Module 16					
Module NAME: Building Materials					
Degree Program(s)	B.Sc. in Architecture				
academic year	2021				
Course Number	ARCH2161				
Course Title	Building Materials and Construction I				
Pre-requisites	None				
Status of Course	Compulsory				
Semester	3				
ECTS Credits	5				
Working Hours (per week)	Lectures	Tutorials & Seminars	Laboratory & Workshop	Home Study	Total Working Hours
	2	6	-	1	9
Attendance Requirements	85%				
Teaching & Learning Methods	Lectures, Seminar, Excursions, laboratory exercise				
Course Objectives & Competences to be Acquired	- This course introduces students to the basic principles and practices of building material with relation to building constructions. - It provides a detail understanding of the material's properties, production processes and how various building elements are planned, joined and executed in solid construction systems. - It raises awareness for the interrelation of materials and construction - Students will be enabled to assess the appropriate use of building construction materials				
Course Description/Course Contents	- Building materials, Natural stone, earth/clay, cement, lime, mortar, sand, reinforced concrete (origin, characteristics, composition, production, preparation, properties, standards) Finishing materials, Building techniques and structural concepts, Masonry Constructions using stone, bricks, blocks Concrete construction, Water/damp proofing - Building elements, foundations to roofs-with respect to the materials, Building Circulation-stairs and ramps -Symbols and abbreviations, material representations and dimensioning.				
Assessment/Evaluation & Grading System	50% Exam 50% Projects				

Literature	- Victoria Ballard Bell and Patrick Rand, Materials for Architectural - Design, Laurence King Publishing, London, 2006 - Lyons, Arthur, Materials for architects and builders: an introduction, Architectural Press, Oxford, 2003 - Kind-Barkauskas, Concrete construction manual , Birkhäuser, Basel, 2002 - Bennett, David, Innovations in concrete, Thomas Telford, London, 2002 - Everett, Alan, Materials, Longman Scientific & Technical, Harlow, 1994 - Liebing, Architectural Working Drawings, Wiley, New York,1999

Building materials and construction I

1. Introduction
2. Earth/clay
3. Stone
4. Bricks
5. Cement and concrete blocks
6. Mortar
7. Fine aggregate
8. Coarse aggregate
9. Questions

- ***Building materials, Natural stone, earth/clay, cement, lime, mortar, sand, reinforced concrete (origin, characteristics, composition, production, preparation, properties, standards)***

Finishing materials, Building techniques and structural concepts,

Masonry Constructions using stone, bricks, blocks

Concrete construction, Water/damp proofing

- ***Building elements, foundations to roofs-with respect to the materials, Building Circulation-stairs and ramps***

-Symbols and abbreviations, material representations and dimensioning.

1.1 Introduction

- Materials which are required for construction of buildings are referred as building materials.
- Building materials are classified into three types
  - Natural Materials: - naturally occurring materials namely wood, stone, mud or clay etc.
  - Artificial materials: - man-made materials namely bricks, cement, glass & steel.
  - Composite materials: - These are combination of two or materials namely concrete, plywood etc.

1.2 Earth/Clay

Definition

- The simplest classification of geological deposits falls generally in to two major classes to provide engineers and others with basic information which is:
- **Rock**:- which refers mainly to a hard rigid and strongly cemented deposit, and
- **Soil**: - Which refers to the soft, or loose and cemented deposis.

Importance

- For construction purposes
- Structure implementation
- Foundation choices
- Reduce the risk of soil/ foundation failure

Soil Stratum

2 layers

- **Top soil**
  - 150-300mm from soil surface
  - Contains vegetation, rubbish & rotten materials
  - Not suitable in supporting foundation/structure
  - Usually the top soil will be cart away before construction

- **Ground soil**
  - Situated between top soil and rock layer
  - The thickness of the soil varies depending on the rock formation
  - This layer are compacter naturally which occasionally can support light construction

Soil formation

- Transported soil
- Residual soil
- Organic soil

Transported soil

- Produced by the formation of wind and water
- Dust flown by wind
- Gravel, sand, silt and clay

Residual soil

- Top soil & laterite
- Weathering action on rock fragments which breaks and crushed and becomes smaller pieces

Organic Soil

- Top soil & peat
- Produce by the formation of rotten vegetation and animals

2.1 Stones

Stones are naturally occurring building materials which are widely used in construction of buildings. Nowadays it has become an important source of aggregate (coarse & fine) for manufacturing concrete.

