Al-Mansour University College

قسم الهندسة المدنية
المرحلة الاولى

Civil Eng. Dept
1st. Stage

# Building Materials

2022 – 2023

# Sheet- 1

# مواد البناء

**Almansour University College**

**Civil Engineering Department**

**First year- First Semester**

**Building Materials**

## SYLLABUS

**Chapter one:** Principle properties of building materials.

1.1. Introduction to properties of Materials

1.2. Physical Properties:

Density, bulk density, specific gravity, types of specific gravity, porosity, permeability, and how calculated it.

1.3. Mechanical Properties:

Behavior of ductile and brittle materials, Durability, stress, types of stress, strain and it types, Stress- strain curve for different types of building materials.

**Chapter Two:** Masonry units.

2.1. Classification of masonry units
2.2. Clay brick, classification according to IQS
2.3. Manufacture of clay brick, harmful materials
2.4. Harmful materials in clay brick
2.5. Effect of deferent ions on properties of clay brick
2.6. Sand lime brick, uses, properties
2.7. Thermostone
2.8. Concrete brick, properties, uses
2.9. Glass brick properties, uses

## References


- Duggal, S. K. Building materials. Routledge.
- Mamlouk, M. S, & Zaniewski, J. P. (2006). Materials for civil and construction engineers: Pearson Prentice Hall.

# Properties of Building Materials

Engineers are responsible for the selection, specifications and quality control of materials to be used in a job. The principal properties of building materials predetermine their applications. Only a good knowledge of the properties of materials allows a correct choice of materials for the construction of certain structure.

Two types of properties of building materials are discussed below:

## (A) Physical Properties

### (1) Density ( ρ ):

Density is the mass of a unit volume of homogeneous material. It is denoted by the following equation:

$\rho = M / V$ (gm / cm³), where :
$M$ = mass ( gm),ρ
$V$ = volume (cm³)

Density of some building materials:

| Material | Density (gm/cm³) |
|---|---|
| Brick | 2.5 – 2.8 |
| Granite | 2.6 – 2.9 |
| Portland cement | 2.9 – 3.1 |
| Wood | 1.5 – 1.6 |
| Steel | 7.8 – 7.9 |

## (2) Bulk Density ( $\rho_b$):

Bulk density is the mass of a unit volume of material in its natural state (with pores and voids). The following equations are used for bulk density:

$$\rho_b = \frac{M}{V} \quad (kg / m^3) \text{, where :}$$

M = mass of specimen (kg)
V = volume of specimen in its natural state ($m^3$)

Note : Bulk density may be expressed in ( gm / $cm^3$), but this may presents some Inconvenience and this is why it is generally expressed in (kg / $m^3$). For example, the bulk density of reinforced concrete is preferably expressed as (2500 kg/$m^3$) rather than (2.5 gm/ $cm^3$).

For most materials, bulk density is less than density, but for liquids and materials like glass and dense stone, the two parameters are practically the same.
Properties like strength and heat conductivity are greatly affected by their bulk density.
Bulk densities of some building materials are given below:

| Material | Bulk Density (kg/$m^3$) |
|---|---|
| Brick | 1600 – 1800 |
| Granite | 2500 – 2700 |
| Sand | 1450 – 1650 |
| Pine Wood | 500 -- 600 |
| Steel | 7850 |

## (3) Density Index ($\rho_o$) is the ratio of bulk density divided by the density.

$$\rho_o = \text{Bulk density / density} = \frac{\rho_b}{\rho}$$

Density index indicates the degree to which the volume of a material is filled with solid matter. For almost all building materials ( $\rho_o$) is less than 1.0 because there are no absolutely dense bodies in nature.

