24 hrs.)

Tar:

- Tar is one of the bituminous material obtained during the destructive distillation of coal, peat, wood or other organic material.