Sources of stone are rock which is not homogeneous in nature, any definite chemical composition and shape.

Classification of rocks

Stones used for

- Geological Classification
- Physical Classification
- Chemical Classification

Geological Classification

Based on their origin of formation stones are classified into three main groups

(i) Igneous rocks
(ii) Sedimentary rocks and

(iii) (iii)Metamorphic rocks

Igneous Rocks: The inside portion of the earth's surface has high temperature so as to cause fusion by heat at even ordinary pressures. The molten or pasty rock material is known as the Magma occasionally tries to come out to the earth's surface through cracks or weak portions. The rocks which are formed by cooling of magma are known as the igneous rocks.

Different types of igneous rocks are

Plutonic rocks, hypabyssal rocks and volcanic rocks.

(i) **Sedimentary Rocks**: formed by the deposition of products of weathering on the pre-existing rocks. All the products of weathering are ultimately carried away from their place of origin by the agents of transport. Such agents are frost, rain, wind, flowing water etc.

(ii) **Metamorphic Rocks**: These rocks are formed by the change in character of the pre-existing rocks. The igneous as well as sedimentary rocks are changed in character when they are subjected to great heat and pressure. The process of change is known as the metamorphism.

Physical Classification

Based on the structure, the rocks may be classified as:

i. Stratified rocks
ii. Unstratified rocks
iii. Foliated rocks

i. **Stratified Rocks**: These rocks are having layered structure. They possess planes of Stratification or cleavage. They can be easily split along these planes. Sand stones, lime stones, slate etc. are the examples of this class of stones.

ii. **Unstratified Rocks**: These rocks are not stratified. They possess crystalline and compact grains. They cannot be split in to thin slab. Granite, trap, marble etc. are the examples of this type of rocks.

iii. **Foliated Rocks**: These rocks have a tendency to split along a definite direction only. The direction need not be parallel to each other as in case of stratified rocks. This type of structure is very common in case of metamorphic rocks.

Chemical Classification

On the basis of their chemical composition engineers prefer to classify rocks as:

1) Silicious rocks
2) Argillaceous rocks and
3) Calcareous rocks

1) **Silicious rocks**: The main content of these rocks is silica. They are hard and durable. Examples of such rocks are granite, trap, sand stones etc.

2) **Argillaceous rocks**: The main constituent of these rocks is argil i.e., clay. These stones are hard and durable but they are brittle. They cannot withstand shock. Slates and laterites are examples of this type of rocks.
3) **Calcareous rocks**: The main constituent of these rocks is calcium carbonate. Limestone is a calcareous rock of sedimentary origin while marble is a calcareous rock of metamorphic origin.

Requirements of good building stones

1) **Crushing Strength**: For a good building stone, the crushing strength should be greater than 100N/mm^2.
2) **Appearance**: The stones which are to be used for face work should be decent in appearance and they should be capable of preserving their color uniformly for longtime.
3) **Durability**: A good building stone should be durable. The various factors contributing to durability of a stone are its chemical composition, texture, resistance to atmospheric and other influences, location in structure etc.
4) **Facility of dressing**: The stones should be such that they can be easily carved, molded, cut and dressed.
5) **Fracture**: for a good building stone, its fracture should be sharp, even, bright and clear with grains well cemented (means bonded) together.
6) **Hardness**:
7) **Percentage wear**: If wear is more than 3%, the stone is not satisfactory. If it is equal to 3%, stone is just tolerable. For a good building stone, the wear should be equal to or less than 3%.
8) **Resistance to fire**: The minerals composing stone should be such that shape of stone is preserved when fire occurs. The failure of stone in case of fire may be due rapid rise in temperature, sudden cooling and different coefficients of linear expansions of minerals.
9) **Seasoning**: the stones should be well seasoned before putting into use. Stones should be dried or seasoned before they are used in structural work. A period about 6 to 12 months is considered to be sufficient for proper seasoning.
10) **Specific gravity**: for a good building stone, its specific gravity should be greater than 2.7 or so. The heavy stones are more compact and less porous and they can be used for various engineering applications like dams, harbors etc.
11) **Texture**: A good building stone should have compact fine crystalline structure from cavities, cracks or patches of soft or loose material.
12) **Toughness index:** In impact test, if the value of toughness index comes below 13, stone is not tough. If it comes between 13 and 19, stone is said to be moderately tough. If it exceeds 19, the toughness of stone is said to be high.
13) **Water absorption:** All the stones are more or less porous, but for a good building stone, percentage absorption by weigh after 24hrs should not exceed 0.6. The porous stones seriously affect the durability of stones.