## (6) Porosity (n)

Porosity is the degree to which the volume of the material is filled with pores. Porosity is expressed as a ratio of the volume of pores to the volume of the specimen.

$$n = \frac{V_v}{V}$$

Porosity is indicative of other properties of the material, such as bulk density, heat conductivity, durability, etc. Dense materials which have low porosity are used for constructions requiring high mechanical strength. On the other hand, walls of buildings are commonly built of materials with high porosity. The following is the relationship between the void ratio (e) and the porosity:

$$n = \frac{e}{1+e}$$

## (7) Void Ratio (e)

Void ratio is defined as the ratio of volume of voids (Vv) to the volume of solids (Vs).

$$e = \frac{Vv}{V_s}$$

## Methods of Measuring Voids

There are two methods commonly used for measuring voids in a material:

### (i) Direct method:

This method consists of determining the volume of water required to fill the voids in a given quantity of a material. Since in pouring water into fine aggregate it is impossible to expel all the air between the particles, the measured voids are smaller than the actual. Therefore, the above direct method should not be used with fine aggregate unless the test is conducted in a vacuum.

## (9) Ductility:

Ductility is defined as the ability of a material to undergo large deformations without rupture before failure.

### Ductility Requirements for Buildings

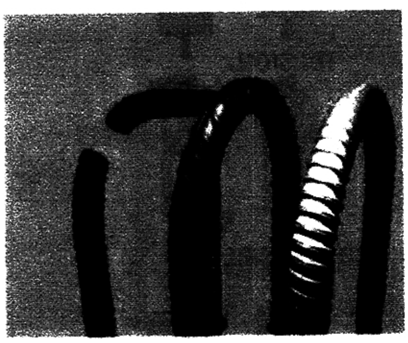
Ductility in concrete is defined by the percentage of steel reinforcement within it. Mild steel is an example of a ductile material that can be bent and twisted without rupture.

For structural members such as steel, ductility may be defined as the ratio of absolute maximum deformation to the yield of the material. This can be defined with respect to strains, rotations, curvature or deflections.

Strain based ductility definition depends almost on the material, while rotation or curvature based ductility definition also includes the effect of shape and size of the cross-section.

In general, the **ductility** of concrete is **increased** by the following:-

- An increase in compression steel content .
- An increase in concrete compressive strength.
- An increase in ultimate concrete strain.



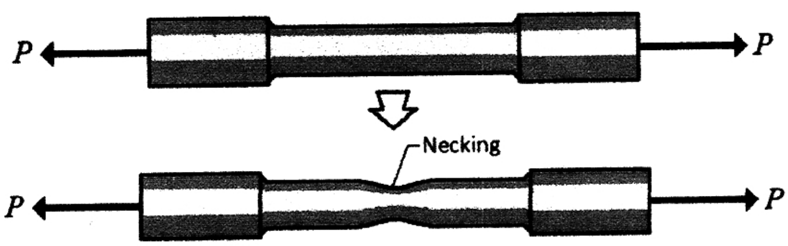



Fig. (1.1) - Behavior of ductile material (steel)

## (10) Brittleness

Brittleness is a property of a material that will fail suddenly without undergoing noticeable deformations.

Brittle structures do not give notice before failure and may collapse and the occupants of a building may not have time to take measures to prevent collapse.

Concrete is an example of brittle material. To avoid failure of structures, the structural engineer must take all measures to increase the ductility of structures. The structural engineer should design a structure functioning as a ductile one by suitably anchoring the reinforcement, thus the ductility of the structure can be increased to greater extent with little increase in cost.

## (11) Durability

Durability is the ability of a material to resist the combined effects of atmosphere and other factors.

A material is considered with good durability when it can resist the following factors:

- Creep and Shrinkage
- Chloride resistance
- Sulfate resistance
- Freezing and thawing resistance
- Corrosion resistance
- Carbonation

## (12) Toughness

Toughness is the property of certain materials which can absorb much energy and deform greatly without rupture under high impact and vibration.

Tough materials are characterized by high tensile strength and high compressive strength such as structural steel, wood and rubber. Tough materials should be used in structures bearing impact and vibration, such as in roads, bridges, cranes and beams.

## (B) Mechanical Properties

The important mechanical properties considered for building materials are: strength, compressive stress, tensile stress, bending , impact, hardness, plasticity, elasticity and abrasion resistance.