14) **Weathering:** A good building stone should possess better weathering qualities. It should be capable of withstanding adverse effects of various atmospheric and external agencies such as rain, frost, wind etc.

Dressing of stones

Stones after being quarried are to be cut into suitable sizes and with suitable surfaces. This process is known as the dressing of stones and is carried out for the following purposes.

- To get the desired appearance from stone work.
- To make the transport form quarry easy and economical
- To suit to the requirements of stone masonry
- To take advantage of local men who are trained for such type of work.

With respect to the place of work, dressing can be divided into two types namely

- Quarry dressing
- Site dressing

Following are various types of finishes that can be obtained by dressing.

1) **Axed Finish**:
2) **Boasted or droved finish**:
3) **Chisel-draughted margins**:
4) **Circular finis**.
5) **Dragged or combed finish**:
6) **Furrowed finish:**
7) **Molded finish:**
8) **Hammer-dressed finish:**
9) **Plain finish:**
10) **Polished finish:**
11) **Punched finish:**
12) **Tooled finish:**

Deterioration of stones

The stones with exposed faces are acted upon by various atmospheric and external agents so as to cause their deterioration. Following are the cause for deterioration of stones.

1) **Alternative wetness and drying**: The stones are made wet by various agencies such as rain, frost, dew etc. Such wet surface is dried by sunlight. It is found that stones subjected to such alternate wetness and drying wears out quickly.

2) **Frost**: In hill stations or very cold places, the moisture present in the atmosphere is deposited in the pores of stones. At freezing point, this moisture freezes and it expands in volume which causes the splitting of stone.
3) **Impurities in atmosphere**: The atmosphere contains various impurities which have adverse effects on stones. For instance, the acids and fumes are predominant in industrial areas. These impurities acts on carbonates of lime and causes deterioration.
4) **Living organisms**: Some living organisms like worms an bacteria act upon stones and deteriorate them. The organisms make holes in stones and thus weaken them. They also secrete organic acids which have a corrosive effect on stone minerals.
5) **Movement of moisture**: If stones of different variety such as limestone and sandstone are used side by side in the same structure, the chemicals formed by the action of atmospheric agents on one stone may move to the other and cause deterioration of both stones.
6) **Nature of mortar**: The nature of mortar used as a binding material in stone masonry may be such that it may react chemically with any one of the constituents of stones and thus it may lead to the disintegration of stones.
7) **Rain water**: The action of rain water on stones is two-fold – physical and chemical.

The rain wets the surface of stone and it is dried by sunlight. Such alternate wetness and drying results in the disintegration of stones. This is the physical action of water.

The rain water, as it descends through the atmosphere to the surface of earth, absorbs carbon dioxide (CO_2), hydrogen sulphide (H_2S) and other gases present in the atmosphere. These gases acts adversely on stones and they cause decay of stones. This is the chemical action of rain water.

8) **Temperature variations**: the rise of temperature results in expansion of stones. The fall of temperature causes contraction of stones. If rise and fall of temperatures are frequent, the stones are easily deteriorated because of the setting up internal stresses.
9) **Vegetative growth**: The creepers and certain trees develop on stone surface with their roots in joints between stones. Such roots attract moisture and keep the stone surface damp. At the same time they try to expand. Such actions accelerate the decay of stones.
10) **Wind**: The wind contains fine particles of dust. If is blowing with high velocity, such particles will strike against the stone surface and thus the stones will be decayed. The wind also allows rain water to enter pores of stones with force. Such water on freezing expands and split the stones.

Preservation of stones

The decay of building stones of inferior is to some extent prevented if they are properly preserved. For this purpose, the preservatives are applied on the stone surfaces. An ideal preservative has the following properties:

1. It does not allow moisture to penetrate the stone surface.
2. It does not develop objectionable color.

3. It hardens sufficiently in order to resist the atmospheric agents.
4. It is easily penetrated in stone surface.
5. It is economical
6. It is non-corrosive and harmless.
7. It remains effective for long time after drying.
8. Its application on stone surface is easy.