### ( a ) Hardness

Hardness refers to the property of a material to resist pressing-in or scratch of a sharp object. The materials of different kinds of hardness need various testing methods. The hardness of steel, wood and concrete is tested by pressing-in method. For example Brinell hardness (HB) test is expressed by the pressure loaded on the press mark per unit area. The hardness of natural minerals is often tested by scratch hardness machine.

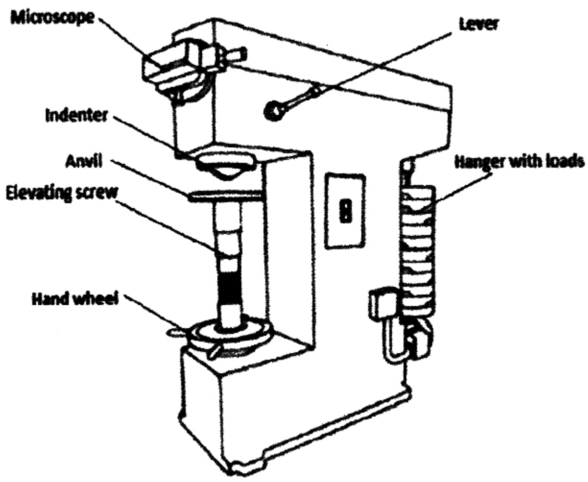



Fig.(1.2) - Hardness testing machine

**Figure (1.3 a)**
This figure shows a linear stress-strain relationship up to the point where the material fails. Glass and chalk are typical materials with this kind of behavior.

**Figure (1.3 b)**
This figure shows the behavior of steel in tension. Here, a linear relationship is obtained up to a certain point called proportional limit, after which the material deforms without much increase in stress.

**Figure (1.3 c)**
This figure shows the behavior of aluminum alloy in tension. Here, linear stress strain relations is obtained up to proportional limit, after which nonlinear relation follows.

**Figure (1.3 d)**
This figure shows a nonlinear relation throughout the whole range. Concrete shows this behavior, although the first portion of the curve is very close to being linear.

**Figure (1.3 e)**
This figure shows the behavior of soft rubber in tension . It is different from most materials that it shows an linear stress-strain relationship followed by reverse curve.

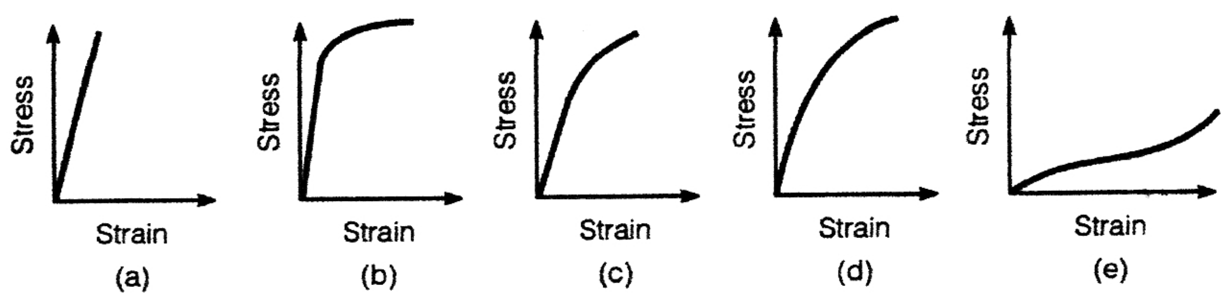



**FIGURE 1.3** Typical uniaxial stress–strain diagrams for some engineering materials: (a) glass and chalk, (b) steel, (c) aluminum alloys, (d) concrete, and (e) soft rubber.

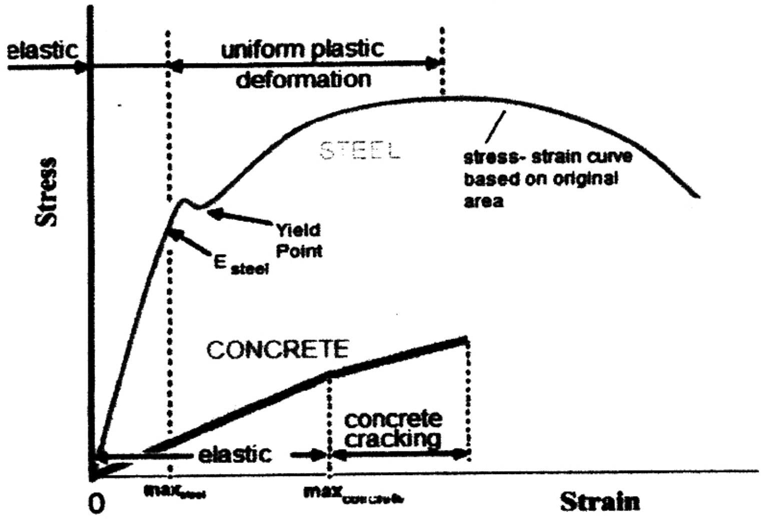



Figure (1.4) . Stress - Strain diagram for Steel and Concrete

## (d) Strength

Strength is the ability of the material to resist failure under the action of stresses caused by loads, the most common types: compression, tension, bending and impact.

Strength is the largest stress that a material can bear under external force (loads) without destruction. According to different forms of external forces, the strength includes tensile strength, compressive strength, bending strength, shear strength and others. These kinds of strength are all determined by static test known as static strength test. The static strength is tested by destructive experiments based on standard methods.

Compressive strength may be defined by the equation : $f = \frac{P}{A}$

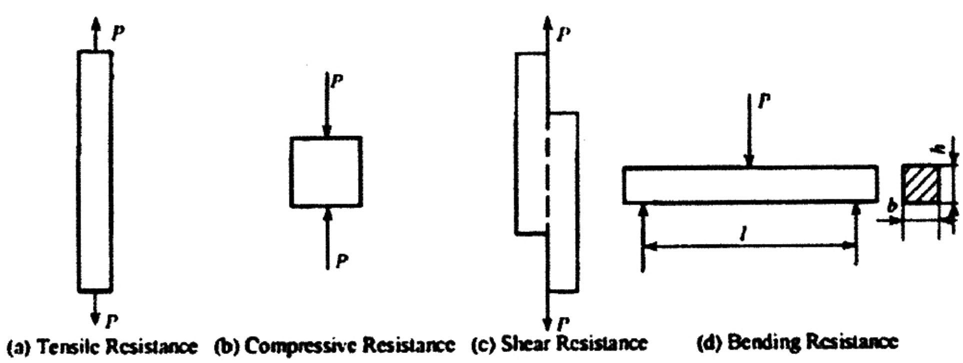



Figure (1.5). Types of Strength in different structural members

Al-Mansour University College

قسم الهندسة المدنية
المرحلة الاولى

Civil Eng. Dept
1st. Stage

# Building Materials

2022 – 2023

# Sheet- 2

# مواد البناء

# CHAPTR TWO

# MASONRY UNITS

## INTRODUCTION

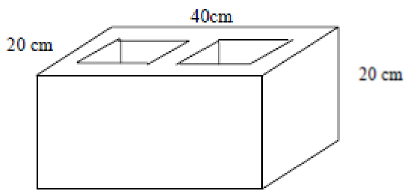
Masonry units can be classified as

- concrete masonry units
- clay bricks
- Sand – Lime bricks
- glass blocks
- thermo stone

## Concrete Masonry Units

These bricks are manufactured from a mixture of Portland cement and aggregate for use in brick masonry. Typical aggregate include sand, gravel, crushed stone and blast furnace slag. Mix proportion varies from 1:2:4 to 1:8:16 according to the required bearing capacity. These bricks are often made hollow for economical purposes and to reduce the weight of the brick. The dimensions of the brick are as follow:

8 Inch Hollow Concrete Blocks - Premiur




- *Uses*:

Concrete bricks are widely used for construction purposes especially in areas where soils are not suitable for manufacture of clay bricks and may be used in the construction of bricks panels for light weight structures and multistory formed structures.