The choice of a preservative depends on chemical composition and location of structure.

Following are the preservatives which are commonly adopted to preserve the stone:

(i) **Coal tar**: If coal tar is applied on stone surface, it preserves stone. But the color of coal tar produces objectionable appearance and surface coated with color tar absorbs heat of the sun. Hence this preservative is not generally adopted because it spoils the color of the stone.
(ii) **Linseed oil**:
(iii) Paint: An application of paint on stone surface serves as a preservative. The paint changes the original color of the stone. It is applied under pressure, if deep penetration is required.
(iv) Paraffin:
(v) Solution of alum & soap: on stone surface it acts as preservative.
(vi) Solution of baryta:

1.3. Bricks

are obtained by moulding clay in rectangular blocks of uniform size and then by drying and brining these blocks.

As bricks are of uniform size, they can be properly arranged and further they are light in weight. The bricks do not require any dressing and the art of laying bricks is simple, so that it can be carried out with the help of unskilled labors. Thus, at places where stones are not easily available and if plenty of clay is available we go for manufacturing the bricks. Thus bricks replace stones.

Classification of brick earth

1) **Loamy, mild or sandy clay:** consists of considerable amount of free silica in addition to alumina. The presence of sand helps in preventing cracking, shrinkage and warping of bricks. The addition of lime in such clay helps to fuse sand and there by increases the hardness of bricks.
2) **Marls, chalky or calcareous clay**: consists of considerable amount of chalk in addition to alumina and silica. Such clay generally makes good bricks. But to avoid undesirable effects of excess lime, the sand is sometimes added to such clay.
3) **Plastic, strong or pure clay**: This clay consists of alumina and silica which is sometimes referred as strong or fat clay. The raw bricks will cracks, shrink and wrap during drying, if pure clay alone is used in making of bricks. Hence such clay

is corrected by the addition of sand and ash. The sand prevents shrinkage and ash provides lime to act as flux.

Manufacturing of clay bricks

Following are the considerations which governs the selection of brick field for manufacturing of bricks:

1. It should be linked up with communicating roads so that the materials can be conveyed easily.
2. It should be situated on a plain ground
3. It should be selected in such a way that the earth required for manufacturing of bricks is readily and easily available.
4. It should offer all the facilities to the workers employed in the

manufacturing process. In the process of manufacturing bricks, the following

four distinct operations are involved.

a) **Preparation of clay**
b) **Molding**
c) **Drying**
d) **Burning**

1. Preparation of clay: The clay for bricks is prepared in the following order

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

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

Cleaning: The clay as obtained in the process of digging should be cleaned of stones, pebbles, vegetative matter etc. If these particles are in excess, the clay is to be washed and screened. Such a process naturally will prove to be troublesome and expensive. The lumps of clay should be converted into powder form in the earth crushing roller.

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

Tempering: In the process of tempering, the clay is brought to a proper degree of hardness and it is made fit for the next operation of moulding. The water in required quantity is added to clay and the whole mass is kneaded or pressed under the feet of men or cattle. The tempering should be done exhaustively to obtain homogeneous mass of clay of uniform character.

Moulding: The Clay which is prepared as above is then sent for the next operation of moulding. Following are the two ways of moulding:

1) **Hand Moulding**: In case of hand moulding, the bricks are moulded by hand i.e., manually. It is adopted where manpower is cheap and is readily available for the manufacture process of bricks on a small scale. The bricks shrink during drying and burning. Hence the moulds are made larger than size of fully burnt bricks. The moulds are therefore made longer by about 8 to 12 percent in all directions.

The bricks prepared by hand moulding are of two types

- **Ground-moulded bricks**: The ground is first made level and fine sand is sprinkled over it. The mould is dipped in water and placed over the ground. The lump of tempered cla is taken and it is dashed into the mould. The clay is pressed or forced in the mould in such a way that it fills all the corners of mould. The extra or surplus clay is removed either by wooden strike or metal strike or frame with wire. A strike is a piece of wood or metal with sharp edge. It is to be dipped in water every time.

  The mould is then lifted up and the raw bricks are left on the ground. The mould is dipped in water and it is placed just near the previous brick to prepare another brick. The process is repeated till the ground is covered with raw bricks.