- *Properties of concrete bricks:*

a. The using of these bricks save time and effort as brick are light in weight and big in size.

b. These bricks give good bonding with plastering materials used in their construction.

c. These bricks have accurate size and shape.

d. These bricks can produced with various bearing capacity according to the cement content used in their production.

e. The weight of bricks can be controlled by varying the size of openings.

***Clay bricks***

Clay bricks are small, rectangular blocks made of fired clay. Clays for brick making vary widely in composition from one place to another. Clays are composed mainly of silica (grains of sand), alumina, lime, iron, manganese, sulfur, and phosphates, with different proportions.

- ***Manufacturing of clay brick***

Bricks are manufactured by grinding or crushing the clay in mills and mixing it with water to make it plastic. The plastic clay is then molded, textured, dried, and finally fired.

Bricks are manufactured with different colors, such as dark red, purple, brown, gray, pink, or dull brown, depending on the firing temperature of the clay during manufacturing. The firing temperature for brick manufacturing varies from 900°C to 1200°C. Clay bricks have an average density of (2000kg/$m^3$).

- ***Uses***:

Bricks are used for different purposes, including building, facing and aesthetics, floor making, and paving. *Building bricks* (*common bricks*) are used as a structural material and typically are strong and durable. *Facing bricks* are used for facing and aesthetic purposes and are available in different sizes, colors, and textures. *Floor bricks* are used on finished floor surfaces and are generally smooth and dense and have high resistance to abrasion. Finally, *paving bricks* are used as a paving material for roads, sidewalks, patios, driveways, and interior floors. Paving bricks are available in different colors, such as red, gray, or brown, and typically they are abrasion resistant and could be vitrified.

- ***Harmful substances in clay Brick***

***Lime:*** When a desirable amount of lime is present in the clay, it results in good bricks, but if in excess, it changes the color of the brick from red to yellow. When lime is present in lumps, it absorbs moisture, swells and causes disintegration of the bricks.

***Pebbles, Gravels, Grits:*** do not allow the clay to be mixed thoroughly and spoil the appearance of the brick. Bricks with pebbles and gravels may crack while working.

***Iron Pyrites:*** tend to oxidise and decompose the brick during burning. The brick may split into pieces. Pyrites discolourise the bricks.

***Alkalis (Alkaline salts):*** forming less than 10 per cent of the raw clay, are of great value as fluxes, especially when combined with silicates of alumina. These are mainly in the form of soda or potash. However, when present in excess, alkali makes the clay unsuitable for bricks. They melt the clay on burning and make the bricks unsymmetrical. When bricks come in contact with moisture, water is absorbed and the alkalis crystallise. On drying, the moisture evaporates, leaving behind grey or white powder deposits on the brick which spoil the appearance. This phenomenon is called *efflorescence.* Efflorescence should always be dry brushed away before rendering or plastering a wall; wetting it will carry the salts back into the wall to reappear later.

***Organic Matter:*** On burning green bricks, the organic matter gets charred and leave pores making the bricks porous; the water absorption is increased and the strength is reduced.

***Sulphur:*** is usually found in clay as the sulphate of calcium, magnesium, sodium, potassium or iron, or as iron sulphide. That will cause the formation of a spongy, swollen structure in the brick and the brick will be decoloured by white blotches.

***Water:*** A large proportion of free water generally causes clay to shrink considerably during drying, whereas combined water causes shrinkage during burning.

- ***Classification of clay bricks in accordance with Iraqi standard No. 25 / 1988: Bricks used in construction works are classified into three grades:***

**Grade A:**

Intended for use in building construction and footing subjected to loads and exposed to sever abrasion by weathering action.

**Grade B:**

Intended for use in building construction subjected to loads and not exposed to sever abrasion by weathering action, such as exterior walls not exposed to penetration of water.

**Grade C:**

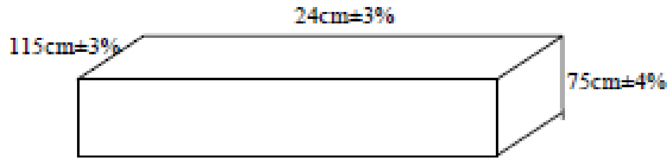
Intended for use in building construction not subjected to loading such as interior masonry walls and partitions, not exposed to sever abrasion by weathering action.

**Appearance**:

A good brick should be rectangular in shape with smooth and even surfaces. They shall be free from cracks and flows and nodules of free lime.

**Dimensions**:

A good brick shall have standard dimensions as shown below:




- Properties of bricks:

The raw materials and the manner and degree of burning influence the physical properties greatly and therefore wide ranges in values are to be expected for each property.

- Compressive strength:

The test is carried out in accordance with Iraqi standard No. 24. The brick placed between two plywood sheets and carefully centered between plates of the compression testing machine. The load shall be applied at a uniform rate until failure occurs.

**Compressive strength = Load at failure/ Cross sectional area subjected to load**


**The efflorescе shall reported as:**

**Nil** – No effloresce visible.

**Slight**- A thin deposit of salts on less than 10% of the area of the brick.

**Moderate**- A heavier deposit of salts covering between 10-50% of the area of the brick, but no powdering or flaking of the surface.

**Heavy –** A heavy deposit of salts covering more than 50% of the area, but no powdering or flaking of the surface.

**Serious** – A heavy deposit of salts and some powdering and flaking of the surface.

**Compressive strength, water absorption and effloresce according to Iraqi standard No. 25/1988:**

| Grade | Effloresce | Minimum compressive strength N/mm$^2$ | | Maximum water absorption | |
|---|---|---|---|---|---|
| | | For one brick | Average for 10 | For one brick | Average for 10 |
| **A** | Slight | 16 | 18 | 22 | 20 |
| **B** | Slight | 11 | 13 | 26 | 24 |
| **C** | - | 7 | 9 | 28 | 28 |

- Pigment:

To make colored sand lime bricks, suitable coloring pigment should be added in the mixture of sand and lime. The quantity of pigment varies from o.2 to 3% of the total weight of the brick.

- ***Manufacture:***

a. Sand, lime and pigment are taken in suitable proportions and they are thoroughly mixed with a required quantity of water.

b. The material is then molded in the shape of the bricks under mechanical pressure (150-200 $kg/cm^2$).

c. Bricks are then placed in closed chamber and subjected to saturated steam pressure of about 8.5-16 kg/cm2 for 6-12 hours to speed up the interaction between lime and sand. The process is known as autoclaving.

CaO + H2O + SiO2 → CaO.SiO2. H2O " Tobermorite " " Hydrous calcium silicate "
Ca( OH )2 + CO2 → CaCO3 + H2 O

- ***Properties of lime sand brick:***

a. The raw materials of these bricks do not contain any soluble salt. Hence the trouble of effloresces does not arise.

b. If plaster is to be provided on sand lime bricks, the quantity of mortar required will be less as bricks are uniform in size and shape.

c. These bricks are hard and strong.

d. These bricks are uniform in colure and texture.

e. Sand lime bricks are used for ornamental work.

Due to its millions of independent air cells, which dampen sound transmission, thermo stone has excellent sound insulation and absorption qualities.

*3. High Thermal Efficiency and energy saving*

Building constructed of thermo stone provides substantial energy saving in both hot and cold climates. The unique closed cellular structure and the thermal mass contribute to a

*4. Fire Resistance*

- Non-combustible and fire resistant up to 1600° C.
- Can withstand up to 6 hours of direct exposure.

**Glass Brick**

Glass block, or glass unit masonry, is used to construct a variety of nonbearing walls or used as nonbearing infill in window openings. If not properly detailed to accommodate movement, glass block units may break and pose a falling hazard.

Glass block divided into numerous subpanels. In addition, the nonbearing glass block panel partition wall is isolated from seismic movement of the building structure.


BUBBLE
BROMO
CLEAR
DIAMOND
ICEBERG
OCEAN VIEW
PRISTAL
QUADRA
WAVE