  A brick moulder can mould 750 bricks per day with working period of 8hrs. When such bricks become sufficiently dry, they are carried and placed in the drying sheds.

  The bricks prepared by dipping the mould in water every time are known as the **slop- moulded bricks**. The fine sand or ash may be sprinkled on the inside surface of mould instead of dipping it water. Such bricks are known as sand-moulded bricks and they have sharp and straight edges.

- **Table moulded bricks:** The process of moulding these bricks is just similar as above. But in this case, the moulder stands near a table of size about 2m X1m. the clay, mould, water pots, stock board, strikes and pallet boards are placed on this table. The bricks are moulded

  on the table and sent for the further process of drying. However the efficiency of moulder decreases gradually because of standing at same place for long duration. The cost of brick moulding also increases when table moulding is

adopted.

2) Machine moulding: The moulding may also be achieved by machine. It proves to be economical when bricks in huge quantity are to be manufactured at the same spot in a short time. It is also helpful for moulding hard and strong clay. These machines are broadly classified into two categories:

a) Plastic clay machines: Such machines contain a rectangular opening of size equal to length and width of a brick. The pugged clay is placed in the machine and as it comes out through the opening, it is cut into strips by wires fixed in frames. The arrangement is made in such a way that strips of thickness equal to that of the brick are obtained. As the bricks are cut by wire, they are called **wire cut bricks.**

b) Dry clay machines: In these machines, he strong clay is first converted into powder form. A small quantity of water is then added to form a stiff paste. Such paste is placed in mould and pressed by machine to from a hard and well shaped bricks. These bricks are known as the pressed bricks and they do not practically require drying. They can be sent directly to the process of burning.

The wire cu bricks and pressed bricks have regular shape, sharp edges and corners. They have smooth external surfaces. They are heavier, stronger and exhibit uniform dense texture than ordinary hand-moulded bricks.

(i) **Drying**: The damp brick, if burnt, are likely to be cracked and distorted. Hence the moulded bricks are dried before they are taken into next step of operation i.e., burning. For drying, the bricks are arranged longitudinally in stacks (means racks) of width equal to two bricks. A stack may contain 8 to 10 tires. The bricks are arranged along and across the stacks in alternate layers. All bricks are placed on edge. The bricks are allowed to dry till they become hard with moisture content of about 2% or so.

a. **Artificial burning**: The bricks are generally died by natural process. But when bricks are to be rapidly dried on a large scale, the artificial drying may be adopted. In such case, the moulded bricks are allowed to pass through dryers which are in the form of tunnels or hot channels or floors. Such dryers are heated with the help of special furnaces or by the hot flue gases. The tunnel dryers are more economical compared to hot floor dryers.

b. **Circulation of air**: The bricks in stacks should be arranged in such a way that sufficient air space is left between them for circulation of air.

c. **Drying yard**: For the drying purpose, special drying yards should be prepared. It should be slightly on a higher level and it is desirable to cover it with sand. Such an arrangement would prevent the accumulation of rain water.

d. **Period for drying**: The time required by moulded bricks to dry depends on prevailing weather conditions. Usually it takes about 3 to 10 days for bricks to become dry.

e. **Screens**: It is to be seen that bricks are not directly exposed to the wind or sun fo drying. Suitable screens, if necessary, may be provided to avoid such situations.

(ii) **Burning**: This is a very important operation in the manufacturing process of bricks. It imparts hardness and strength to the bricks and makes them dense and durable. The bricks should be burnt properly. If bricks are over burnt, they will be brittle and hence break easily. If they are under burnt, they will be soft and hence cannot carry loads.

When the temperature of dull red heat, about 650^0C, is attained, the organic matter contained in the brick is oxidized and also the water of crystallization is driven away. But heating of bricks is done beyond this limit for the following purposes

1. If the bricks are cooled after attaining the temperature of about 650^0C, the bricks formed will absorb moisture from the air and gets rehydrated.
2. The reactions between the mineral constituents of clay are achieved at higher temperature and these reactions are necessary to give new properties such as strength, hardness, less moisture absorption, etc. to the bricks.

When the temperature of about 1100^0C is reached, the particles of two important constituents of brick clay minerals namely, alumina and sand, binds themselves together resulting in the increase of strength and density of bricks. Further heating is not desirable and if the temperature is raised beyond 1100^0C, a great amount of fusible glassy mass is formed and the bricks are said to be vitrified. The bricks begin to lose their shape beyond a certain limit of vitrification.

The burning of bricks is done either in clamps or in kilns. The clamps are temporary structures and they are adopted to manufacture bricks in small quantity to serve a local demand or a specific purpose. The kilns are permanent structures and they are adopted to manufacture bricks on a large scale.

Qualities of good brick

1. The bricks should be table-moulded, well-burnt in kilns, copper-colored, free from cracks and with sharp and square edges. The color should be uniform and bright.
2. The bricks should be uniform in shape and should be of standard size.
3. The bricks should give a clear metallic ringing sound when stuck with each other.
4. The bricks when broken or fractured should show a bright homogenous and uniform compact structure free from voids.
5. The bricks should not absorb water more than 20 percent by weight for I class brick and 22 percent by weight for II class brick when soaked in water for 24hrs.
6. The bricks should be sufficiently hard. No impression should be left on brick surface, when it is scratched with finger nail.
7. The bricks should not break into pieces when it is dropped on hard ground from a height of 1 meter.
8. The bricks should have low thermal conductivity and they should be sound-proof.
9. The bricks when soaked in water for 24hrs should not show deposits of white salts when allowed to dry in shade.

10. No brick should have the crushing strength less than 3.5 N/mm^2.

Tests on Bricks

(1) **Absorption:** A brick is taken and it is weighed dry. It is then immersed in water for a period of 16hrs. It is weighed again and the difference in weight indicates the amount of water absorbed by brick. It should not in any case exceed 20% of weight of drybrick.
(2) **Crushing** strength: The crushing strength of a brick is found out by placing it in a compression testing machine. It is pressed till it breaks. As per the code IS: 1077-1970, the minimum crushing strength should not be less than 3.5N/mm^2. The brick with crushing strength of about 7 to 14 N/mm^2 are graded as A and those having greater than 14N/mm^2 are graded as AA.
(3) **Hardness**: In this test, a scratch is made on brick surface with the help of a finger nail. If no impression is left on the surface, the brick is treated to be sufficiently hard.

Presence of soluble salts: the soluble salts, if present in bricks, will cause efflorescence on the surface of bricks. For finding out the presence of soluble salts in a brick, it is immerse in water for 24hrs. It is then taken out and allowed to dry in shade. The absence of grey or white deposits on its surface indicates the absence of soluble salts

If the white deposits cover about 10% surface, the efflorescence is said to be slight and it is considered as moderate, when the white deposits cover about 50% o surface. If grey or white deposits are found on more than 50% of surface, the efflorescence becomes heavy and it is treated as serious.

(4) **Shape and size**: In this test, a brick is closely inspected. It should be of standard size and its shape should be truly rectangular with sharp edges. For this purpose, 20 bricks (19cm X 9cm X 9cm) are selected at random and they are stacked lengthwise, along the width and along the height.
For good quality bricks, the results should be within the following permissible limits. Length: 3680mm to 3920mm
Breadth: 1740mm to 1860mm Height: 1740mm to 1860mm
(5) **Soundness:** In this test, the two bricks are taken and they are trucked with each other. The bricks should not break and a clear ringing sound should be produced.
(6) **structure:** A brick is broken and its structure is examined. It should be homogeneous, compact and free from any defects such as holes, lumps etc.

Classification of bricks

He bricks can be broadly classified into two categories as follows:

1. The un-burnt or sun-dried bricks are dried with the help of heat received from sun after the process of moulding. These bricks can only be used in the construction of temporary and cheap structures. Such bricks should not be used at places where they are exposed to heavy rains.
2. The bricks used in construction field are burnt bricks I Class Bricks:

1.6 Mortar

The term mortar is used to indicate a paste prepared by adding required amount of water to a mixture of binding material like cement or lime and fine aggregate like sand.

Classification of Mortar

Mortars are classified based on the following factors:

1. **Bulk density**: According to the bulk density, mortars are classified as

a. **Heavy mortars**: The mortars whose bulk density is greater than equal to 15KN/m^3 are known as heavy mortars and they are prepared from heavy quartz or other sands.

b. **Light-weight mortars**: The mortars whose bulk density is less than 15KN/m^3 are known as light-weight mortars and they are prepared from light porous sands from pumice and other fine aggregates.

2. **Kind of binding material**: The kind of binding material for a mortar is selected based on working conditions, hardening temperature, moisture conditions etc. according to kind of binding material, mortars are classified as follows:

i. **Lime mortar**: In this type of mortar, lime is used as binding material. The lime may be fat lime or hydrated lime.

The fat lime shrinks to a great extent and hence it requires about 2 to 3 times its volume than sand. The lime should be slaked before use. This mortar is undesirable for water-logged areas or in damp situations.

ii. **Surkhi mortar**: This type of mortar is prepared by using fully Surkhi instead of sand or by replacing half of sand in lime mortar..

The Surkhi mortar is used for ordinary masonry works of all kinds in foundation and super-structure. But it cannot be used for plastering or pointing works. Since Surkhi is likely to disintegrate after some time.

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

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

iii. **Gauged mortars**: To improve the quality of lime mortar and to achieve early strength, the cement is sometimes added to it. This process is known as gauging. It makes the lime mortar economical, strong and dense. The usual proportion of cement to lime by volume is about 1:6 to 1:8. It is also known as the composite mortar or lime-cement mortar and it can also be formed by the combination of clay. This mortar may be used for bedding and for thick brick walls.

iv. **Gypsum mortar**: These mortars are prepared from gypsum binding materials such as building gypsum and anhydrate binding materials.

3. **Nature of application**: According to the nature of application, the mortars are classified into two categories:

1. **Brick laying mortars**: The mortars for brick lying are intended to be used for brickwork and walls. Depending upon the working conditions and type of construction, the composition of masonry mortars with respect to the kind of binding material is decided.
2. Finishing mortars: These mortars include common plastering work and mortars for developing architectural or ornamental effects. The cement or lime is generally used as binding material for ordinary plastering mortars. For decorative finishing, the mortars are composed of suitable materials with due consideration of mobility, water retention, resistance to atmospheric actions etc.

4. **Special mortars:** Following are the various types of special mortars which are used for certain conditions:

1. **Fire resistant mortars**: The mortar is prepared by adding aluminous cement to the fine crushed powder of fire bricks. The usual proportion is 1 part of aluminous cement to 2 parts of powder of fire bricks. This mortar is fire resistant and it is therefore used with fire bricks for lining furnaces, fire places, ovens etc.
2. **Light-weight mortars:** This mortar is prepared by adding materials such as sawdust, wood powder etc., to the lime mortar or cement mortar. Other materials which may be added are asbestos fibers, jute fibers, coir etc. This mortar is used in the sound-proof and heat-proof constructions.
3. **Packing mortars:** To pack oil wells, special mortars possessing the properties of high homogeneity, water-resistance, pre-determined setting time, ability to form solid water- proof plugs in cracks and voids of rocks, resistance to sub-soil water pressure etc., have to be formed. The varieties of packing mortars include cement-sand, cement-loam, and cement-sand-loam. The composition of packing mortar is decided by taking into consideration of hydro-geologic conditions, packing methods and type of timbering.
4. **Sound absorbing mortars:** To reduce the noise level, the sound absorbing

plaster is formed with the help of sound absorbing mortars. The bulk density of such a mortar varies from 6 to 12 KN/m^3 and the binding materials employed in its composition may be

Portland cement, lime, gypsum, slags etc. The aggregates are selected from light-weight porous materials such as pumice, cinders etc.

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

Properties of good mortar

The important properties of a good mortar mix are mobility, place ability and water retention.

- The term mobility is used to indicate the consistency of mortar mix which may range from stiff to fluid. The mobility of mortar mix depends on the composition of mortar and the mortar mixes to be used for masonry work, finishing work etc., are made sufficiently mobile.
- The placeability or the ease with which the mortar mix can be placed with minimum cost in a thin and uniform layer over the surface depends on the mobility of the mortar. The placeability of the mortar mix should be such that a strong bond should be developed with the surface of the bed.
- A good mortar mix should possess the ability of retaining adequate humidity during transportation and laying over the porous bed. If water retention power of the mortar mix is low, it separates into layers during transportation and when it comes into contact with porous bed such as brick, wood etc., it gives away its water to the surface. Thus the mortar becomes poor in amount of water and the remaining water proves to be insufficient for its hardening. Hence the required strength of mortar will not be achieved with such a mortar mix.

Following are the properties of good mortar

1. It should be capable of developing good adhesion with the building units such as bricks, stones etc.
2. It should be capable of developing the designed stresses.
3. It should be capable of resisting penetration of rain water.
4. It should be cheap.
5. It should be durable.
6. It should be easily workable.

Aggregates
Introduction

Aggregates are defined as inert, granular and inorganic materials that normally consist of stone or stone like solids. Aggregates can be used alone (in road bases and various types of fill) or can be used with cementing materials (such as Portland cement or asphalt cement) to form composite materials or concrete.

Since aggregates constitutes about $3/4^{th}$ of the volume of concrete, it contributes significantly to the structural performance of concrete especially strength, durability and volume stability. Aggregates are formed from natural sources by the process of weathering and abrasion or by artificially by crushing a large parent rocks.

Classification of aggregates

Aggregates can be divided into several categories according to different criteria.

a) **In accordance with size**:

Coarse aggregate: if particle size is greater than 4.75mm are regarded as coarse aggregates

Fine aggregates: if particle size in between 75μ & 4.75mm are regarded as fine aggregates

b) **In accordance with sources**:

Natural aggregates: This kind of aggregates is taken from natural deposits without changing their nature during the process of production such as crushing and grinding. Some examples in this category are sand, crushed limestone and gravel.

Manufactured aggregates: This is a kind of man-made materials produced as main product or an industrial by-product. Some examples are blast furnace slag, lightweight aggregate (e.g. expanded perlite), and heavy weight aggregates (e.g. iron ore or crushed steel.

c) **In accordance with unit weight**:

Light weight aggregates: the unit weight of aggregates is less than 1120kg/m^3. The corresponding concrete has a bulk density less than 1800kg/m^3. (Cinder, blast-furnace slag, volcanic pumice).

Normal aggregates: The aggregates have unit weight of 1520-1680kg/m^3. The concrete made with this type of aggregates has a bulk density of bulk density of 2300-2400kg/m^3.

Heavy weight aggregate: The unit weight is greater than 2100kg/m^3. The bulk density of the corresponding concrete is greater than 3200kg/m^3. A typical example is magnesite limonite, a heavy iron ore. Heavy weight concrete is used in special structures such as radiation shields.

Fine Aggregates Grading of aggregates

- Particle size distribution of an aggregate is determined by sieve analysis is known as "Grading of the aggregate"
- Aggregate comprises about 55% of the volume of mortar and about 85% of volume of concrete. Mortar contains aggregates of size 4.75mm and the concrete contains aggregates up to a max. Size of 150mm.
- Strength of concrete is dependent upon water-cement ratio. One of the most important factors for producing workable concrete is good grading of aggregates.
- Grading of aggregates are of 3 types

Good graded or well graded: It implies that a given sample of aggregates contains all standard fractions such there will be minimum number of voids.

Uniformly graded or poor graded: It contains aggregate particles that are almost of the same size. This means that the particles pack together, leaving relatively large voids in the concrete.

Gap graded: It consists of aggregate particles in which some intermediate size particles are missing.

1.7 Coarse Aggregates

Importance of size, shape and surface texture of aggregates on workability and strength

- **Size of aggregate:** Bigger the size of particles less will be the surface area and hence less amount of water is required and also less cement paste required for lubricating the surfaces of aggregates. So bigger the size, gives higher workability.
- **Shape of aggregate:** Angular, elongated or flaky aggregates make the concrete very harsh when compared to rounded or cubical aggregates. Contribution to better workability of rounded aggregate will come from the fact that for a given volume or weight. It will have a less surface area and less voids. Not only is that being in rounded in shape, the frictional resistance between the aggregates also reduced. Hence the workability will be more in case of rounded than compared to flaky aggregates. Hence the strength will be more by using rounded or cubical aggregates.
- **Surface texture:** Surface texture is the property, the measure of which depends upon the relative degree to which particle surface are polished or dull, smooth or rough. Surface texture depends on hardness, grain size, pore structure and structure of the rock.

  Total surface area of rough texture aggregate is more than that of surface area of smooth rounded aggregates of same volume. Rough textured aggregates will show poor workability and smooth textured aggregates will give better workability because of lesser frictional resistance of inner surface particle.